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VALORIZATION OF *BETE BETE* YAM WASTE (*DIOSCOREA ALATA*) BY PRODUCING FLOUR FOR CHILDREN AGED 6 TO 24 MONTHS

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Abstract – With a view to alleviating the problems of nutritional deficiencies in children, this study set itself the objective of developing a complementary food of improved nutritional quality for children from 6 to 24 months from yam peels accessible and available. To achieve this objective, a survey was carried out in the city of Abidjan to find out the traditional infant flours most consumed in Côte d'Ivoire. The most widely used flour will be taken as a control to compare its physicochemical and microbiological characteristics with those of the flour produced from yam peels. It emerged from this survey that the most widely used traditional flour is millet flour (29.8%). Moreover, the physicochemical characteristics showed that the yam peel flour contains more ash (7.01 ± 0.03 g / 100g) than that of millet (1.49 ± 0.04 g / 100g).). On the other hand, the energy value (401.22 ± 0.21 Kcal) of millet flour is higher than that of yam peel flour (377.72 ± 0.27 Kcal)). At the microbiological level; the aerobic mesophilic germs (AMG) load of the yam peel flour was (5.7 ± 0.1) × 10^4 CFU / g against (3.8 ± 0.3) × 10^4 CFU / g for the millet flour. However, both types of flour have fillers that meet the standard prescribed by the WHO. A tasting panel was carried out and found that porridge made from yam peel flour was accepted in the same way as porridge made from millet flour. Thus, the valuation of yam peel for the preparation of local infant flours in Côte d'Ivoire will not only solve environmental problems but also a complementary contribution for infant nutrition.

INTRODUCTION

The child's diet closely participates in the different processes of his development by the choice of foods gradually introduced and by inputs quantitatively and qualitatively adapted to his evolutionary needs (Ancellin and Dumas, 2004). During the first six months of life, breast milk helps cover the nutritional needs of the infant. That is why WHO recommends exclusive breastfeeding during this period. However, after six months, the exclusive milk diet no longer covers the ever-changing needs of the infant. During this so-called "weaning" period, babies need special food that provides them with enough energy, protein, and other nutrients such as vitamins, minerals, and trace elements (Dupont, 2005). It is necessary to introduce novel foods in form liquid or semi-liquid into the infant's diet to supplement the intake of breast milk (OMS, 2010). The quality of the infant flours used during this period is therefore of great importance. Generally speaking, in developing countries, the WHO estimates the prevalence of malnutrition in children under 5 at 29%. This represents around 168 million children, 70% of whom live in Asia, 26% in Africa and around 4% in Latin America and the Caribbean. In Côte d'Ivoire, according to EDSCI (2012), 75% of children aged 6-59 months have anemia. The main causes of this malnutrition are related to a global deficit of ingested protein-energy and a deficiency of some key micronutrients in this case calcium, iron and zinc (Tété-Bénissan, 2012). In, sub-Saharan Africa, mothers typically feed their children with porridges prepared from simple or compound flours from cereals or tubers that are high-carbohydrate, low-protein foods (Kouassi *et al.,* 2015). On the other hand, commercial infant flours are not generally used by low-income households because it is relatively expensive (Yewelsew *et al.*, 2006). In the face of this situation, the promotion and production of infant flours from locally available, energy-dense food products (cereals and vegetables) is necessary to expand the range of basic complementary foods. It is with this in mind that this work is located which has as its general objective the development of complementary foods of improved nutritional quality for children from 6 to 24 months from yam peel

MATERIALS AND METHODS

Biological Material

The biological material consists of flour from yam *Bêtê Bêtê* (*Dioscorea alata*), and millet flour (Fig.1). Millet flour and yam tubers were purchased at the market in Abobo commune.

Survey sheet

A survey form was developed and was used to carry out surveys on consumer traditional flour boiled in five communes of Abidjan (Abobo, Adjame, Cocody, Treichville and Yopougon)

Conducting the survey

The sampling method adopted in this work is random sampling. The survey was carried out in October 2020 among 500 mothers of children aged 6 to 24 months due to 100 mothers per commune in order to determine the level of use of traditional porridges in Abidjan. The questionnaire was explained chapter by chapter to the mothers interviewed. The questions were multiple choice questions and questions with yes or no answers. The questionnaire is composed of three parts (Survey sheet 1). The first part to focus on the knowledge of infant flour, the second part on the choice of the type of flour used, and the last part on the number of consumption per day. Interviews were conducted individually and were conducted in French. Information collected from respondents was expressed as a percentage.

