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Sensory evaluation of biscuits resulting from partial substitution of wheat flour with spent grain from three varieties (Bakor, Kponan and Lokpa) of *Dioscorea cayenensis-rotundata* complex cultivated in Brobo (Centern, Ivory Coast)

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Abstract

The aim of this study is to valorize yam spent grain obtained after extraction of starch in biscuit production. After extracting the starch from three varieties (Bakor, Kponan and Lokpa) of *Dioscorea cayenensis-rotundata*, the spent grains were dried at 45°C for 48 h then crushed and the flours were incorporated into the wheat (*Triticum aestivum*) flour at 5 and 10%. The physicochemical and functional properties of formulated flours were determined as well as the sensory characteristics of the biscuits produced. The results of the physicochemical properties of the formulations reveal moisture, fiber and carbohydrate levels varying respectively from 11.82±0.04 to 11.99±0.0; 1.84±0.01 to 2.35±0.03 and from 76.71±0.02 to 76.88±0.06. The formulated flours have appreciable functional properties in terms of water absorption capacity (83.32±0.32 - 87.78±0.40 g), water absorption capacity (126.29± 0.48 – 148.73±0.58 g) and inflation capacity (8.83±0.12 – 10.64±0.23 g). On the sensory level, the results showed that biscuits produced with 5% incorporation are the most appreciated. In order to contribute to food security, yam spent flours can be incorporated at a rate of 5%, thereby reducing wheat flour by 5%.

Keywords: Dioscorea cayenensis-rotundata complex; Spent grain; Formulation; Biscuit; Functional

1. Introduction

Production of pastry products requires wheat as a raw material [1], which is not produced in Ivory Coast. To meet pastry and bakery needs, it imports a significant quantity of wheat (*Triticum aestivum*). This import has increased significantly due to changes in eating habits and overpopulation in urban areas [2]. This increased dependence on wheat is detrimental to the Ivory Coast economy. In addition, it worsened with the Russo-Ukrainian war, which led to an increase in the cost of wheat on the world market. Furthermore, pastry products such as biscuits are expensive and their accessibility to the most vulnerable populations is not yet ensured.

In turn, an alternative approach would be to promote the consumption of local food resources. Several studies have revealed that flours from local cereals and tubers can be used as a partial replacement for wheat flour in the production

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of bread and biscuits [3, 4]. One of the solutions would be the use of agricultural residues, including yam spent grain (*Dioscorea cayenensis*) from starch extraction. The use of yam spent flour in pastries would contribute to the food security of the Ivorian population by reducing the cost of biscuits produced as well as improving the health of consumers, especially diabetics and obese people due to their richness in fiber and their poverty in fat and sugar [5].

Despite the work of [6] on the use of ginger residue in the production of bread, it must be recognized that there is no scientific data on the use of yam spent grain in biscuit production.

Hence, the objective of this study is to evaluate the sensory characteristics of biscuits resulting from partial substitution of wheat (*Triticum aestivum*) flour with spent grain flours from three *Dioscorea- cayenensis* complex varieties “Bakor”, “Kponan” and “Lokpa” from three varieties of yam (Bakor, Kponan and Lokpa).

2. Material and method

2.1. Materials

2.1.1. Biological material

Three varieties of *Dioscorea cayenensis* complex and wheat (*Triticum aestivum*) flour type 45 constituted the plant material used in this study. Yams tubers were collected from an experimental field located in the sub-prefecture of Brobo (7°43'0'' N and 4°42'0' W) in the Center of Ivory Coast and were harvested in September 2023.

Bakor Lokpa Kponan

Figure 1 Different varieties of yams

2.1.2. Chemicals

All solvents (n-hexane) and sulfuric acid were purchased from Merck. Sodium hydroxide was purchased from Sigma-Aldrich. All chemicals used in the study were of analytical grade

2.2. Methods

2.2.1. Production of yam spent grain flour

Yam spent grain flour was obtained during starch extraction. Yam’s tubers were transported to the laboratory of Peleforo GON COULIBALY University where they were washed, with distilled water, peeled, diced, steeped in a 0.1% sodium bisulfite solution and finally, crushed in a blender containing distilled water. The crushed material was sieved successively through 500 µm, 250 µm and 100 µm. The residue was diluted in 1 liter of distilled water then sieved through 100 µm. This operation is repeated 3 times. Residue obtained after these washes was dried at 45 °C in an electric dryer for 48 hours. After drying, the residue was grounded with a laboratory crusher (Culatti) equipped with a 10 µm mesh sieve. The dried powdered obtained was stored in plastic jars

2.2.2. Preparation of the Compound Flour

Flour production was carried out according to the method described by [7] and recorded in the following table 1. Residue flour from each variety (Lokpa, Kponan and Bakor) of yam was mixed with wheat flour at proportions of 5 and 10%. Wheat flour served as a control.

