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Research Article

Physicochemical and Sensory Characteristics of Developed Instant *Foutou* (*Fufu*), Plantain-Based Dough in West Africa

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This study is aimed at evaluating the physicochemical and sensory characteristics of developed instant *foutou* flour. Blanched semiripe plantain dried flakes, blanched/unblanched cassava dried flakes, and cassava starch were blended in the proportions 70 : 20 : 10 (FTF1), 80 : 30 : 0 (FTF3/FTF2), and 80 : 0 : 20 (FTF4), respectively, and ground. *Foutou* made from FTF1 and FTF2 were the most similar to traditional *foutou* (FTTRAD) for texture attributes. These *foutou* were fairly stick (5.66-5.73), firm (5.66-6.04), easy to mold (6.13-6.20), and pasty (6.00-6.26). FTF1 was appreciated and preferred by consumers because its color is relatively more yellow and its sweetness is relatively higher than those of other reconstituted *foutou*. All studied *foutou* flours exhibited low moisture content (6.09%-8.33%) and values of $a_w < 0.6$. FTF1 and FTF2 formulations had the highest ash (1.71%-1.73%) and protein (4.08%-4.53%) contents. FTF1 had the highest a^* value (1.80) and total sugar (TS) content (7.77%).

1. Introduction

Foutou (fufu) is highly cherished and consumed dough-like food, traditionally prepared by pounding boiled cassava roots together with plantain pieces in a wooden mortar until thick dough is formed [1]. Small balls of this dough are manually rolled by the consumer and eaten with traditional sauces of meat, fish, or vegetable. *Foutou* is also prepared from cassava alone or yams or cocoyams [2–4].

The consumption of *foutou* is gradually fading out in urban households because its traditional preparation required long cooking and pounding time. Also, this traditional way is described as an unhygienic preparation method [5]. Furthermore, plantain is a climacteric fruit, so it is a high-perishable crop. Its storage in a fresh state causes problems limiting its availability and utilization period [6]. Many studies have been carried out to promote the production and use of precooked flour in the preparation of traditional African dough food [7, 8]. The production of precooked flour and its suitability for the preparation of dough might be limited by browning reactions and texture of reconstituted products.

Texture and color are the key desirable sensory attributes of fufu [1]. They define the acceptability of fufu by consumers [9, 10]. Oduro-Yéboah et al. [11] have proposed a formulation of fufu flour allowing to obtain a reconstituted product with textural characteristics quite close to the pounded fufu. This work was only done on unripe plantain, although it is known that the ripening stage and the type of variety are critical factors in the acceptability of plantain processed products [12].

The quality of *foutou* has been known to vary from one location to another and would be influenced by plantain and cassava varieties and proportions, plantain ripening stage, and cassava age. In Côte d'Ivoire, both Corn and French varieties are preferred for *foutou*, semiripe plantain at stage "more yellow than green" being the most used for this dish [13]. Moreover, it was noted that the color of fufu flour may be influenced by the variety of plantain and cassava and also by flour particle size [11]. Very little data are available at this date on fufu flours produced from semiripe plantain.

The present study is aimed at developing and comparing the physicochemical characteristics and color parameters of semiripe plantain-based *foutou* flours and conducting a sensory evaluation of dough produced from them to ensure Ivorian consumer acceptability.

2. Material and Methods

2.1. Samples

2.1.1. Plant Material. Three varieties of plantain, Orishele, Corne 1, and French 2 and cassava variety Bonoua were used for the sensory analyzes tests. Plantains were grown in a farm located in Azaguié (Côte d'Ivoire, 5° 37′ 40″ N, 4° 5′ 12″ W) at 50 km east of Abidjan. They were all harvested at a stage of maximal maturity (stage 1 of ripening), i.e., when at least one ripe fruit appeared on the bunch and ripened artificially up to stage "more yellow than green" by using a solution of 20 : 80 (*v*/*v*) ethylene glycol : deionized water [14]. Fresh cassava roots of Bonoua variety were purchased at the wholesale market of Port-Bouet (Abidjan, Côte d'Ivoire). The semiripe fruits of plantain and cassava roots were separated into two parts, one for traditional *foutou* cooking and the second part for making instant flours used for the preparation of reconstituted *foutou*.

2.1.2. Blanched Plantain Dried Flakes Processing. Plantain dried flakes were processed using the method proposed by Gnagne et al. [14]. Plantain fingers were blanched for 15 min in boiling water containing 0.5% (*w*/*v*) citric acid (Sigma-Aldrich), then peeled. After that, pulps were longitudinally cut in half and soaked during 15 min in 1% (*w*/*v*) sodium metabisulphite (E223, Sigma-Aldrich) solution in order to limit enzymatic browning. Then, pulps were sliced into 10 mm^3 cubes using a food slicing device (Vitalex, Cantanduva, Brazil) and dried by dehumidifying in a mechanical dryer (MINERGY, ATIE PROCESS, France) at 65°C for 8 h to reach about 8-10% moisture content.

2.1.3. Cassava Dried Flakes Processing. Cassava dried flakes were processed according to the method described by Gnagne et al. [14]. Blanched and raw cassava dried flakes were obtained from tubers after peeling, washing, cutting into 10 cm length slices, and blanching 10 min in boiling water or not for the 2 types of flakes, respectively. Then, the slices were cooled and sliced into cubes of 10 mm thick using a food slicing Vitalex. The cubes were also dried in a mechanical dryer at 65.0°C for 6 h, to attain moisture content of about 8-10%.