Monitoring of flour production with yam peelings

A production monitoring was carried out in all the units involved in the study. The purpose of the monitoring was to observe the processors in the preparation of yam flour, and to support certain points if necessary, by asking specific questions according to the observation made. Thus, the working methods, hygiene practices and processing procedures were carefully identified. This made it possible to draw up the production diagram for the preparation of yam peel flour , and also to explain certain results of the microbiological and physico-chemical analyses.

Biochemical analysis

Forty grams of inoculum samples (waste yam flour or millet flour) were ground in 300 ml of distilled water in a porcelain mortar and then centrifuged at 4000 tours/min for 30 min. The pH was determined on 50 ml of the supernatant using a pH-meter (P107 Consort). Total titratable acidity (TTA) was determined by titrating 30 ml of supernatant used for pH determination against 0.1 M NaOH using phenolphthalein as indicator. TTA was calculated as percentage of lactic acid. The percentage of dry matter and Moisture content were determined

Fig. 1. Millet flour **(A)** and Yam peel flour **(B)**

Survey sheet 1: Consumption survey on traditional flours

1. Neighbourhood: 1-Abobo ☐ 2-Adjamé ☐ 3-Yopougon ☐ 4-Trechville ☐ 5-Cocody ☐
2. Gender of the child: 1- F ☐ 2-M ☐
3. How old is the child: 1.6-12 month ☐ 2 .12-18 monyh ☐ 3.18-24 month ☐
4. Marital status of the mother: 1- Married ☐ 2-single ☐ 3-cohabitation ☐
5. Mother's ethnic group: 1-Akan ☐ 2-Krou ☐ 3-Mandé ☐ 4 Gour ☐ 5-Foreign (to be specified) :
6. Level of study: 1-Primary ☐ 2-secondary ☐ 3-Supérior ☐ 4- other (to be specified) :
7. Profession: 1-Student ☐ 2-Functionalist ☐ 3- other (to be specified): ....
8. Do you know about infant formula: 1-Yes ☐ 2-not ☐
9. Do you use children's flour: 1-Yes ☐ 2-Not ☐
10. Traditional flours: 1-Yes ☐ 2-Not ☐
11. What kind of flour: 1. Millet ☐ 2-corn ☐ 3-sorghum ☐ 4-wheat ☐ 5- other (to be specified) : ....
12. Which one do you use for the slurry: 1- Millet ☐ 2- corn ☐ 3-sorghun ☐ 4- Wheat ☐ 5- other (to be specified) : ....
13. What do you spend per day on making your porridge? 1. 200-500fr ☐ 2.500-1000fr ☐ 3. Plus de 1000fr ☐
14. Why do you give it: on the doctor's recommendation (paediatrician or midwife Woman) :
    1- Yes ☐ 2-Not ☐ 5- other (to be specified): ....
15. How many times the child consumes the porridge per day: 1. 1 - 2 ☐ 2. 2 - 3 ☐ 3. 3 - 4 ☐ 4. 4 - 5 ☐ more than 5 ☐
16. At what time of day does it consume: 1- Morning ☐ 2-Midi ☐ 3-Evening ☐ 4- other (to be specified) : ....

gravimetrically in an oven at 105°C until a stable weight was obtained (AOAC, 1995). The results were shown in grams of moisture per 100g of fresh sample. The extraction of the lipid fraction was carried out using a Soxhlet Tecatorin3 accordance to Association of Official Agricultural Chemists (AOAC, 1995) method. The results were shown in grams of total lipids per 100g of fresh sample. The total nitrogen determination was carried out using the Kjeldahl method (AOAC, 1995) thus total protein was calculated by multiplying the total nitrogen by 6.25, the conversion factor calculated from the amino acid of total sample. The results were expressed in grams of total protein per 100 g of fresh sample. The total carbohydrate content was obtained by the difference of protein, moisture, lipid and expressing the sum in grams of total carbohydrates/100g of fresh sample. Total ash content was determined by previous carbonization of the dry samples followed by incineration in an oven at 550 °C (AOAC, 1995). The results were expressed in grams of total ash/100g of sample. The total energy value (TEV) was calculated using the traditional conversion factors for proteins (4kcal/gram), lipids (9kcal.gram-1), and carbohydrates (4kcal.gram^{-1}) according to FAO (2006). The results were expressed in kcal/100g of fresh sample. The minerals were determined by atomic absorption spectrophotometry according to the AOAC (1990) digestion method using strong acids. The content of each mineral element was determined using a VARIAN AA.20 brand flame atomic spectrophotometer at a specific wavelength by comparison with standard solutions.