Table 1 Different formulation

Flour	F0	FB1	FB2	FK1	FK2	FL1	FL2
Wheat flour (g)	100	95	90	95	90	95	90
Lokpa flour (g)		5	10				
Kponan flour (g)				5	10		
Bakor flour (g)						5	10
Total	100 g	100 g	100 g	100 g	100 g	100 g	100 g

2.2.3. Determination of physicochemical parameters

Moisture, ash, proteins and lipids were determined using official methods [8]. Moisture content was determined by the difference of weight before (5 g) of flour in an oven (Memmert, Germany) at 105 °C until a constant weight. The ash fraction was determined by the incineration of flour (5 g) in a muffle furnace (Pyrolabo, France) at 550 °C for 12 hours. Proteins were determined through the Kjeldhal method, and the lipid content was determined by Soxhlet extraction using hexane as a solvent. For crude fibers,the [9] method was used. 2 g of flour were weighed into separate 250 mL round-bottom flasks, and 50 mL of 0.25 M sulfuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 50 mL of 0.3 M sodium hydroxide solution was added and the mixture was boiled again under reflux for 30 min and filtered through Whatman paper. The insoluble residue was then incinerated, and weighed for the determination of crude fibers content. Carbohydrates content and calorific value were calculated and expressed on a dry matter basis using the following formulas [10] : Carbohydrates (%) = 100 – (% moisture + % proteins + % lipids + % ash + % fibers).

2.2.4. Determination of fonctional parameters

Water absorption capacity (WAC) and water solubility index (WSI) were determined according to the method [11] with slight modifications. One (1) g of flour is mixed with 10 mL of distilled water for 30 min. The mixture is centrifuged for 10 min at 1200 trs/min. The pellet is weighed, and the supernatant is dried at 105 °C. Water absorption capacity and water solubility index were determined using the following formulas:

$$WAC (\%) = [(Pm - Sw) / Sw] \times 100$$ with Pm: pellet mass, Sw: flour weigh

$$WSI (\%) = [ms / Sw] \times 100$$ with ms: supernatant dried mass.

Oil absorption capacity (OAC) was determined according to the method of [12]. One (1) g of flour was dispersed in 10 mL of palm oil. After stirring for 30 min, the mixture was centrifuged at 1200 rpm for 10 min. The supernatant was collected and then the pellet was weighed. The following formula allowed us to determine the OAC.

$$OAC(\%) = [(Pm - Sw) / Sw] \times 100$$

Swelling capacity (SC) was determined according to the method [13]. Four (4) g of flour is homogenized in 40 mL of distilled water. The mixture is heated at 90 °C for 1h. After 1h, the tube is cooled and then centrifuged at 5000 rpm for 10 min. The pellet is weighed and then dried at 105°C and finally weighed. The following formula was used for to determine the swelling capacity:

$$SC (g/g) = Pm / [Sw (1 - Mo) \times (100 - So)]$$ with Pm: pellet mass, Sw: flour weight, Mo: moisture, So: solubility.

2.2.5. Biscuit production

Biscuits production was carried out according to the method of [4]. Flour was kneaded with the other ingredients (yeast, sugar, butter, salt and water). The pasta obtained was calibrated then shaped and finally baked at 200 °C for 15 min.

Table 2 Formulation of compound pasta

Ingredient	F0	FB1	FB2	FK1	FK2	FL1	FL2
Flour (g)	100	100	100	100	100	100	100
Yeast (g)	7	7	7	7	7	7	7
Butter (g)	25	25	25	25	25	25	25
Sugar (g)	20	20	20	20	20	20	20
Salt (g)	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Water (g)	30	30	30	30	30	30	30

2.2.6. Sensorial evaluation

Hedonic tests using thirty (30) untrained subjects were used for sensory analysis [14]. The test focused on of appearance, color, smell and taste on a scale from 1 to 9 points indicating the level of panelist preference. Biscuits are coded according to the formulations and submitted to each panelist randomly.