2.1.4. Cassava Starch Processing. Starch was isolated from cassava according to a procedure reported by Gnagne et al. [14]. Cassava tubers were washed, peeled, and immediately cut into small slices that were crushed in a blender (Moulinex, Lyon, France). Obtained paste was mixed with water (1 : 5 (*w*/*v*)), and the obtained suspension was sieved at 100 μm (Retsch, Haan, Germany). Starch was finally recovered after decantation of sieved suspension. This process was repeated four times, and the recovered starch was dried in a ventilated oven (Memmert, Schwabach, Germany) at 45°C for 48 h to reach about 8% (*w*/*w*) moisture content (on wet basis).

2.1.5. Foutou Flours Processing. Blanched plantain dried flakes, blanched/unblanched cassava dried flakes, and cassava starch were mixed in proportions 70 : 20 : 10, 70 : 30 : 0, and 80 : 0 : 20, respectively. Mixtures were grounded in a first time in a hammer mill (I2T, Abidjan, Côte d'Ivoire) equipped with a sieve of 500 microns and regrounded secondly in another hammer mill (Forplex, Béthune, France) equipped with a sieve of 200 microns. The obtained *foutou* flours were then packed into 250 mg polyethylene bags and filled into Kraft paper bags to extend their shelf life and prevent discoloration. The details of *foutou* flour processing are shown in Figure 1, and the compositions of flours are presented in Table 1.

2.1.6. Cooking of Traditional Foutou. We used the traditional method of *foutou* cooking described by Osseo-Asare [15] with slight modifications. Peeled plantain fingers and cassava roots were cooked until the pieces were soft, which occurred after 30 min in the proportion of 70 : 30 (% *w*/*w*), respectively. The cooked pieces were immediately pounded separately and then mixed using a wooden mortar and pestle. During pounding, water was added intermittently to help in the pasting and molding processes of the *foutou*. *Foutou* were molded into spherical balls to about 10 g each other and covered with a plastic wrap to prevent dehydration and cooled for about 3 h before analysis.

2.1.7. Cooking of Reconstituted Foutou. Reconstituted *foutou* was prepared according to the method described by Johnson et al. [16] with slight modifications. 500 g of each formulation was mixed in 1000 mL of cold water and allowed to stand for 15 min, except for the *foutou* FTF2 for which 1200 mL of water per 500 g of flour was used in order to obtain final products with a same level of hydration, determined empirically. The mixtures were then cooked with gentle stirring for 15 min at moderate heat. During cooking, additional water (50 mL) was added to the mixture and gently stirred. After cooking, *foutou* samples were molded into spherical balls to about 10 g each other and stored under the same conditions as before.

2.2. Physicochemical Parameters Determination. Moisture, ash, fat, protein, and crude fibers contents of *foutou* flour samples were determined by standard methods developed by the Association of Official Analytical Chemists [17]. Total sugar content (TS) was determined by the phenol-sulfuric acid method [18]. Carbohydrate (CHO) content and energy value were calculated using the following equations [19]:

$$\text{CHO}\ (\%) = 100 - \%(\text{moisture} + \text{protein} + \text{fat} + \text{ash}), \quad (1)$$

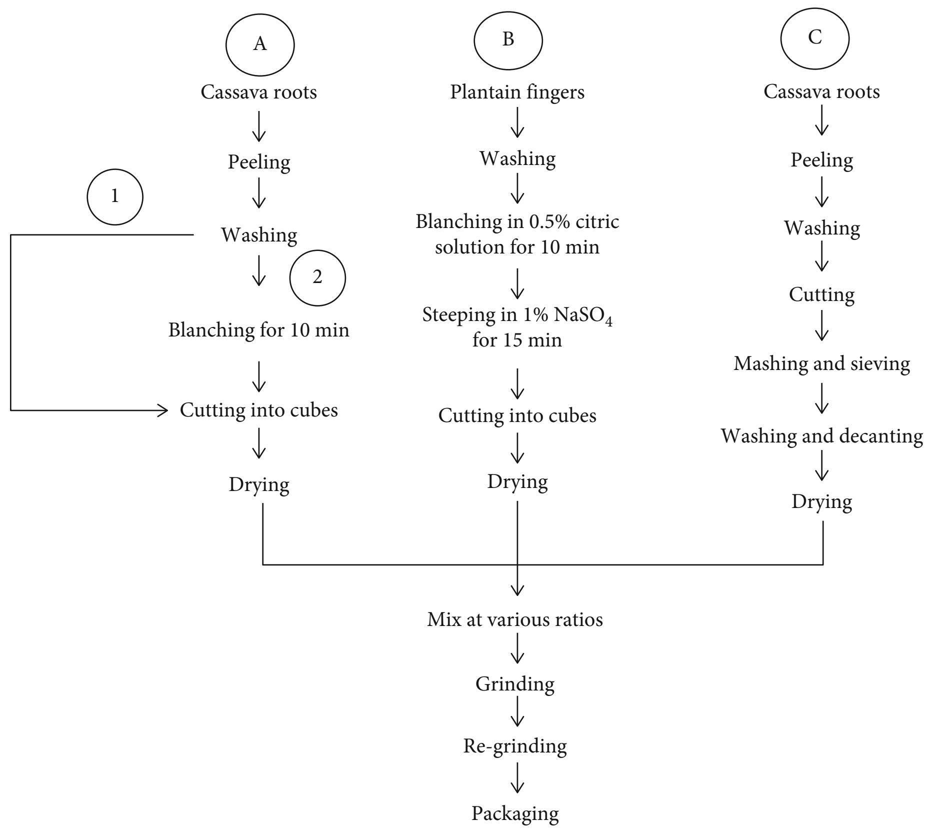

Figure 1: Sequence of operations employed in the processing of *foutou* flour samples. (A) The production of cassava dried flakes. (B) The production of plantain dried flakes. (C) The production of cassava starch.