Microbial analysis

The microbial analysis was carried out to determine the microbiological loads of inoculum samples. Preparation of stock solutions, inoculation of agar plates, cultivation and quantification of microorganisms were carried out according to Coulin *et al.*, 2006. For all determinations, 10 g of samples (waste yam flour or millet flour) were homogenized in a stomacher with 90 ml of sterile peptoned buffered water (AES Laboratoire, COMBOURG France). Tenfold serial dilutions of stomacher fluid were prepared and spread plated to determine microorganism counts. aerobic mesophilic were counted on PCA (Plate count Agar) agar (Oxoid LTD, Basingstore, Hamsphire, England) after two (2) days of incubation at 30°C according to AFNOR Standard NF V08-051,1999. Yeasts and moulds were enumerated on plates of Sabouraud chloramphenicol agar (Fluka, Bochemica 89579, Sigma-Aldrich Chemie GmbH, Inda) incubated at 30 °C for 4 days. The research and counting of *Staphylococcus aureus* was done on Baird Parker agar after one (1) day incubation at 30°C using (Capita *et al.,* 2001) method. The eosin methylene blue agar (Becton Dickinson GmbH, Heidelberg, Germany) was used to particularly enumerate and isolate *E. coli*, which grows on the medium giving a distinctive metallic green sheen colony. Violet crystal and neutral red biliated lactose agar (VRBL agar) was used for coliform count. after one (1) day of incubation at 30 °C for total coliforms and 44 °C for faecal coliforms according to AFNOR Standard, NF ISO 4832 July 1991. Bacili species were enumerated on plates Mossel agar (AES Laboratoire, COMBOURG France) after incubation at 30°C for 2 days. Sulfito-reductor bacteria were enumerated using tubes of Trypton Sulfite Neomycin agar (Biorad, Marnes-La-Coquette, France) at 37 °C for 24–48 h. The isolation and enumeration of *Salmonella* was carried out using Hendriksen (2003) method in several steps. This was achieved by pre-enrichment in a non-selective medium, followed by enrichment in a selective medium and culture on selective agar. For enrichment in non-selective or pre-enrichment media, a mass of Twenty-five grams (25) g of samples were homogenized with 225 mL of peptonned water in a sterile jar, incubated at 37°C for 24 hours. For selective recording, one milliter (1 ml) of the pre-enriched culture was transferred using a sterile pipette into 10 mL of previously prepared sterile Rappaport Vassililiadis broth and incubated for 24 hours at 37°C. *Salmonella* enumeration was performed on *Salmonella-Shigella* agar (Oxoid). Each enrichment culture was streaked on *Shigella-Salmonella* (SS) agar and incubated at 37°C for 24 hours. On *Salmonella-Shigella* agar, the presumptive colonies were colourless, transparent, with or without a black centre.

Sensory analysis of porridge

Two (2) types of sensory analysis were performed namely the descriptive test of sensory attributes to characterize the food and the hedonic test to judge the appreciation or acceptance of the food (Survey sheet 2). The sensory tests looked at the taste, color, flavor and odor of the porridge made from yam peel flour compared to the characteristics of the porridge made from millet flour. A hedonic sensory

Survey sheet 2: Sensory analysis sheet for traditional porridge

1. Colour

A= Brown ☐ bank ☐ Brown - bank ☐ Brown -brown ☐ brown ☐

B= Brown ☐ bank ☐ Brown - bank ☐ Brown -brown ☐ brown ☐

2. Odour

A= Presence of aroma ☐ Lack of aroma ☐

B= Presence of aroma ☐ Lack of aroma **Saveur** ☐

A= Sweet ☐ Acid ☐ Sour ☐

B= Sweet ☐ Acide ☐ Sour ☐

3. Goût

A= Very pleasant ☐ pleasant ☐ unpleasant ☐

B= Very pleasant ☐ pleasant ☐ unpleasant ☐

Please taste the products from left to right and rate them on the following scale:-

- Note 5 : Very pleasant
- Note 4 : pleasant
- Note 3: neither pleasant nor unpleasant
- Note 2: unpleasant
- Note 1: very unpleasant

Product ☐

Note ☐

Then, please rank the products you tasted in descending order according to your pleasure (from the most liked to the most disliked)

Order of classification	1	2
Product code		

Comments:

The reason why you like the product ranked 1:

The reason why you hate the product ranked 2:

evaluation was carried out according to standards NF ISO 5492 and V 09-001 (AFNOR, 1995) using a questionnaire. The principle of this test is based on the pleasant or unpleasant nature of the product.

