
Effects of Baobab (*Adansonia Digitata*) Fruit Pulp Powder Incorporation On the Nutritional, Functional and Sensory Properties of the Composite Bread Made with Wheat Flour

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Abstract: *The Baobab (*Adansonia digitata*) is nicknamed the “tree of life” because of its exceptional versatility in terms of food, medicine, economics and ecology, with edible fruit. The aim of this study is to diversify the use of *Adansonia digitata* pulp, a local food resource that is little exploited for everyday products such as bread. *Adansonia digitata* fruit pulp, dried and ground into a very fine mixture, is incorporated into Type 55 wheat flour. Composite formulations containing 0%, 5%, 10%, 12% and 15% *Adansonia digitata* powder were analyzed for their nutritional, functional and sensory characteristics. The results show a significant improvement in fiber content (2.15%), bioactive compounds (polyphenols (2737.75 mg EAG/100g DM); flavonoids (804.91 mg EQ/100g DM) and tannins (968.25 mg EAT/100g DM)) and minerals (1.47%). Formulations containing up to 10% *Adansonia digitata* were the best accepted from a sensory point of view. The moderate incorporation of *Adansonia digitata* pulp into wheat flour therefore appears to be an effective strategy for improving the nutritional quality of bread while preserving its acceptability by consumers.*

Keywords: Baobab, *Adansonia digitata* fruit pulp powder, breadmaking, composite bread.

INTRODUCTION

Bread is one of the daily diets throughout generally in the world and particularly in Ivory Coast. It is mainly produced from wheat flour. This cereal is not grown in Ivory Coast. Its flour is imported. This flour is expensive due to foodstuffs prices fluctuations. Moreover, wheat flour pasta is not consumed by everyone due to gluten content that its difficult digestion and the sensitivity of some people to the gluten for their health (Wolter *et al.*, 1979). Refined wheat flour, the main raw material of bread, not contain enough fiber, minerals, and antioxidants nutriment. To address these issues, it would be advisable to use certain local products such as *Adansonia digitata* fruit pulp, which has high levels of these nutrients in the wheat bread production. *Adansonia digitata* fruits, commonly called "monkey breads,"

contain a white, dry and floury pulp (Asogwa *et al.*, 2021). This pulp is flavorful and citrusy taste, which hardens upon drying to form powdery lumps (Musyoki *et al.*, 2022). The pulp of this fruit is an important source of vitamins (A, B1, B2, B6 and C), minerals (Cu, Fe, Na, P, K, Mg and Ca) and phenolic compounds (catechins, tannins, polyphenols and flavonoids) (Coulibaly *et al.*, 2014).

In Ivory Coast, the use of *Adansonia digitata* is mainly oriented in its fruit enclosed the pulp. This pulp can be consumed directly as a dessert or, in the form of nectar, juice and syrup after the juice extraction. It can be used in numerous food formulations such as cocktails and fruit medleys. The pulp is also used as some seasoning in traditional dishes and aperitifs (Ajayi *et al.*, 2003). Sufficient quantity of *Adansonia digitata* pulp consumption can offer to the human body the essential reference minerals (sodium, potassium, calcium, magnesium, phosphorus, iron, copper, zinc and manganese), vitamin C, thiamine or vitamin (B1), riboflavin or vitamin (B2) (Chadare *et al.*, 2010). The high mineral content of African *Adansonia digitata* fruit pulp is an indication of its ability to provide necessary minerals to the human body, regardless of age, sex and health status (Offiah *et al.*, 2023). *Adansonia digitata* pulp powder provides additional nutritional value when it is combined with millet, soy flour, pineapple, yogurt and others complementary meals (Dendegh *et al.*, 2019; Adelekan and Saleh, 2020; Millicen *et al.*, 2021; Wairimu *et al.*, 2022). It is that a better suitable to reduce the body micronutrient deficiencies (Mwangi *et al.*, 2023). *Adansonia digitata* fruit pulp combined with pineapple, black plum and other edible fruits juices creates a rich functional beverage an antioxidant with optimal benefits for consumers who are deficient diets micronutrient (Badejo *et al.*, 2020; Adedokun *et al.*, 2022). *Adansonia digitata* fruit pulp contains active plant metabolites, especially secondary metabolites (Hussein and El-Anssary, 2019). These metabolites are responsible of various properties such as antioxidant, anti-inflammatory, antibacterial, antihelminthic, anticoagulant, anticancer, antihypertensive, antidiabetic and hypolipidemic effects (Silva *et al.*, 2023, Monteiro *et al.*, (2022); Chiacchio *et al.*, (2022). The pulp is the part of the *Adansonia digitata* fruit, which contributes at most to medicinal using. It is used in the treatment of several diseases that the most important are anemia, malaria and diarrhea. Its richness in prebiotic fibers helps to regulate intestinal transit combating constipation (Kamatou *et al.*, 2011; Althwab *et al.*, 2019). The pulp of *Adansonia digitata* fruit can be used as a functional food for the treatment and prevention of hyperlipidemia, stimulating the activity of antioxidant enzymes (Kamatou *et al.*, 2011; Althwab *et al.*, 2019). It is thus often used as hair rinse. *Adansonia digitata* is an African tree with multiple uses. The pulp is rich in vitamins, minerals, amino acids, total phenolics, terpenoids, condensed tannins, chlorogenic acid; epicatechin; procyanidin, protein, fat, carbohydrates, pectin, ash and fiber (Sidibé and Williams, 2002; Kamatou *et al.*, 2011).