Table 1: Composition of the different *foutou* flours investigated in this study.

Designation	Composition
Foutou F1 = FTF1	70% blanched plantain flour; 20% blanched cassava flour; 10% cassava starch
Foutou F2 = FTF2	70% blanched plantain pulp flour; 30% raw cassava flour
Foutou F3 = FTF3	70% blanched plantain pulp flour; 30% blanched cassava flour
Foutou F4 = FTF4	80% blanched plantain pulp flour; 20% cassava starch

$$\begin{aligned}\text{Energy value (kcal/100g)} = (&(\text{protein }(\%) \times 4\text{ (kcal/g)}) \\ &+ (\text{fat }(\%) \times 9\text{(kcal/g)}) \\ &+ (\text{CHO }(\%) \times 4\text{(kcal/g)}).)\end{aligned} \tag{2}$$

Water activity (a_w) of flour samples was determined using the HygroPalm water activity-meter (HP23AW-A, Rotronic, Croissy-Beaubourg, France) by the method described by Irie et al. [20].

2.3. Color Parameters Determination. The color parameters were determined on *foutou* flours using a Datacolor Microflash 4.0 spectrophotometer (Datacolor international, Switzerland) as described by Gnagne et al. [21]. The flour samples were placed into Petri dishes and covered. The light source was placed above the cover for carrying out the measure. The L^*, a^*, and b^* values were recorded, where L^* corresponds to the brightness, a^* the saturation in red, and b^* the saturation in yellow.

2.4. Sensory Testing

2.4.1. Descriptive Analysis. A panel of 15 trained panelists (nine women and six men, aged between 25 and 40 years old) on the I2T (Ivorian Society of Tropical Technologies) panel was used for the analysis. Sensory profile of *foutou* samples was led according to a descriptive analysis described by Sidel et al. [22]. Preliminary panelists were recruited on the basis of motivation, availability, their ability to express and communicate ideas with others, and their familiarity with the *foutou*. The subjects retained for the analysis were then selected using screening tests, which included taste identification and exercises to describe difference among some roots and tubers dough in two sessions of 1 h per day. After prescreening, panelists were trained in four sessions of 1 h per day. Training session covered basic information about *foutou* samples and sensory evaluation methods; scaling training and evaluation training with real *foutou* samples were conducted. During training, a total of eight sensory attributes (appearance, texture, and taste) with definitions, reference, and methodology of evaluation were developed (Table 2). Evaluation of the *foutou* samples was replicated three times in sessions of 1 h per day for three days. Each attribute was evaluated on a 10-point linear structured scale (1–10) ranging from 1 (attribute less intense) to 10 (attribute very intense). About 10 g of spherical ball of each unknown *foutou* samples coded with random a three-digit code was provided monadic in random order to each panelist for evaluation. *Foutou* balls were served 3 hours after preparation.

2.4.2. Acceptability Test. About 10 g of spherical ball of each *foutou* samples were coded with three-digit numbers and presented monadically in random order to forty (40) untrained panelists, familiar to *foutou* that were recruited at I2T (Ivorian Society of Tropical Technologies). The panelists comprising males and females, from 20 to 50 years old, were given consent forms each to fill before being asked to analyze the samples. The acceptability test was performed using a 9-point structured hedonic scale. The following numerical values were used for the scoring: dislike extremely = 1, dislike very much = 2, dislike moderately = 3, dislike slightly = 4, neither like nor dislike = 5, like slightly = 6, like moderately = 7, like very much = 8, and like extremely = 9 [23].

2.4.3. Preference Test. The test was carried out by the method described by Nindjin et al. [24] with slight modifications. About 10 g of spherical ball of each foutou sample, coded with random three-digit numbers, was presented simultaneously to forty (40) foutou consumers including female and male, from 20 to 50 years old in random order. The consumers received no training. They were invited to taste and rank the samples in descending order of preference. In all cases, each foutou sample was served with a sauce goua-gouassou made from eggplants and "gombo" as it is usually served locally.

2.5. Statistical Analysis. The software used for statistical evaluation was StatisticaV.8.05 (StatSoft Inc., Tulsa, Oklahoma). Data from physicochemical, color, descriptive, and acceptability tests were analyzed by one-way ANOVA, and the means were separated by Tukey's test at $p < 0.05$.

The statistical evaluation of the preference test involved calculating the sum of the ranks obtained for each sample, and Friedman and Wilcoxon tests were assessed for a global and pairwise comparison, respectively.

The relationship between *foutou* and sensory attributes was illustrated by principal component analysis (PCA) on correlation matrix.

Pearson's correlation was performed to evaluate the links *foutou* acceptability and sensory attributes.

3. Results

3.1. Physicochemical Characteristics. Significant differences ($p < 0.05$) in moisture, ash, fat, protein, total sugar, crude fibers, CHO contents, and a_w (Table 3) were observed between the *foutou* flours. The moisture content of the *foutou* flours varied from 6.09% (FTF2) to 8.33% (FTF4). a_w ranged from 0.55 (FTF4) to 0.52 (FTF2). The ash content of the *foutou* flours varied from 1.56% to 1.73%. There was no significant differences ($p > 0.05$) between FTF1 and FTF2 which exhibited the highest ash values (1.71%-1.73%). The fat, protein, and TS contents ranged from 1.11% to 1.94%, 3.46% to 4.53%, and 6.42% to 7.77%, respectively. FTF2 exhibited the highest fat content, and FTF1 had the highest TS content. There were no significant ($p > 0.05$) differences between FTF1 and FTF2 and between FTF3 and FTF4 for protein content. FTF1 and FTF2 recorded the highest protein content (4.08%-4.53%), and FTF3 and FTF4 the lowest protein value (3.46%-3.51%).