Statistical analysis

The software R. 3.01, ANOVA method with post-hoc Tukey test, significance level 5% was used. This software made it possible to calculate the means, the standard deviations of the biochemical and microbiological parameters. It also made it possible to compare the means of the parameters of the samples and to determine whether the differences observed at the level of the means of the biochemical and microbiological parameters are significant at the 5% level. The survey data was processed with IBM SPSS software (statistics 20)

RESULTS

Types of cereals used for traditional infant flours

The survey showed that of the 168 people using traditional flours, 29.8% use millet, followed by those using maize (22.2%). The other flours (wheat, rice, or a mixture of the various flours) are used to a lesser extent, with proportions ranging from 1% to 13% (Fig. 2).

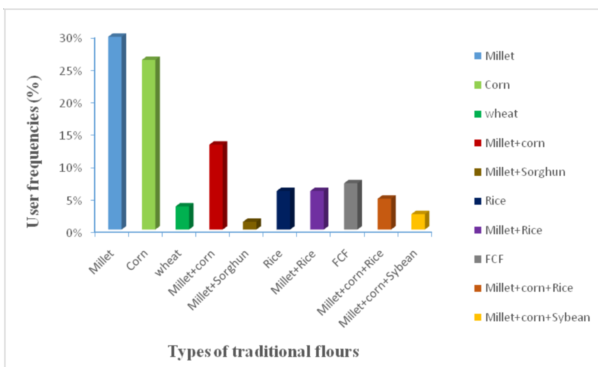

Fig. 2. Types of cereals used for traditional flours. **FCF:** Fermented cassava flour

Preparation of yam peel flour

The yam tubers purchased, were first sorted to remove the damaged tubers and thoroughly washed, then peeled with a knife. In addition, the peelings obtained are pre-cooked for 15 minutes. After 15 minutes of pre-cooking, they were transferred to a colander to remove the pre-cooking water. Then, after getting rid of their first layer in Boise. They were rinsed, drained, and dried in the sun for 72 hours. After drying, the grinding of peelings was done using a mortar. The obtained raw powder was sieved at room temperature using a mesh screen whose diameter is between 300-500µm. The collected product is flour (Fig. 3).

Physicochemical characteristics of the flours

Table 1 shows the values of the physicochemical characteristics of the flours according to the raw material. The results showed that there is a significant difference from one sample to another at the 5% threshold. Humidity rate is 15.78±0.01% and 35.32±0.02% in yam peel flour and millet flour respectively, while dry matter is 84.22±0.01% and 64.68±0.02% in yam peel flour and millet flour respectively. The pH of yam flour is 6.15±0.01 with a titratable acidity of 0.02±0.01%. Millet flour has a pH of 3.79±0 with an acidity of 0.61±0.03%. The soluble sugar content was 1 ± 0° Brix and 0.85±0.07° Brix for yam peel flour and millet flour respectively. The lipid, carbohydrate and protein contents are respectively 0.54±0.04 g/100g, 74.73±0.03 g/100g and 9.55±0.02 g/100 g for the yam peel flour, while the millet flour contains 0.78±0.02 g/100 g of lipid, 83.93±0.05 g/100g of carbohydrate and 9.98±0.02 g/100g of protein. On the other hand, the energy value of millet flour (330.51±0.21 Kcal) is higher than yam peel flour (294.61±0.27 Kcal). As for the fiber content, the yam peel (8.17±0.03 g/100g) contains more fiber than the millet flour (3.82±0.04 g/100g).

Mineral composition of millet and yam peel flours

The trace elements measured in this study were iron, zinc, magnesium, potassium and calcium. Millet flour is richer in the desired trace elements than yam peel flour, except for calcium. Indeed, the calcium content of yam peel flour is 293.76±0.6 mg / 100 g while that of millet flour is 105.99±0.04 mg / 100g. Regarding the contents of iron, zinc, magnesium, phosphorus and sodium, they are respectively 10.02±0.02 mg / 100 g; 2.24±0.04 mg / 100 g; 9.09±0.04 mg / 100 g; 693.41±1.13 mg / 100 g and 409.45±0.96 mg / 100 g in yam peel flour. In millet flour the iron content is 11.04±0.04 mg / 100 g, the zinc content is 2.88±0.03 mg / 100 g, the magnesium content is 30.12±0.03 mg / 100 g, the potassium content is 1311.37±2.08 mg / 100 g and the sodium content is 702.96±0.05 mg / 100 g (Table 2).