2.2.7. Statistical analysis

Statistical analyses were performed with Graph Pad Prism software version 8.0.2 (263). The variance analysis (ANOVA) was conducted to determine differences between the averages according to method of Turkey at the 5% threshold ($p<0.05$ was considered significant). The results were expressed as averages with standard error on mean (mean ± SEM).

3. Results and discussion

Physicochemical parameters of the different flours are represented in Table 3. The moisture of these flours varies from 9.84±0.28% for lokpa flour to 12.05±0.02% for wheat flour. The different formulations have statistically identical contents with an average of 11.92%. These results are higher than those of [15] whose contents varied from 8.29±0.28% to 10.75% in formulations from wheat and voandzou. These low moisture contents could be due to the drying technique used. These contents of less than 12% would be favorable for the long storage of these flours because they would limit the proliferation of yeasts and even molds, which have a positive impact on the quality of the flours [16]. The different flours have ash contents ranging between 0.09±0.00% and 0.46±0.01%.

Formulations with 5 and 10% spent grain have statistically identical contents with an average of 0.40%. These results are much lower than those of [17] in formulations based on yam, corn, voandzou and fish. The low mineral contents of our formulations could be due to leaching of minerals during starch extraction. To fit the diet, the consumption of our flours should be supplemented with foods rich in minerals such as leafy vegetables [18]. Concerning proteins, the statistical analysis of formulations FB1, FK1 and FL1 differ statistically from formulations FB2, FK2 and FL2. Protein values range from 2.58±0.05% to 10.20±0.07%. The contents of our different formulations are lower than lafu flour (1.1%) in Benin [19]. These low protein contents of our different formulations could be explained by the low protein content of yams and wheat. These formulations with contents lower than 12% [20] could not be considered as sources of protein, hence their consumption would suggest their supplementation with protein sources such as meat and fish. The analysis shows statically identical contents in the different formulations (1.07±0.00 to 1.12±0.01%). These contents are identical to those of [21] which were 1.13% in artisanal flours in Cameroon. These low levels could be explained by the fact that yams and wheat are not lipid sources. However, the consumption of different flours could be advantageous for obese people in the case of a hypolipidemic diet [22]. The fiber contents in the formulations increase with the incorporation rate of yam spent flour. These contents range between 1.87±0.00 and 2.35±0.03% compared to wheat flour (0.11±0.02%). This trend was also recorded by [15] in formulations based on wheat and voandzou. This high fiber content could be explained by the concentration of fiber in the spent grains during starch extraction. This richness in fiber of spent grain flours and our formulations could be advantageous for the consumer since the fibers fight against constipation by facilitating intestinal transit and reducing the absorption of glucose [23, 24]. Consumption of spent grain flour could largely cover daily needs estimated at between 25 and 30 g [25]. The carbohydrate level of our different formulations is statically identical and is approximately 77% compared to the level of spent grains (33.50%). This observation is different from that of [15] who observed a drop that evolved with the rate of incorporation of voandzou flour into wheat flour. The high contents of the different formulations could be a good source of energy for infants. On the other hand, spent grains could be recommended for diabetics in the case of a hypoglycemic diet.

Table 3 Physicochemical properties of wheat, yam spent grain and formulations

	Moisture %	Ash %	Proteins %	Lipids %	Crude fibres %	Carbohydrates %
F0	12,05±0,02a	0,46±0,01a	10,20±0,07a	1,40±0,01a	0,11±0,02f	75,89±0,14b
Bakor	10,33±0,02e	0,09±0,00d	2,62±0,00d	0,02±0,00c	53,11±0,11b	33,80±0,00d
Lokpa	9,84±0,28f	0,09±0,00d	2,59±0,03d	0,02±0,00c	52,85±0,09c	34,59±0,33c
Kponan	10,95±0,08d	0,09±0,00d	2,58±0,05d	0,02±0,00c	53,54±0,22a	32,82±0,12e
FB1	11,97±0,04a	0,43±0,00b	9,76±0,02c	1,12±0,00b	1,88±0,02e	76,71±0,02a
FB2	11,88±0,02b	0,40±0,00c	9,80±0,00b	1,09±0,01b	2,31±0,04d	76,82±0,00a
FL1	11,95±0,05ab	0,42±0,00b	9,74±0,02c	1,12±0,01b	1,84±0,01e	76,77±0,09a
FL2	11,82±0,04c	0,41±0,00c	9,81±0,01b	1,07±0,00b	2,28±0,04d	76,88±0,06a
FK1	11,99±0,01a	0,43±0,01b	9,74±0,01c	1,10±0,01b	1,87±0,00e	76,74±0,00a
FK2	11,94±0,04ab	0,42±0,00b	9,79±0,01b	1,07±0,00b	2,35±0,03d	76,77±0,05a