CHO content ranged from 85.02% to 86.31%. There was no significant differences ($p > 0.05$) between FTF1 and FTF2 which presented the lowest CHO values (85.02%-85.49%). FTF3 had the highest CHO content. Energy value varied from 366.00 kcal/100 g (FTF4) to 378.44 kcal/100 g (FTF2).

3.2. Color Parameters. Color parameters of *foutou* flours are presented in Table 4. Significant differences ($p < 0.05$) were observed between flours. The *foutou* flours were rather bright as indicated by the high L^* values that ranged from 87.61 to 89.45. There were no significant differences ($p > 0.05$) between FTF1 and FTF4 which had the highest L^* values (88.95-89.45) and between FTF2 and FTF3 which presented the lowest mean L^* value (87.61-87.65). a^* values varied from 1.02 (FTF4) to 1.80 (FTF1). b^* values ranged from 20.39 to 18.75. There were no significant differences ($p > 0.05$) between FTF1 and FTF3 which presented the highest mean b^* value (20.30-20.39). FTF4 had the lowest b^* value.

3.3. Foutou Sensory Analysis

3.3.1. Sensory Profiling of Foutou and Relationship between Foutou and Sensory Attributes. The sensory attributes of traditional and reconstituted *foutou* samples are presented in Table 5. Traditional *foutou* (FTRAD) had the highest mean score for the yellow attribute (6.13). They were fairly yellow. The yellow color of the *foutou* follows the trend: FTRAD (6.13) > FTF1 (4.60) > FTF3 (3.98) > FTF2 (2.95) > FTF4 (2.20). All reconstituted that *foutou* are quite smooth (6.75-7.24), whereas traditional *foutou* were moderate smooth (5.22). FTRAD (5.73), FTF1 (5.66), and FTF2 (5.73) were fairly sticky. The reconstituted *foutou* FTF3 (6.40) and FTF4 (4.53) were quite stick and moderate sticky, respectively. FTRAD (5.66), FTF1 (6.04), and FTF2 (5.80) were fairly firm. Reconstituted *foutou* FTF4 (6.52) and FTF3 (3.49) were quite firm and a slightly firm, respectively. FTRAD (6.20), FTF1 (6.20), FTF2 (6.13), and FTF3 (6.60) *foutou* were fairly easy to mold, whereas *foutou* FTF4 (3.71) were slightly easy to mold. FTF4 (6.76) were quite tender, FTRAD (6.22) and FTF2 (6.08) were fairly tender, FTF1

Table 2: List of sensory attributes selected for samples analysis and its references products [a] [24], [b] [25].

Attributes	Descriptions	Mode of testing	Rating scale	References
Color				
1. Yellow	Close to the color of cake	By the sight	0: low 10: strong	Cake
Texture				
2. Smooth	Lack of particles on the surface, has a smooth surface	By the sight By the fingers	0: low 10: strong	Tomato surface
3. Sticky	Clings to fingers Clings to teeth	By the fingers In the mouth	0: low 10: strong	175 g of tender wheat flour in 100 mL water, well kneaded (duration: 7 min) (100 mm)[a]
4. Easy to mold	Moderate elasticity, may be mold easily	By the fingers	0: low 10: strong	175 g of tender wheat flour in 100 mL water, well kneaded (duration: 7 min) (100 mm)[a]
5. Tender	Low chewiness, require short time to chew before swallow	In the mouth	0: low 10: strong	*Foutou* made from sweet potato (*Ipomea batatas*)
6. Pasty	Moderate gumminess, require small effort to chew before swallow	In the mouth	0: low 10: strong	Puree of potato
7. Firm	Moderate hardness, resists to pression	By the fingers	0: low 10: strong	Olive[b]
Taste				
8. Sweet	Sensation of sugar	In the mouth	0: low 10: strong	*Foutou* made from sweet potato (*Ipomea batatas*)[a]

(5.46) were moderately tender, and FTF3 (3.44) were a little tender. FTRAD (6.26), FTF1 (6.02), and FTF2 (6.00) were fairly pasty, FTF3 (6.66) were quite pasty, and FTF4 (3.87) were a slightly pasty. The sweetness of *foutou* follows the trend: FTF3 = FTF4 = FTF2 < FTF1 < FTRAD. FTF2 (3.04), FTF3 (3.05), and FTF4 (2.57) were slightly sweet, FTF1 (4.64) were moderately sweet, and FTRAD (5.89) were fairly sweet.

PCA was performed to evaluate relationship between *foutou* samples and sensory attributes (Figure 2). The first two dimensions of the PCA were found to explain 80.2% of the total variance. The dimension 1 explained the majority (53.6%) of the variance while the dimension 2 explained 26.6% of the variance. The first dimension (CP1) was positively correlated with sticky ($r = 0.89$; $p < 0.05$), easy to mold ($r = 0.90$; $p < 0.05$), and pasty ($r = 0.90$; $p < 0.05$) and negatively correlated with firm ($r = -0.75$; $p < 0.05$) and tender ($r = -0.73$; $p < 0.05$) textures. The second dimension (CP2) is positively correlated with sweetness ($r = 0.83$; $p < 0.05$) and negatively correlated with smooth texture ($r = -0.64$; $p < 0.05$). The yellow color is both positively correlated with CP1 ($r = 0.65$; $p < 0.05$) and CP2 ($r = 0.60$; $p < 0.05$).

The tender texture is both negatively ($r = -0.73$; $p < 0.05$) and positively ($r = 0.60$; $p < 0.05$) correlated to the CP1 and CP2 axes, respectively.