Microbial load of flours

The loads of the microorganisms tested in the flours

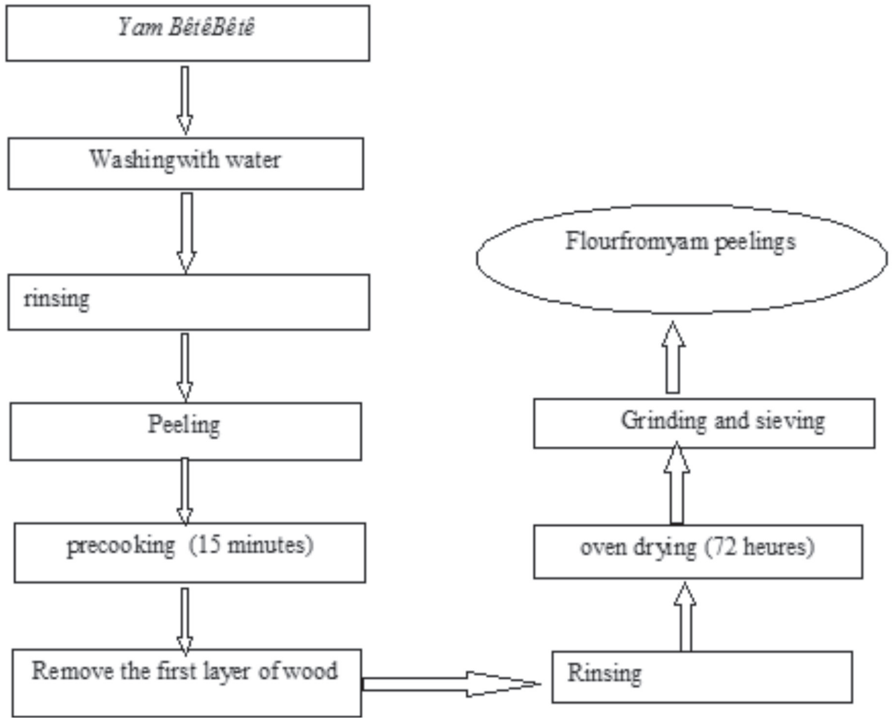

Fig. 3. Diagram of the preparation of yam peel flour

are recorded in Table 3. Millet flour has (3.8. ±0.3) $\times 10^4$CFU/g of aerobic mesophilic germs (AMG) with an average of (8.5. ± 0.3) $\times 10^2$ CFU/g of fungal flora (yeasts and moulds), and total and faecal coliforms are estimated at (2.2. ± 0.6) $\times 10^2$ CFU/g and (5. ±1) $\times 10^1$CFU/g respectively. The yam peel flour presents an average load of (5.7. ±0.1) $\times 10^4$ CFU/g of AMG with an average of fungal flora (yeasts and molds) estimated at (4.6. ± 0.9) $\times 10^2$ CFU/g and total and fecal coliforms (5. ±1.4) $\times 10^1$ CFU/g are absent. The presence of pathogenic microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, *Bacillus* and sulphite-reducing anaerobic microorganisms in both flours at loads below the microbiological criteria should be noted. However *Salmonella* was absent in both types of flour (Table 3).

Sensory profile of different flours

The sensory profile of the flours was made from averages of the scores from 0 to 5 assigned to the attributes (Color, Taste, Flavor, Odor) by the panelists (Fig. 4). The highest intensities were

Table 1. Physico-chemical and nutritional characteristics of millet and peel flours**.**

Parameters	Flour from yam peelings	Millet flour
Dry matter (%).	84.22±0.01^{a}	64.68±0.02^{b}
Humidity rate (%).	15.78±0.01^{b}	35.32±0.02^{a}
pH	6.15±0.01^{a}	3.79±0.01^{b}
Titratable acidity (%).	0.02±0.01^{b}	0.61±0.03^{a}
Soluble sugar (¨° Brix).	1±0.0^{a}	0.85±0.07^{a}
Ash (g/100g)	7.01±0.03^{a}	1.49±0.04^{b}
Protein (g/100g)	9.55±0.02^{b}	9.98±0.02^{a}
Carbohydrate (g/100g)	74.73±0.03^{b}	83.93 ±0.05^{a}
Lipid (g/100g)	0.54±0.04^{b}	0.78±0.02^{a}
Fiber (g/100g)	8.17±0.03^{a}	3.82±0.04^{b}
Energy value (Kcal)	294.61±0.27^{b}	330.51±0.21^{a}

The values obtained are means ± standard deviation determined in three trials. On the lines of each parameter, the averages affected by no common letter are significantly different between them at the 5% threshold