In the context of malnutrition eradication and the valorization of local resources of each country, the incorporation of fruits rich of nutrients such as pulp of *Adansonia digitata* fruit represents a promising alternative. The general objective of this work is to develop and promote the use of *Adansonia digitata* fruit pulp in the food industry through the knowledge of some of its nutritional, functional and sensory properties.

MATERIALS AND METHODS

Vegetable material

2.1.1. Floury pulp of *Adansonia digitata* fruit



Figure 1: Floury pulp of *Adansonia digitata* fruit. **a** and **b** : ripe and dried fruits of the *Adansonia digitata*); **c** : powder of *Adansonia digitata* fruit pulp ; **d** : pulp of *Adansonia digitata* fruit ; **e** : ripe fruit, pulp and dried fruit of *Adansonia digitata* *Adansonia digitata*.

Adansonia digitata fruits were obtained from a local market of Adjame Forum Market in Abidjan, South-western Ivory Coast, also without any supplementation (Figure 1). These fruits were immediately transported in jute bags to the biocatalysis and bioprocesses laboratory of Nangui Abrogoua University for nutritional, functional and sensory properties of the composite bread made with wheat flour analyses.

Adansonia digitata pulp powder

The powder of *Adansonia digitata* was obtained according to the method described by Makawi *et al.* (2019). Stainless steel knife is used to break the fruits pods. Three (3) Kg of seeds coated by pulp were removed from the pods and then dried in a ventilated oven at 45°C for 24 hours. They were grinded with a mixer. The ground material was sieved with a mesh sieve of 250 µm. The obtained powder was stored in hermetically closed boxes (Figure 2). The powder was stored in a freezer at -20 °C for 7 days and then at 4 °C for 1 to 3 days before use.