The projection of the different *foutou* in the factorial plane formed by dimensions CP1 and CP2 revealed that FTRAD were characterized by sweetness and yellowness; FTF3 were characterized by the sticky, easy to mold, and pasty textures; and FTF4 were characterized by the firm and tender textures. FTF2 and FTF1 were not clearly separated on the first two axes of the PCA.

3.4. Acceptance of Foutou. The hedonic test performed to assess the consumer acceptability of *foutou* samples is shown in Figure 3. Significant differences ($p < 0.05$) were observed in the degree of acceptability of *foutou*. Traditional *foutou* FTRAD (7.24 ± 0.72) were very liked, reconstituted *foutou* FTF1 (6.57 ± 0.11) were quite liked, followed by FTF2 (5.77 ± 0.35) which were fairly liked, and finally, the reconstituted *foutou* FTF3 (5.00 ± 0.00) and FTF4 (4.94 ± 0.10) were moderately liked. Positive correlations were observed between general acceptability and yellow color ($r = 0.83$; $p < 0.05$) and sweetness ($r = 0.83$; $p < 0.05$).

No significant correlation was found between texture attributes and general acceptability. Within the limitations of this study, the acceptability of *foutou* is governed by color and taste. This test therefore made it possible to isolate the FTF1 and FTF2 formulations out of the four proposed to the panelists.

3.5. Preference of Foutou. The preference test was conducted to determine consumer choice. For each type of variety, the preference was determined between traditional and reconstituted *foutou*. There were significant differences ($p < 0.05$) in the panel's preference for *foutou*. The results presented in Table 6 show that traditional *foutou* FTTRAD and reconstituted *foutou* FTF1 were the panel's favorites. In general, the panelists preferred the rather yellow color and the rather sweet taste of the traditional *foutou* but also the smooth appearance of the reconstituted *foutou*.

The preference scores of the different *foutou* for the sticky, firm, easy to mold, tender, and pasty textures were statistically identical.

4. Discussion

Moisture content and water activity of powder materials are critical properties that can affect other physical and chemical characteristics of foods. They are also critical factors for shelf

Table 3: Physicochemical parameters of *foutou* (fufu) flours.

Samples	Moisture (%)	a_w	Ash (%)	Fat (%)	Protein (%)	TS (%)	CHO (%)	Energy value (kcal/100 g)
FTF1OR	7.32	0.53	1.61	1.55	4.24	8.74	85.27	372.03
FTF1C1	7.66	0.53	1.89	1.72	3.82	6.86	84.91	370.41
FTF1FR2	7.55	0.54	1.63	1.73	4.18	7.72	84.90	371.93
Mean ± SD	$7.51^{b} \pm 0.16$	$0.53^{b} \pm 0.00$	$1.71^{a} \pm 0.13$	$1.66^{b} \pm 0.09$	$4.08^{a} \pm 0.22$	$7.77^{a} \pm 0.82$	$85.02^{b} \pm 0.23$	$371.46^{b} \pm 0.80$
FTF2OR	5.66	0.52	1.67	1.80	4.84	8.43	86.03	379.68
FTF2C1	6.94	0.52	1.83	1.82	3.97	5.67	85.44	374.05
FTF2FR2	5.68	0.52	1.69	2.21	4.79	7.66	85.63	381.58
Mean ± SD	$6.09^{c} \pm 0.65$	$0.52^{c} \pm 0.00$	$1.73^{a} \pm 0.07$	$1.94^{a} \pm 0.20$	$4.53^{a} \pm 0.42$	$7.25^{ab} \pm 1.23$	$85.70^{ab} \pm 0.31$	$378.44^{a} \pm 3.46$
FTF3OR	7.04	0.54	1.56	1.12	3.92	8.41	86.36	371.17
FTF3C1	7.66	0.54	1.81	1.33	2.71	5.26	86.48	368.77
FTF3FR2	7.16	0.54	1.62	1.34	3.77	7.59	86.10	371.58
Mean ± SD	$7.29^{b} \pm 0.29$	$0.54^{b} \pm 0.00$	$1.66^{ab} \pm 0.12$	$1.26^{c} \pm 0.12$	$3.46^{b} \pm 0.57$	$6.42^{b} \pm 0.94$	$86.31^{a} \pm 0.21$	$370.51^{b} \pm 1.36$
FTF4OR	8.54	0.56	1.52	0.70	3.78	7.54	85.46	363.29
FTF4C1	8.12	0.56	1.62	1.30	2.96	5.21	85.99	367.57
FTF4FR2	8.32	0.55	1.54	1.32	3.79	6.90	85.02	367.17
Mean ± SD	$8.33^{a} \pm 0.18$	$0.55^{a} \pm 0.01$	$1.56^{b} \pm 0.06$	$1.11^{c} \pm 0.30$	$3.51^{b} \pm 0.42$	$6.58^{b} \pm 1.08$	$85.49^{ab} \pm 0.42$	$366.00^{c} \pm 2.04$

Mean values followed by identical letters in the same column were not significantly different at $p < 0.05$. The notations of *foutou* from Orishele, Corne 1, and French 2 were followed by OR, C1, and FR2, respectively.

Table 4: Color parameters of *foutou* (fufu) flours.