Table 2. Mineral compositions of yam and millet peelings flours

Parameters (mg / 100 g)	Flour from yam peelings	Millet flour	Standards FAO/0MS (2006)
Iron	10.02±0.02[b]	11.04±0.04[a]	8.5
Calcium	293.76±0.6[a]	105.99±0.04[b]	341.2
Zinc	2.24±0.04[b]	2.88±0.03[a]	3.7
Magnesium	9.09±0.04[b]	30.12±0.03[a]	48.7
Potassium	693.41±1.13[b]	1311.37±2.08[a]	408.7
Sodium	409.45±0.96[b]	702.96±0.05[a]	60

The values obtained are means ± standard deviation determined in three trials. On the lines of each parameter, the averages affected by no common letter are significantly different between them at the 5% threshold

Table 3. Average load of desired microorganisms in flours according to cereals

	Microbial load (CFU / g)		
Germs	Flour from yam peelings	Millet flour	Baking flour Standard (FAO, 2009)
Aerobic mesophilic germs	(5.7±0.1) ×10^{4}[a]	(3.8. ±0.3) ×10^{4} [a]	<10^{6}
S. Aureus	(8. ±1.4) ×10^{1}[a]	(9.5± 0.7) ×10^{1}[a]	<10^{2}
Bacillus	(1.1±0.1) ×10^{2}[a]	(3.3. ±0.9) ×10^{2}[a]	-
TC	(5. ± 1) ×10^{1} [a]	(2.2. ± 0.6) ×10^{2}[a]	<10^{3}
FC	nd	(0.5. ±0.1) ×10^{2}[a]	-
E. coli	(0.7. ± 0.2) ×10^{1}[a]	(0.5. ± 0.1) ×10^{1}[a]	<10^{2}
Yeasts-Moulds	(4.6. ± 0.9) ×10^{2}[b]	(8.5. ± 0.3) ×10^{2}[a]	<10^{3}
ASR	(1.5. ± 0.7) ×10^{1}[a]	nd	<10^{2}
Salmonella	Abs	Abs	Abs

The values obtained are means ± standard deviation determined in three trials. On the lines of each parameter, the averages affected by no common letter are significantly different between them at the 5% threshold. TC : Total coliforms, FC : Fecal coliforms, nd : not detected, Abs : Absent, ASR : Anaerobic sulfite-reducing.

obtained with millet porridges with (3.2 ± 0.1) for color and (1.7 ± 0.2) for taste, while the yam peel flour porridge showed (1.5 ± 0.2) and (1.9 ± 0.2) respectively.

Acceptability of different porridges

The results of the evaluation of the acceptability of the cooked porridges based on the different flours are shown in Table 4. The highest rating (4.1± 0.6) for the millet flour porridge versus 3.4 ± 0.8 for the yam peel flour porridge. The differences were in color and smell.

Table 4. Acceptability of slurries based on the different flours

Type of flour	Acceptability
Millet flour	4.1± 0.6[a]
yam peel flour	3.4 ± 0.8[b]

The values obtained are means ± standard deviation determined in three tests. On the column for each parameter, the means affected by a different letter are significantly different from each other at the 5% threshold