Data are represented as Means ± SD (n = 3). Means in the colonn with no common letter differ significantly ($p<0.05$) for each flour.F0 : wheat flour ; Bakor, Lokpa and Kponan : Variety yam spent grain ; FB1 : 5% Bakor ; FB2 : 10% Bakor ; FL1 :5% Lokpa ; FL2 :10% Lokpa ; FK1 :5% Kponan ; FK2 :10% Kponan.

Table 4 presents the functional properties of the different flours. The solubility index values of wheat flour and formulated flours are statically identical and differ from that of spent grains from different varieties of yams. Wheat flour and formulated flours have solubility indices varying from 11.99±0.14 to 12.15±0.08%. These results are significantly lower than those of [15] in flours formulated with voandzou (28.12±2.29 to 34.23±1.04%) and higher than those of [26] in three varieties of cassava (9.10±0.50 to 11.02±1.47%). The low solubility of the different formulations can be explained by their richness in fiber. As for spent grains, this low solubility is due to their lack of starch. The water absorption capacity of formulations, wheat and spent grains are statically different. The values range between 80.10±0.35 and 257.48±0.84%. The water absorption capacity of the formulations (83.32±0.32 to 87.78±0.40%) is lower than that of [6] in flour composed of wheat and 5% of ginger residue (128.21±0.33%). The high water absorption capacity of spent grains (231.09±1.30 to 257.48±0.84%) would be due to their high fiber content which has the capacity to retain water [27]. Spent flours and different formulations could be used in the preparation of soups, creams and baked goods. The oil absorption capacity of the different flours is statically different with values oscillating between 126.29±0.48 and 169.72±0.74%. These values are higher than those of [15] in formulations based on wheat and voandzou (93.53±15.67 to 123.30±9.76%) and lower than those of [28] and [29] in Apki (227.4%) and soybean (194%) respectively. This high oil absorption capacity of our formulations can be explained by their high fiber content as well as the particle size [22]. The different formulations could be used in bakery and charcuterie products because they would enhance the flavor and preservation over a long period of these products [30, 31]. The swelling capacity of our different flours is statically different. Wheat and formulations recorded the highest values (8.83±0.12 to 11.46±0.20 g/g) compared to spent grain flours (8.07±0.06 to 8.38± 0.05 g/g). The values of the different formulations are lower than those of [6] and [32] respectively in the formulation based on ginger residue (12.66±0.45 g/g) and in sorghum. (12 to 15 g/g). This low swelling capacity of our formulations could be due to their low protein and lipid content as well as temperature. Indeed, the swelling power depends on the protein, lipid and amylose content creating a strong bond leading to the formation of inclusion complexes as well as the gelatinization of the starch which solubilizes [33].

Table 4 Fonctional properties of different flour

	Water solubility index %	Water absorption capacity %	Oil absorption capacity %	Swelling capacity g/g
F0	12,10±0,02a	80,10±0,35h	155,67±0,59c	11,46±0,20a
Bakor	3,43±0,01c	255,80±0,62b	169,72±0,74a	8,09±0,09h
Lokpa	3,53±0,05b	231,09±1,30c	151,69±0,30d	8,38±0,05g
Kponan	3,59±0,03b	257,48±0,84a	159,22±1,03b	8,07±0,06h
FB1	12,10±0,07a	87,04±0,41e	148,73±0,58e	10,64±0,23b
FB2	11,99±0,14a	87,78±0,40d	144,72±0,48f	9,98±0,02d
FL1	12,07±0,03a	83,32±0,32g	135,25±0,42h	9,43±0,28e
FL2	12,02±0,02a	84,58±0,65f	126,29±0,48i	8,83±0,12f
FK1	12,15±0,08a	86,20±0,13e	144,97±0,16f	10,13±0,06c
FK2	12,07±0,03a	87,59±0,58d	139,84±0,38g	9,75±0,35cd

Data are represented as Means ± SD (n = 3). Means in the colonn with no common letter differ significantly (p<0.05) for each flour.