Samples	L^*	a^*	b^*
FTF1OR	89.46	1.90	20.20
FTF1C1	89.67	1.76	19.73
FTF1FR2	89.24	1.72	21.24
Mean ± SD	$89.45^{a} \pm 0.23$	$1.80^{a} \pm 0.09$	$20.39^{a} \pm 0.86$
FTF2OR	87.78	1.15	20.04
FTF2C1	88.08	1.49	19.60
FTF2FR2	87.00	1.16	19.63
Mean ± SD	$87.61^{b} \pm 0.49$	$1.26^{b} \pm 0.25$	$19.76^{ab} \pm 0.57$
FTF3OR	87.52	1.11	20.67
FTF3C1	88.72	1.28	19.53
FTF3FR2	86.71	1.21	20.71
Mean ± SD	$87.65^{b} \pm 0.91$	$1.20^{bc} \pm 0.21$	$20.30^{a} \pm 0.66$
FTF4OR	89.45	1.10	19.81
FTF4C1	89.39	0.91	17.26
FTF4FR2	88.03	1.06	19.20
Mean ± SD	$88.95^{a} \pm 0.71$	$1.02^{c} \pm 0.12$	$18.75^{b} \pm 1.29$

Mean values followed by identical letters in the same column were not significantly different at $p < 0.05$. The notations of *foutou* from Orishele, Corne 1, and French 2 were followed by OR, C1, and FR2, respectively.

life and food stability [26]. The low water content of the *foutou* flours between 6.09 and 8.33 < 14%, and the values of $a_w < 0.6$ which represents the limit threshold of growth of microorganisms (yeasts, molds, bacteria) show that our flours present good aptitudes for conservation and storage at room temperature [20, 27]. Indeed, at these values of water content and a_w, our flours can be considered biochemically and microbiologically stable. The water content values of our *foutou* flours were within the range of values reported for different fufu flours [27, 28].

The ash contents of *foutou* flours ranging from 1.56%-1.73% are higher than those reported for fufu flours produced from cassava [29, 30] but lower than those reported for cocoyam and instant poundo yam flour [27].

Table 5: Comparative study of traditional and reconstituted *foutou* sensory attributes.

	Yellow	Smooth	Sticky	Firm	Easy to mold	Tender	Pasty	Sweet
FTRADOR	6.06	4.86	5.60	5.40	6.00	6.33	6.60	6.06
FTRADC1	6.80	6.20	6.20	5.60	6.80	6.80	6.40	5.80
FTRADFR2	5.53	4.60	5.40	6.00	5.80	5.53	5.80	5.80
Mean ± SD	$6.13^{a} \pm 0.64$	$5.22^{b} \pm 0.86$	$5.73^{b} \pm 0.42$	$5.66^{b} \pm 0.30$	$6.20^{a} \pm 0.53$	$6.22^{ab} \pm 0.64$	$6.26^{a} \pm 0.42$	$5.89^{a} \pm 0.15$
FTF1OR	4.60	7.46	5.40	6.00	6.00	5.60	6.20	5.00
FTF1C1	5.20	7.13	6.20	6.00	7.00	5.40	6.13	4.33
FTF1FR 2	4.00	6.40	5.40	6.13	5.60	5.40	5.73	4.60
Mean ± SD	$4.60^{b} \pm 0.60$	$7.00^{a} \pm 0.54$	$5.66^{ab} \pm 0.46$	$6.04^{ab} \pm 0.07$	$6.20^{a} \pm 0.72$	$5.46^{b} \pm 0.11$	$6.02^{a} \pm 0.25$	$4.64^{b} \pm 0.34$
FTF2OR	3.33	7.53	5.60	5.80	5.80	6.53	6.00	3.00
FTF2C1	3.33	7.40	6.20	5.40	7.00	5.93	6.40	2.33
FTF2FR2	2.20	6.80	5.40	6.20	5.60	5.80	5.60	3.80
Mean ± SD	$2.95^{cd} \pm 0.65$	$7.24^{a} \pm 0.39$	$5.73^{ab} \pm 0.41$	$5.80^{b} \pm 0.40$	$6.13^{a} \pm 0.76$	$6.08^{ab} \pm 0.39$	$6.00^{a} \pm 0.40$	$3.04^{c} \pm 0.73$
FTF3OR	4.33	7.00	6.20	3.40	6.20	3.33	7.00	3.50
FTF3C1	4.20	6.93	7.00	3.66	7.20	3.40	6.60	3.00
FTF3FR 2	3.40	6.33	6.00	3.40	6.40	3.60	6.40	2.66
Mean ± SD	$3.98^{bc} \pm 0.50$	$6.75^{a} \pm 0.37$	$6.40^{a} \pm 0.52$	$3.49^{c} \pm 0.15$	$6.60^{a} \pm 0.53$	$3.44^{c} \pm 0.14$	$6.66^{a} \pm 0.30$	$3.05^{c} \pm 0.42$
FTF4OR	2.20	7.26	4.40	6.53	3.20	6.80	4.20	2.93
FTF4C1	2.60	6.86	5.00	6.70	4.60	6.60	3.73	2.20
FTF4FR 2	1.80	6.50	4.20	6.33	3.33	6.90	3.70	2.60
Mean ± SD	$2.20^{d} \pm 0.40$	$6.87^{a} \pm 0.38$	$4.53^{b} \pm 0.41$	$6.52^{a} \pm 0.18$	$3.71^{b} \pm 0.77$	$6.76^{a} \pm 0.15$	$3.87^{b} \pm 0.28$	$2.57^{c} \pm 0.36$

Mean values followed by identical letters in the same column were not significantly different at $p < 0.05$. The notations of *foutou* from Orishele, Corne 1, and French 2 were followed by OR, C1, and FR2, respectively.