DISCUSSION

The survey on children's flours has set itself the objective not only to know the different (Traditional) flours used for children's porridge but also the type of cereal most used for the preparation of traditional children's flours. In this regard, this study revealed that all respondents are familiar with infant flours. However, only 65.2% of them use it to make a complementary food for their child. In addition, 48.15% of the people questioned who use infant flours choose industrial infant flours and 51.15% for traditional flours (results not shown). In addition, the majority of users of traditional infant flours (29.8%) use flours made from millet and corn (22.2%), other cereal flours are used less. This result could be justified by the fact that this type of flour is more accessible and at low prices compared to industrial flour. Indeed; according to Gbogouri *et al.* (2019) in Côte d'Ivoire, industrial complementary foods for children sold in supermarkets and large commercial brands are inaccessible to a large part of the population because they are sold at very high prices. At the end of this survey, millet flour, being the most used for infant food, was used as a control to compare its physico-chemical and microbiological characteristics with that formulated from yam peels. Yam flour is obtained according to the diagram shown in Figure 3. Thus Table 1 presents the values of the physicochemical characteristics of the flours according to the raw material. The pH of the millet flour was 3.79±0.01 with a titratable acidity of 0.61±0.03%. The flour obtained from yam peelings had a pH of 6.15±0.01 and a titratable acidity of 0.02±0.01%. These results for flour obtained from yam peels are consistent with those of Soro *et al.* 2013 on *bêtê bêtê* yam flour. Indeed, the acidification of the flours is the result of the production of various organic compounds (acids) such as lactic and acetic acids (Bottier, 2006). Millet flour is more acidic than yam peelings. The production of organic acids in millet flour would be higher than that obtained from yam peelings. Similarly; the moisture content of millet flour has an average content of 35.32± 0.02%. This value is higher than that of yam peel flour (15.78±0.01%). According to Aryee *et al.* (2006), the moisture content is a very important parameter in the preservation of flours as a moisture content above 12% favours the growth of microorganisms. It could be said that yam peel flour has a longer shelf life than millet flour. The ash content of millet flour (1.49 ± 0.04 g/ 100g) is lower than that of yam peel flour (7.01±0.03 g/ 100g). According to Abiodun *et al.* (1999), high ash content is most often attributed to mineral richness of the food. Thus, yam peel flour would be richer in minerals than millet flour. Proteins were also detected in the various flours analysed. These proteins play an essential role in the construction and repair of the body (Hayat *et al.*, 2014), as well as in the defence against certain diseases (Ponka *et al.*, 2016). The protein contents of millet and yam peel flours are 9.98±0.02 g/ 100g and 9.55±0.02 g/ 100 g respectively. These values are lower than the recommended value for unfermented (14.5%) and fermented (15%) flours according to Camara (2002). This low protein content could be justified by the fact that millet and yam grains undergo different treatments to obtain the different flours. To improve their protein content, it would be interesting to control the treatments of the raw materials and even the flours. The addition of legume flours to these flours could be considered, as legumes are very rich in protein, containing between 20-50% (Singh *et al.*, 2004). As for lipids, they are important macronutrients in nutrition. Indeed, they increase the energy density of foods (Tenegashaw *et al.*, 2017) and contribute to improving the nutritional composition of fat-soluble vitamins (A D E K) in foods by facilitating their availability in the body (Amegovu *et al*. 2013; Levitsky and Patapoud, 2015). The lipid levels of millet flour and yam peel flour are 0.78±0.02 g/ 100g and 0.54±0.04 g/ 100g respectively. These low lipid contents could be explained by the fact that the flour was processed during production. Indeed, in view of the production practices, the fat-rich parts could certainly be rejected. The carbohydrate content of millet flour (83.93±0.05 g/100 g) was higher than that of yam peel flour (74.73±0.03 g/100 g). These levels are above the UNICEF (2002) standard for carbohydrate content in infant flour of 68 g/100 g of flour. These high levels of total carbohydrates are thought to be due to the fact that the flours were not fortified with legumes or other cereals and did not undergo technological treatments such as fermentation and germination for millet flour. In an earlier study, Brou (2000) showed that fortification and fermentation of the flours would reduce the carbohydrate content, which could lead to a carbohydrate content close to the standard. The