F0 : wheat flour ; Bakor, Lokpa and Kponan : Variety yam spent grain ; FB1 : 5% Bakor ; FB2 : 10% Bakor ; FL1 :5% Lokpa ; FL2 :10% Lokpa ; FK1 :5% Kponan ; FK2 :10% Kponan.

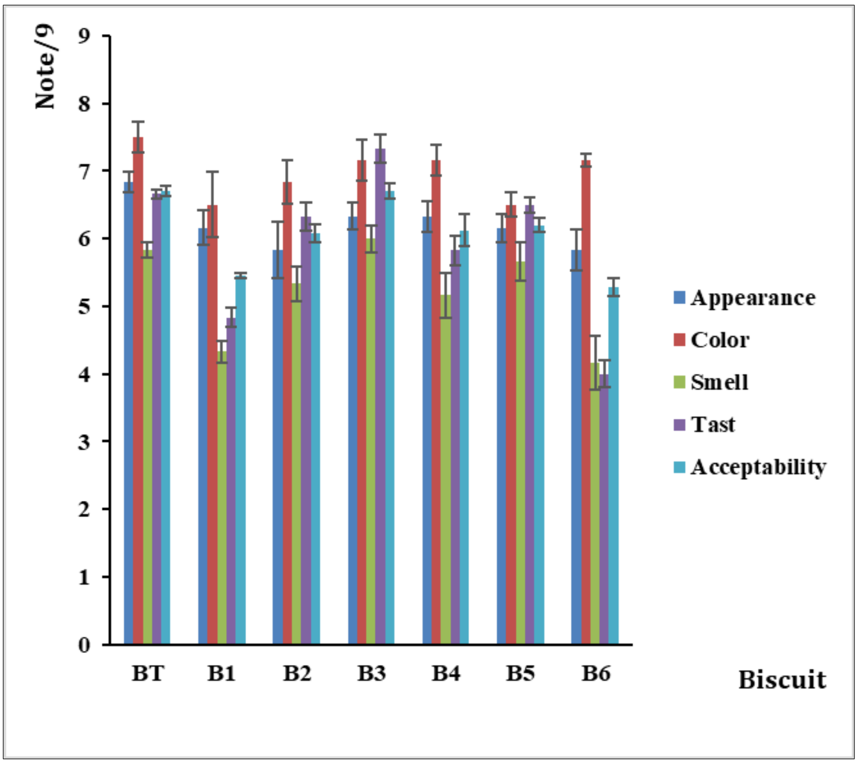

Figure 2 Sensory characteristics of the biscuit produced

The sensory characteristics of the biscuits produced according to the different formulations are represented by Figure 2. Concerning the appearance, it appears that the tasters appreciated the BT biscuits the most (6.83) followed by B3 (6.33) and B4 (6.33). This observation was also recorded by [4] for biscuits formulated with orange sweet potato flour. The color of the different biscuits was appreciated by the tasters. This golden color is explained by the low protein content of our different formulations which does not favor the Maillard reaction. The aroma (6) and taste (7.16) of B3 are the most popular followed by that of the control BT, B5 and B2. These results confirm those which stipulate that incorporation rates of up to 50% in biscuits gave appreciable organoleptic qualities [34]. The biscuits most accepted by the panelists are BT and B3 followed by B5, B4, B2, B1 and B6.

4. Conclusion

Yam spent grains are commonly utilized as livestock feed in developing countries. To promote their use in human food, the flours derived from these spent grains have been examined as potential substitutes for wheat in biscuit production. Upon evaluation, the results revealed that the incorporation of these flours increased the fiber content, water and oil absorption capacity and swelling capacity of the formulations. This enhanced fiber, water and oil absorption capacity and swelling capacity would offer benefits in baking, pastry and charcuterie. Generally, biscuits from the Lokpa variety (B3 and B4) outperformed those from the Kponan variety (B5 and B6), followed by Bakor (B1 and B2). The optimal incorporation rate is 5% which would reduce the use of wheat flour in production by 5%. It would be advisable to evaluate the *in vitro* digestibility of the produced biscuits.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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