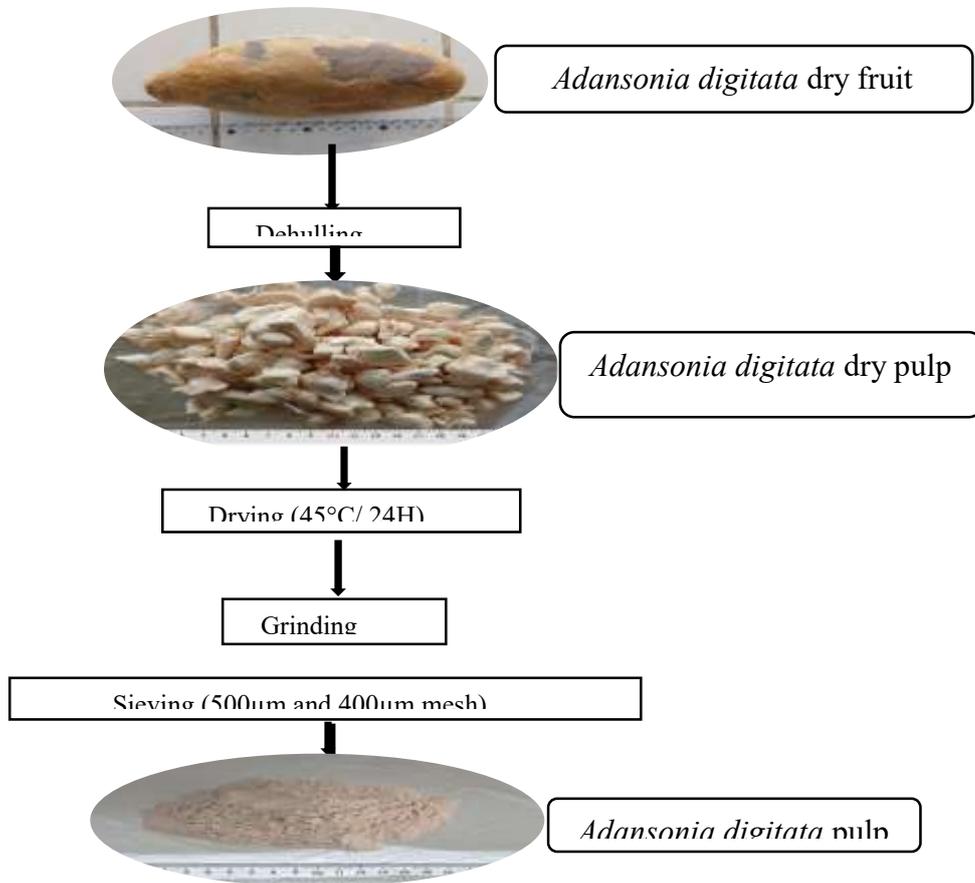


Figure 2: Diagram of *Adansonia digitata* fruit pulp powder process (Makawi *et al.*, 2019).

Wheat flour

All-purpose wheat flour (type 55) variety “Malika” obtained from 100% soft wheat (Cote d’Ivoire) was used without any chemical or protein supplementation (12.3 wt % water, 11.6 wt % proteins and 0.58 wt % ash (moist basis) (Figure 3).



Figure 3: Grains and flour of wheat: **a:** grains of wheat; **b:** Wheat flour type 55.

Composite *Adansonia digitata* pulp powder-wheat flour

Five (5) composite flour formulations were prepared. The different composite flours formulated were labelled F0 (100% wheat flour), F1 (95% wheat flour and 5% *Adansonia digitata* pulp powder), F2 (90% wheat flour and 10% *Adansonia digitata* pulp powder), F3 (88% wheat flour and 12% *Adansonia digitata* pulp powder) and F4 (85% wheat flour and 15% *Adansonia digitata* pulp powder). They were stored in food-grade plastic bags on the same day for laboratory analysis. The composite flour containing 5% of *Adansonia digitata* pulp powder (F1) is the composite flour with 5% of *Adansonia digitata* pulp powder and 95% of wheat flour. A similar sample name was given to the samples with 10%; 12% and 15% of *Adansonia digitata* pulp powder content. Nutritional characteristics (ash, fibre, protein, lipid, total carbohydrate, pH and moisture content), phytochemicals (total polyphenols, flavonoids and tannins) and sensory properties (hedonic test by a panel of 60 untrained men and women who are regular bread consumers) were then studied.

Ingredients for composite Bread Dough

The bread dough samples were prepared by mixing ingredients such as flour, water, yeast, sugar, fat and salt. All-purpose wheat flour (type 55, 12.3 wt % water, 11.6 wt % proteins and 0.58 wt % ash (moist basis)) produced from variety “Malika” and obtained from 100% soft wheat (Cote d’Ivoire) was used without any chemical or protein supplementation. Quantities (0%; 5%; 10%; 12% and 15% DM) of *Adansonia digitata* pulp powder (11.91 wt % water, 2.92wt % proteins and 0.98 wt % ash (moist basis)) were used without any chemical or protein additives.