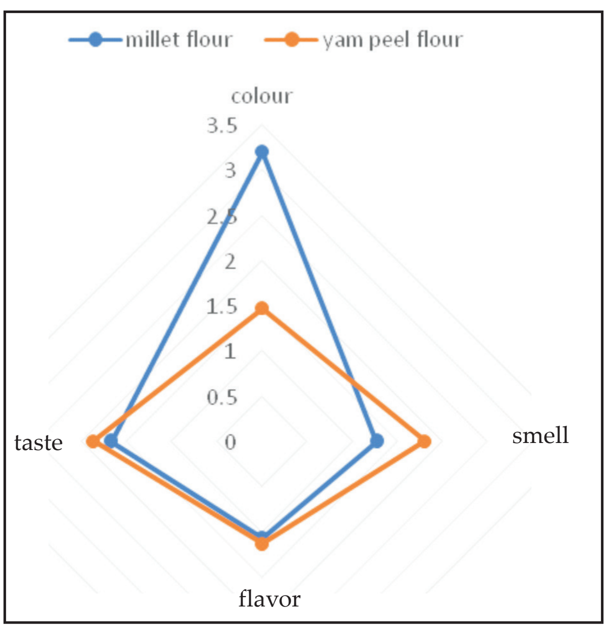

Fig. 4. Sensory profile of slurries

fibre content of infant flours should not exceed 5g per 100g of product on a dry matter basis (FAO/ OMS, 2006). The fibre content of millet flour is 3.82±0.04 g/ 100g and 8.17±0.03 g/ 100g for yam peel flour. This high fibre content of yam peel flour could increase the bulkiness of the feed and promote low digestibility and absorption of nutrients such as proteins and minerals as reported by Olorufémi *et al.* (2006). However, according to AFSSA (2002), the high presence of fibre in these composite flours would be favourable to the reduction of postprandial glycaemia and insulinemia. The energy value of millet flour is relatively higher at 330.51±0.21 Kcal than that of yam peel flour at 294.61±0.27 Kcal. Energy is one of the most important elements in the growth of infants. These values are close to the norm of 400 Kcal (Dewey and Chapano, 2007). The high content of total carbohydrates would be the main factor explaining this good energy value as these flours are low in protein. However, the presence of minerals in both flours should be noted. The mineral profile of millet and yam peel flour consists of macroelements (potassium, sodium, magnesium, calcium) and microelements (iron, magnesium, zinc) in significant quantities that could be useful for children. Yam peel flour contains sufficient potassium, magnesium, iron and calcium; so does millet flour. The presence of these minerals in these flours is beneficial because they are involved in the development of the body and in the growth of the child and could limit the occurrence of nutritional deficiencies (Dewey and Chapano, 2007). Yam peel flour and millet flour provide many minerals with very variable contents. The potassium, zinc, magnesium and especially iron contents comply with the values recommended by the FAO/OMS (2006) standard. The iron provided, in sufficient quantity, is the determining factor for ensuring the needs of the infant's body. Indeed, iron is a component of haemoglobin and is involved in cellular respiration, immunity and muscle metabolism (FAO, 2000). Similarly, the presence of calcium in yam peel flour could be involved in bone structure, coagulation, muscle concentration, and nerve transmission. A zinc content of 2.24±0.0 mg / 100g is also obtained in yam peel flour compared to 2.88±0.03 mg /100g. The presence of zinc in yam peel flour and millet flour is an important contribution to child growth (Sangronis and Machado, 2007). Indeed, the presence of all these micronutrients in the flours could protect the young child from deficiency diseases (malnutrition) that threaten many children in developing countries. Regarding the microbiological parameters, the enumeration of germs (AMG, *Staphylococcus, Baccillus, E. coli*, yeasts and moulds, ASR, and *Salmonella*) was carried out on the different flours. The results showed that both types of flour (yam peel flour and millet flour) have a satisfactory level of contamination according to the criteria of FAO, 2009. The load of AMG (aerobic mesophilic germs) contamination of millet flour was $(3.8 \pm 0.3)\times10^4$ CFU/g against $(5.7 \pm 0.1)\times10^4$ CFU/g for yam peel flour.The presence of AMGs such as coliforms, *Staphylococcus, Bacillus, E. coli*, and anaerobic sulphite reductants (ASR), in the flours analysed could be explained by the lack of hygiene and a lack of control of technical production and an unhealthy production environment (CCA, 2008). This lack of hygiene in food factories has been reported by Karou *et al.* (2001) in relation to the environment, labour, equipment and working methods combine to degrade the quality of food. As for the yeast and mould loads, they could be due to poor post-harvest treatment and poor storage conditions of cereals and tubers before processing into flour. Moulds have the property of spawning under unfavourable conditions and multiplying by germination when conditions become favourable. The massive presence of moulds constitutes a danger because they can produce mycotoxins that are toxic to humans (Filtenborg *et al.*, 1996). The organoleptic quality (taste, colour, aroma...) of the millet flour and yam peelings porridges influences their acceptability (Besançon, 1999). Millet flour porridges have a brown colour, yam peel porridge has a brown colour. The porridges were accepted by the tasters with a slightly higher acceptability of the millet flour porridge. In addition, the work of Halima et *al.* (2012) showed that 60% of malnourished children regained a good nutritional status following the consumption of good organoleptic and nutritional quality complementary porridges**.**The study consisted of developing a complementary food for infants and young children based on accessible and available local inputs (yam peels). Beforehand, a survey was carried out on the consumption of traditional porridges by children aged 6 to 24 months. The traditional porridges consumed are prepared from different cereals, but millet flour is the one most used by the mothers. The study carried out with a view to contributing to the supplementary feeding of infants during the weaning period led to the development of flour. The yam peel flour contains sufficient potassium, magnesium, iron and calcium, which meet WHO standards. Yam peel flour and millet flour do not provide sufficient protein to meet the FAO criteria; this flour is low in fat, as is millet flour. Flour made from yam peelings has a dry matter and energy density close to the standard prescribed by UNICEF for standard flours. The flours produced contain pathogenic germs whose loads are below the threshold values indicated by the FAO. The organoleptic test indicates that the yam peel porridge is as acceptable as the millet porridge. Moreover, this flour can be reproduced by mothers and is less expensive than local and imported flours. Thus, the development of the yam peel flour manufacturing process for the elaboration of local infant flours in Côte d'Ivoire will make it possible to alleviate nutritional deficiencies and malnutrition in children, particularly during weaning, by improving nutritional quality through the addition of inputs.

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Conflict of interest

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Availability of data and materials

The data files associated with this study have been submitted along with this manuscript and are available upon request. Please contact the Corresponding Author with any questions or concerns

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