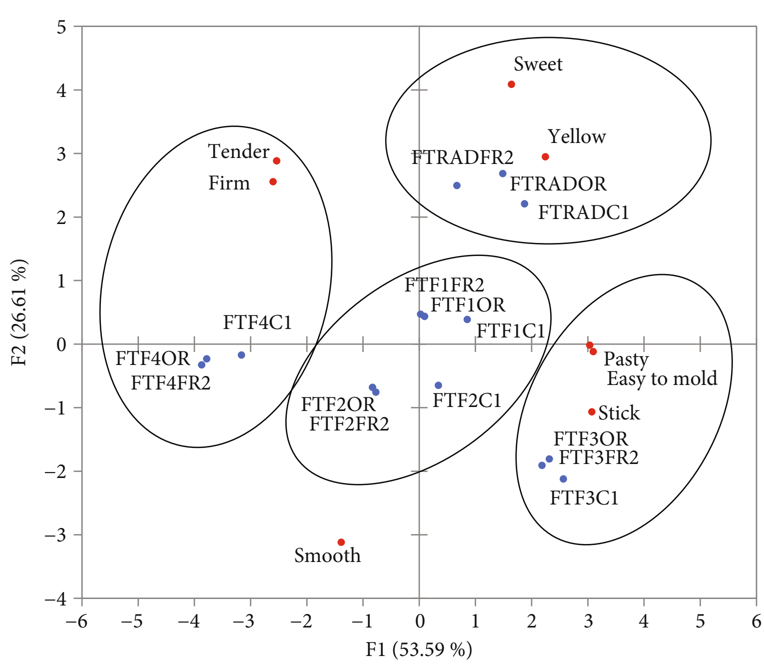

Figure 2: Principal component analysis of sensory attributes of traditional and reconstituted *foutou* on the two first principal dimensions. The notations of *foutou* from Orishele, Corne 1, and French 2 were followed by OR, C1, and FR2, respectively.

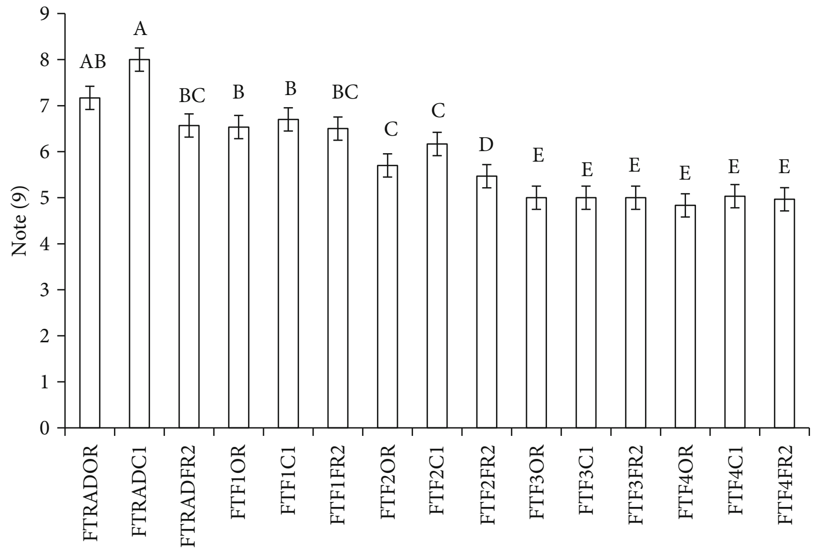

Figure 3: Acceptability of different *foutou*. Histograms with different letters indicate significantly different results ($p < 0.05$). The notations of *foutou* from Orishele, Corne 1, and French 2 were followed by OR, C1, and FR2, respectively.

Table 6: Consumer preference for traditional and reconstituted *foutou*.

	Overall preference	Yellowness	Smoothness	Firmness	Easiness to mold	Tenderness	Sweetness
			Sum of rank				
FTRADOR	47[a]	30[a]	73[b]	74[b]	72[b]	56[ab]	45[a]
FTF1OR	59[a]	62[b]	49[a]	51[a]	52[a]	54[a]	59[a]
FTF2OR	74[b]	88[c]	58[ab]	55[a]	56[a]	70[b]	76[b]
FTRADC1	38[a]	41[a]	56[a]	54[a]	56[a]	55[a]	30[a]
FTF1C1	64[b]	59[b]	56[a]	56[a]	58[a]	57[a]	68[b]
FTF2C1	78[c]	80[c]	68[a]	70[a]	66[a]	68[a]	82[c]
FTRADFR2	45[a]	52[a]	84[b]	54[a]	60[a]	60[a]	43[a]
FTF1FR2	58[a]	58[a]	48[a]	58[a]	54[a]	54[a]	60[b]
FTF2FR2	77[b]	70[b]	48[a]	68[a]	66[a]	66[a]	77[c]

Sum of rank values followed by identical letters in the same column were not significantly different at $p < 0.05$. The notations of *foutou* from Orishele, Corne 1, and French 2 were followed by OR, C1, and FR2, respectively.

These values were within the range of values reported by [28] for unfermented fufu composite flours from blends of cassava, guinea corn, and unripe plantain flours.

The low lipid (1.11%-1.94%) and protein (3.46%-4.53%) contents of our *foutou* flours reflect the low lipid and protein contents of plantain [31] and cassava [3]. The average lipid and protein content values recorded here are consistent with those reported previously for cocoyam and instant poundo yam flour [27] and for composite flours of unfermented fufu from mixtures of cassava, guinea corn, and unripe plantain flours [28].

The TS content of *foutou* flours ranged from 6.42% to 7.77% and was higher than those of cassava fufu flours obtained by Awoyale et al. [29]. These high TS contents of our flours can be explained by the high total sugar contents (7.7%-10.1%) of plantain at stage 5 of ripening, i.e., more yellow than green, used in our study [21]. Indeed, the sugar content of plantain increases during fruit ripening by enzymatic hydrolysis of starch.