Determination of composite (wheat flour- *Adansonia digitata* pulp) flour nutritional properties

Water, pH, ash, total fibre, protein, lipid and carbohydrate of the composite flour were determined according to AOAC (1990) method. Each test was been realized at triplicate to ensure the reliability of the results.

pH of the composite flour

The pH was measured in aqueous suspension to assess product acidity or alkalinity. Ten (10) g of composite flour was weighed and mixed into 100 ml of distilled water. It was then homogenised for 30 minutes. Five (5) ml of the filtrate was titrated with NaOH (0.1 N) with phenolphthalein until obtained pink color. The pH value was that collected using a calibrated pH meter (pH 4 and 7 buffers).

Moisture of the composite flour

Five 5 g of composite flours were weighed in a tared container. It then placed in an oven at 105°C for 24 hours. Finally, it was cooled in a desiccator for thirty (30) hours. The moisture content was obtained using the difference of its weight before and after drying.

Organic matter and ash

This method consists of calcining the sample at 550°C in a muffle furnace until a whitish ash of constant weight was obtained. 2g of sample (PE) was weighed in a dried porcelain container of mass M1. The sample and porcelain container both gave a mass of M2. They were placed in

a furnace muffle at 550°C until a white ash was obtained during 5h. The sample thus cremated was placed in a desiccator for cooling. The crucible containing the calcined sample was weight (M₃).

Organic matter is calculated according to the following formula:

$$M_0(\%) = \frac{(M_1 - M_2)}{p} \times 100$$

M₀: Organic matter (%);

M₁: Mass of the crucible containing the test portion (g);

M₂: Mass of crucible and ash (g);

P: Weight of the test portion (g).

The ash content is calculated as follows: Ash (%) = 100 - M₀

Proteins

The composite flour protein content was determined using the Kjeldahl method. It consists to measure the total nitrogen using a digestion device. One (1) g of composite flour sample is digested in concentrated sulphuric acid (H₂SO₄) at the presence of catalysts (selenium and potassium sulphate (K₂SO₄)). It is then neutralised by NaOH, which distils the ammonia. It is then collected in H₃BO₃ (boric acid) and the mixture is titrated with HCl (hydrochloric acid, 0.1 N). The nitrogen content is then converted to protein content using a factor specific (6.25 for general foods) to the composition of the sample.

Lipids

The lipid was extracted at SOXHLET using hexane as the volatile organic solvent. Five (5) g of composite flour was placed in an extracting cartridge. 200 ml of hexane was placed in an extracting bottle already weighed at empty. The bottle containing the hexane was heated to 110°C on the SOXHLET's heating plate during eight (8) hours. The bottle was then removed from the SOXHLET and placed in an oven at 130°C during one (1) hour in order to completely the solvent evaporation.

Total carbohydrate

The total carbohydrate content was obtained using the method of Bertrand and Thomas (1910) according to the following formula:

$\text{Total carbohydrate (\%)} = 100\% - (\% \text{ Water} + \% \text{ Protein} + \% \text{ Lipid} + \% \text{ Ash})$
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Total polyphenols

Total polyphenols were performed according to the method described by Juntachote *et al.* (2006). One (1) ml of methanolic extract was placed in a tube. One (1 ml) of Folin-Ciocalteu reagent was then added. The mixture was incubated during 30 min at 25°C. The mixture sample absorbance was read to spectrophotometer at 725 nm against a control extract without phenolic solution. A calibration curve of gallic acid standard solution (1 mg/ml) was used to determine the total polyphenol quantities.

Flavonoids

Flavonoids were obtained according to the method of Meda *et al.* (2005). 0.5 ml of supernatant polyphenol extraction was placed in a tube. 0.5 ml of distilled water, 0.5 ml of aluminum chloride (10%, w/v), 0.5 ml of sodium acetate, and 2 ml of distilled water were then added. The mixture sample was incubated during 30 min at 25°C on the working bench. The mixture sample absorbance was read to spectrophotometer at 415 nm against a control extract without phenolic solution. A calibration curve of quercetin standard solution (0.1 mg/ml) was used to determine the flavonoid quantities.

Tannins

Tannins were obtained according to the method of Bainbridge *et al.* (1996). One (1 ml) of polyphenol extraction supernatant was placed in a tube. Five (5) ml of vanillin reagent (0.1 mg/ml of vanillin in 70% of sulfuric acid (v/v)) were added. The mixture sample was incubated during 20 min at 25°C on the working bench but in total darkness. The mixture sample absorbance was read to spectrophotometer at 500 nm against a control extract without phenolic solution. A calibration curve of tannic acid standard solution (0.1 mg/ml) was used to determine the tannin quantities.

Statistical analysis

All the measurements were carried out in triplicate. The numerical values obtained were expressed as the arithmetic mean with the corresponding standard deviation. Statistical data processing was performed using STATISTICA 7 software. Comparisons between dependent variables were determined according to analysis of variance (ANOVA) and Duncan's tests. Statistical significance was defined at $P \leq 0.05$.

RESULTS

Nutritional parameters

The Add of Baobab pulp powder to wheat flour increase some nutrients of the composite flour. The values are ranged $0.51 \pm 0.01\%$ to $1.47 \pm 0.03\%$ for ash, $0.98 \pm 0.05\%$ to $2.30 \pm 0.03\%$ for reducing sugars, $1.08 \pm 0.07\%$ to $1.13 \pm 0.01\%$ for total fibers and $1.30 \pm 0.03\%$ to $1.56 \pm 0.07\%$ for lipids. This increasing effect of nutrients proves the composite flour nutritional benefit (Table 1).

Table 1: Some nutrients of the composite of wheat flour and Baobab pulp powder

Sam	Ash (%)	Reducing Sugars (mg /100 g DM)	Total fibers (%)	Lipids (%)	Total energy (Kcal)	Humidity	pH
F0	0,51±0,00 ^a	980,03±5,26 ^a	1,08±0,07 ^a	1,30±0,03 ^a	350,28±0,69 ^b	13,59± 0,48 ^b	5,87±0,04 ^d
F1	1,01±0,00 ^b	1629,71±8,04 ^b	1,13±0,01 ^a	1,54±0,05 ^b	347,04±0,54 ^a	13,28± 0,23 ^b	4,27± 0,14 ^c
F2	1,25±0,00 ^c	2076,06±8,04 ^c	1,35±0,01 ^b	1,54±0,03 ^b	346,36±0,72 ^a	13,13±0,25 ^{ab}	4,00±0,05 ^b
F3	1,36±0,02 ^d	2182,69±3,04 ^d	1,60±0,02 ^c	1,55±0,03 ^b	344,58±0,89 ^a	13,03±0,18 ^{ab}	3,85±0,00 ^{ab}
F4	1,47±0,03 ^e	2299,23±3,04 ^e	2,15±0,01 ^d	1,56±0,07 ^b	345,00±2,19 ^a	12,47±0,12 ^a	3,72± 0,00 ^a

Averages assigned of different letters in the same column are significantly different at 5% according to Duncan's test. Sam = Samples; DM=Dry Matter; F0 (wheat flour); F1 (95% wheat flour and 5% baobab pulp powder); F2 (90% wheat flour and 10% baobab pulp powder); F3 (88% wheat flour and 12% baobab pulp powder); F4 (85% wheat flour and 15% baobab pulp powder).

Phytochemical properties

Baobab (*Adansonia digitata*) pulp powder increases the polyphenol, flavonoid, and tannin contents of wheat and baobab pulp composite flour. *Adansonia digitata* pulp powder is naturally rich in antioxidants (Table 2).

Table 2: Some Phytochemicals composition of different composite flours

Sam	Total Polyphenols (mg EAG/100g DM)	flavonoids (mg EQ/100g DM)	Tannins (mg EAT/100g DM)
FO	1955,28±0,00 ^a	133,44±0,86 ^a	103,27±6,38 ^a
F1	2127,15±2,77 ^b	229,88±1,31 ^b	617,39±6,38 ^b
F2	2285,46±7,33 ^c	583,25±0,86 ^c	743,66±6,38 ^c
F3	2380,33±0,03 ^d	572,30±0,86 ^d	870,84±1,28 ^d
F4	2737,75±2,77 ^e	804,91±0,99 ^e	968,25±0,64 ^e

Sam= Sample; DM= Dry Matter; F0 (100% wheat flour); F1 (95% wheat flour and 5% baobab pulp powder); F2 (90% wheat flour and 10% baobab pulp powder); F3 (88% wheat flour and 12% baobab pulp powder); F4 (85%

wheat flour and 15% baobab pulp powder). Each value corresponds to an average of three tests. Values are means \pm standard deviation according to Duncan's test, ($p \leq 0.05$).