The CHO contents of the *foutou* flours ranged from 83.30% to 84.61%. These values were within the range of values reported by a previous study for fufu powder produced from cassava [30] and cocoyam and instant poundo yam flour [27]. However, these values are lower than those reported by N'guessan et al. [32] for M'bahou (87.29%), another traditional Ivorian dish.

The energy values of our *foutou* flours ranging from 366.00 kcal/100 g to 378.44 kcal/100 g were higher than those reported by N'guessan et al. [32] for M'bahou (364.87 kcal/100 g) and Awolu et al. [33] for fufu produced from sweet cassava and guinea corn flour (361.25 kcal/100 g-367.30), but lower than those of boiled plantain (386.32 ± 0.02 kcal/100 g-388.89 ± 0.11 kcal/100 g) observed by Wohi et al. [34].

The L^* (87.61-89.45) and b^* (20.39-18.75) values of the *foutou* flours studied were higher than the L^* (57.29-61.24) and b^* (11.15-16.79) values of fufu produced from sweet cassava and guinea corn flour. However, our flours had lower values of a^* (1.02-1.80) than the latter (2.29-2.94) [33]. The high L^* values of FTF1 and FTF4 flour can be explained by the addition of cassava starch with L^* values > 90 [35].

Sensory tests carried out on samples of *foutou* produced from plantain at stage "more yellow than green" and cassava revealed that their sensory profile can be described from the color (yellow), texture (smooth, sticky (medium stickiness), firm (medium hardness), easy to mold (medium elasticity), tender (medium chewiness), and pasty (medium gumminess)), and taste (sweet). Previous authors reported that the most identified food quality characteristics of pounded plantain and pounded plantain with yam/cocoyam/gari relate to color, texture (softness, smoothness, firmness, and stickiness/gumminess), taste ,and the smell of the product [12]. The extensible, loose, fibrous, lumpy, and watery descriptors suggested by Nindjin et al. [24] to describe yam *foutou* were not stated or considered relevant by the panel of panelists for the description of plantain and cassava *foutou* in our study. The PCA conducted for the different *foutou* revealed that consumer perception of the *foutou* was not related to the variety but rather to the formulation.

The reconstituted *foutou* are, respectively, less yellow than the traditional *foutou*. The development of a brown coloring in reconstituted *foutou* can be linked to the development of nonenzymatic browning during the reconstitution of the dough. Browning/darkening after cooking can be related to chlorogenic acid Teeken et al. [36].

Differences in the textural attributes of the studied *foutou* would be influenced by starch composition and gelatinization process, as reported in the literature [37]. FTF1, FTF2, and FTRAD have quite similar textural characteristics. These *foutou* were fairly sticky, firm, and easy to mold. This can be justified by the fact that the addition of starch in the FTF1 formulation and the use of raw cassava flour in the FTF2 formulation would have improved the pasting properties of these *foutou* flours. Precooking causes starch gelatinization and thus a decrease in the viscosity of precooked flours [38]. It can be deduced from this that FTF3 *foutou* showed different textural characteristics from traditional FTTRAD *foutou*. These *foutou* were fairly sticky and therefore slightly firm. FTF4 were slightly sticky, easy to mold, and fairly firm. The total substitution of starch for cassava flour would have modified the textural properties of these *foutou*, thus differentiating them from the traditional ones.

Previous studies have shown that softness, smoothness, smell, taste, and color influenced plantain and cassava *foutou* preference [1]. Other authors reported that the major preferred quality attributes of pounded yam are textural quality (stretchability > moldability > stickiness > smoothness > moderately hard/soft) and color followed by taste and aroma [10]. It was also observed that smoothness, not sticky, easy to swallow, and drawability (stretchability) appear to be major traits that drive cassava fufu acceptance [9]. Teeken et al. [36] revealed that texture attributes of fufu are preferred at different levels depending on the region, culture, and personal preferences.

In our study, although texture attributes are important to describe the different *foutou* studied, only color and taste control the acceptability of the *foutou*. Dough texture no longer appears to be a major determinant of acceptability. In this respect, the *foutou* FTRAD, FTF1, and FTF2 were the most appreciated by the panelists. *Foutou* FTRAD was very much appreciated, while the FTF1 and FTF2 were quite appreciated. This also justifies the panelists' preference for the FTRAD and FTF1. They also prefer the *foutou* to be smooth.

5. Conclusion

The different formulations of *foutou* flours proposed had significant effects ($p < 0.05$) on the sensory properties of *foutou*. The FTF1 formulation gave a *foutou* that was fairly close to traditional *foutou* and therefore fairly appreciated. The general acceptance and preference of the *foutou* have been related to color, taste, and smoothness. So, *foutou* of good quality had yellow color and sweet taste and was fairly smooth. There was no difference in acceptability between varieties. The appreciate formulation FTF1 exhibited the highest total sugar (TS) content (7.77%) and a^* value (1.80) and was a good source of calories (375.46 kcal/100 g). The production of *foutou* from flours is therefore an interesting alternative to overcome the perishability and seasonality of plantain and thus guarantee the food security of West African populations.

Data Availability

Data is avalaible on request from the corresponding author.

Additional Points

Practice Application. *Foutou* (fufu) is a traditional highly cherished and consumed dough-like food prepared by pounding boiled cassava roots together with plantain pieces in a wooden mortar. This is time consuming and tedious. With the expansion of urbanization, studies are carried out in order to provide consumers with processed products in line with the evolution of food systems and lifestyles, thus allowing them to achieve their energy needs and food preferences. In addition, these processed products have longer shelf-stability compared to fresh products. In this study, different formulations of *foutou* flours were submitted to physicochemical and sensory tests in order to propose to Ivorian consumers flours best suited to their needs.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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