Sensory analysis

Breads, crust and crumb of different composites flours

Figure 4 shows different breads made from composite flours of wheat and baobab (*Adansonia digitata*) pulp powder. The bread obtained with 5% and 10% of baobab (*Adansonia digitata*) pulp powder has approximately the same color to that of the bread produced with 100% wheat flour. However, the breads obtained with flours containing 12% and 15% of baobab (*Adansonia digitata*) pulp powder have slightly a darker color. The baobab (*Adansonia digitata*) pulp powder increases the color (darkly) of the resulting bread texture proportionally to its quantity (Figure 4).



Figure 4: Bread, crust and crumb of different formulations of composite flours and the resulting breads produced.

F0 (100% wheat flour); *F1* (95% wheat flour and 5% baobab pulp powder); *F2* (90% wheat flour and 10% baobab pulp powder); *F3* (88% wheat flour and 12% baobab pulp powder); *F4* (85% wheat flour and 15% baobab pulp powder).

Sensory parameters of different composites breads

A sensory analysis was performed on the composite breads of wheat flour and baobab pulp powder (*Adansonia digitata*). The results are presented in the Table3. Significant differences were observed between the different breads (F0 to F4) according to their appearance, smell, taste, texture and overall appreciation. Breads F1 (5% baobab pulp powder (*Adansonia digitata*) and 95% wheat flour) and F2 (10% baobab pulp powder (*Adansonia digitata*) and 90% wheat flour) have scores (quality) relatively the same of the control bread (100% wheat flour). The results gave the following values for breads F1 and F2 according to their visual overall: appearance of the whole bread (F1 (7.00±0.44%) and F2 (7.18±1.22%)), crumb texture (F1 (7.17±0.7%) and F2 (7.09±1.3%)), crust texture (F1 (6.94±0.85%) and F2 (6.65±1.15%)) and general appreciation (F1 (7.23±0.51%) and F2 (7.32±0.73%)).

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Table 3: Sensory parameters of different composites breads

Samples	Appearance of whole loaf	odor effect of <i>Adansonia digitata</i>	Crust color	Cells size	Crumb taste texture	Crust texture	taste	Taste of <i>Adansonia digitata</i>	Aftertaste of <i>Adansonia digitata</i>	Overall Appearance Assessment
F0	7,91±0,47 ^c	4,83±1,88 ^a	7,91S±0,6 ^c	7,31±0,64 ^b	7,51±0,6 ^c	7,31±1,04 ^b	4,83±2,60 ^a	3,80±1,89 ^a	7,91±0,31 ^c	
F1	7,00±0,44 ^b	6,97±0,70 ^b	7,11±0,65 ^b	7,09±0,82 ^b	7,17±0,7 ^{bc}	6,94±0,85 ^b	7,11±0,59 ^b	6,42±1,83 ^b	7,23±0,51 ^b	
F2	7,18±1,22 ^b	6,58±1,66 ^b	7,47±0,92 ^c	7,15±0,95 ^b	7,09±1,3 ^{bc}	6,65±1,15 ^b	7,06±1,45 ^b	6,50±1,09 ^b	7,32±0,73 ^{bc}	
F3	4,28±1,28 ^a	7,24±1,02 ^{bc}	4,98±1,42 ^a	6,89±1,61 ^b	6,69±1,8 ^b	6,67±1,91 ^b	7,29±0,93 ^b	6,97±0,43 ^{bc}	4.86±1,38 ^a	
F4	2,83±1,15 ^a	7,71±0,72 ^c	4,60±2,11 ^a	3,66±1,53 ^a	3,91±1,2 ^a	3,54±1,27 ^a	7,77±0,50 ^b	7,66±0,53 ^c	3,29±1,75 ^a	

F0 (100% wheat flour); F1 (95% wheat flour and 5% baobab pulp powder); F2 (90% wheat flour and 10% baobab pulp powder); F3 (88% wheat flour and 12% baobab pulp powder); F4 (85% wheat flour and 15% baobab pulp powder). Each value corresponds to an average of three tests. Values are means ± standard deviation according to Duncan's test, ($p \leq 0.05$).

DISCUSSION

Physico-chemical, functional, nutritional and sensory of food raw material properties determine the different areas of application for various food products (Odedeji and Oyeleke, 2011). This study was conducted to investigate the possible of *Adansonia digitata* powder utilisation in the food industries. The analyses of composite flours (F0, F1, F2, F3 and F4) assess the evolution of the nutritional, functional and sensory properties versus the proportion (0%, 5%, 10%, 12% and 15%) of *Adansonia digitata* powder incorporation into wheat flour.

Ash, protein, total carbohydrate, total fiber, and lipid levels varied significantly with the ratio (0%, 5%, 10%, 12% and 15%) of *Adansonia digitata* pulp powder incorporation into the wheat flour. Thus, the ash rate increased from 0.51% (F0) to 1.47% (F4) attribute to 5% of *Adansonia digitata* pulp powder incorporation into the wheat flour. This increasing effect is attributed to the natural richness of the *Adansonia digitata* fruit pulp at minerals such as calcium, potassium, magnesium and iron (Glew et al., 2005). Consequently, the incorporation of *Adansonia digitata* pulp powder into wheat flour fortifies the resulting composite flour at minerals. According to Chadare et al. (2009) the *Adansonia digitata* pulp powder is richer in ash than wheat flour. According to these authors, 15% of *Adansonia digitata* pulp powder in a cereal matrix triples the mineral content.

The ash content defines the commercial types of flours (Feillet, 2000; Khelil, A., and Kasmi, N. 2023). Therefore, the composite flour containing 5% of *Adansonia digitata* pulp powder and 95% of wheat flour is rich in ash and remains a type of commercial flour.

Unlike the ash content, proteins quantities decreases significantly with the level of *Adansonia digitata* powder incorporation. This decrease effect of proteins quantities would be due to the decrease of the wheat flour quantity in the final composite flour. Indeed, wheat flour is naturally rich in proteins than that of *Adansonia digitata* powder, so their reduction affects of the protein content in composite flours.

Protein level of flour is a crucial importance nutritional parameter in breadmaking due to the highly important and strategic role of gluten. Thus, wheat flour is suitable for breadmaking because of the gluten, a protein that it contains (Kasarda et al., 1976; Edwards et al., 1977).

Adansonia digitata powder does not contain gluten and it is therefore not suitable for bread making. Its Incorporation into wheat flour leads to a reduction of the gluten level in the composite flour depending of its incorporation percentage. This is conform to difficulties encountered in breadmaking with composite flours. They have been the subject of breadmaking tests as noted by various previous works incorporating cassava, rice, sweet potato, corn and sorghum flour by different authors (Tharise et al., 2014; Rocha et al., 2015).

The reducing sugars of the composite flour increased significantly with the incorporation level of *Adansonia digitata* powder from 980.03 mg/100 g (F0) to 2299.23 mg/100 g (F4). This increase effects could be attributed to *Adansonia digitata* powder. Indeed, Chadare et al., (2009) state that the pulp of *Adansonia digitata* is particularly rich at simple carbohydrates, such as glucose, fructose and sucrose. This increasing effect of reducing sugars in the composite flour

may enhance to the natural sweet flavor of processed products containing *Adansonia digitata* powder.

Total dietary fiber increased significantly from 1.08% (F0) to 2.15% (F4). *Adansonia digitata* is known at food industries to its high level of soluble and insoluble fiber (Besong et al., 2016). They thus promote intestinal transit and have a hypoglycemic effect. According to (Anhe and Roy, 2020), the soluble fibers contained in the pulp of *Adansonia digitata* exert a prebiotic action, promoting the growth of bacteria, which are beneficial to the intestinal microbiota such as *Bifidobacterium* and *Lactobacillus*. This property contributes to the improvement of digestive and immune health.

The lipid quantity increases slightly, ranging from 1.30% (F0) to 1.56% (F4), suggesting that the lipid intake of *Adansonia digitata* remains moderate. The fruit pulp is mostly unliked of lipid than its seeds, which explains the low variation of lipids level observed in the composite flour (Gebauer et al., 2002).

The water content decreased significantly from $13.59 \pm 0.48\%$ (F0) to $12.47 \pm 0.12\%$ (F4) versus *Adansonia digitata* powder incorporation pourcentage. This decreasing effect would be due to the low water retention capacity of the insoluble fibers of *Adansonia digitata* powder (Chadare et al., 2019). According to the Codex Alimentarius standards (STAN 152-1985), the stability of flours is ranged from 11% to 13%. This quantity level of water is optimal to the preservation and the reduction of microbiological risk (Danso et al., 2019; Boateng, 2013).

The pH provides informations on the evolution of the acidity of the environment or products solution, depending on the metabolism of the microorganisms (Ould el hadj et al., 2001). According to the results obtained, the different flours have an acid pH ranging from 5.87 ± 0.04 to 3.72 ± 0.00 . These results obtained show that Wheat flour (F0) and composite flours (F1, F2, F3 and F4) are acidic. These results are similar to those of Mokhtari et al. (2020). An acidic pH has advantages in the preservation of certain vitamins that as the group B and C (Bourgeois et al., 2003) which are the predominant vitamins in the pulp of *Adansonia digitata*. The naturally acidic pH of *Adansonia digitata* contributed to the lower pH of all composite flours and can be attributed to the high concentration of organic acid of *Adansonia digitata*, mainly citric acid (Tembo et al., 2017). Our results are in agreement with those of Cissé et al. (2013). They attested that the acidity taste of the *Adansonia digitata* pulp powder is due to organic acids such as citric acid, tartaric acid, malic acid and succinic acid.

Phytochemical properties are essential to evaluate antioxidant, anti-inflammatory, and therapeutic potential of functional foods. *Adansonia digitata* fruit pulp powder is particularly rich at phenolic compounds, flavonoids, tannins, and ascorbic acid, which contribute to its numerous promoting health effects (Braca et al., 2001; Charade et al., 2009).

The progressive incorporation of *Adansonia digitata* fruit pulp powder caused a significant increase of total polyphenol levels. The maximum polyphenol (PFT) contents were obtained with the composite flour (F4) at 15% of the *Adansonia digitata* fruit pulp powder incorporation. Quantities obtained are polyphenols (2737.75 ± 2.77 mg GAE/100 g DM), flavonoids (804.91 ± 0.99 mg QE/100 g DM) and tannins (968.25 ± 0.64 mg EAT/100 g DM).

These results concord with those of Barakat (2021) who found that the more added of *Adansonia digitata* fruit pulp in a solution or a composition, higher become the level of polyphenols, flavonoids, and tannins. These secondary metabolites have beneficial decrease effects on the glycemic response (GR) and improving various other metabolic parameters.

Some functional properties such as bulk and packed densities and porosity of composite flours were studied. The results indicate a significant decrease of their quantity in the composite flour with the increase of the level of *Adansonia digitata* fruit pulp powder incorporation. The results are respectively from 71.42g/ml to 67.56g/ml for apparent density, from 54.93g/ml to 46.60g/ml for packed density and from 35.18g/ml to 25.28g/ml for porosity. This reduction effect is due to the gradual addition of *Adansonia digitata* fruit pulp powder. Our results are in agreement with those of Sidibé and Williams (2002); Ndoye et al. (2018) who stated that the fibrous and aerated structure of *Adansonia digitata* pulp acts as a natural texturizing agent.

The results of the sensory analysis showed that the crust color and the appearance of the bread containing the of the of *Adansonia digitata* fruit pulp powder were as acceptable as those of the control bread (100% wheat flour (F0)) up to 10% of *Adansonia digitata* fruit pulp powder incorporation.

Above this level of *Adansonia digitata* fruit pulp powder incorporation, the color of the final breads was relatively dark, and very unacceptable by the consumers. These observations are due to *Adansonia digitata* fruit pulp phenolic compounds and reducing sugars contain (Codina et al., 2019). According to these authors, during the baking, these compounds nutrients participate to Maillard and caramelization reactions, which intensifies the brown coloring. The higher is the proportion of *Adansonia digitata*, the browner and darker are the crust of the final bread.

The crumbs of composite breads are increasingly dense, less airy and have fewer alveoli depending on the quantity of *Adansonia digitata* fruit pulp powder added. *Adansonia digitata* fruit pulp does not contain gluten. This would deteriorate the gluten network necessary for complexing the CO₂ produced by the yeast during the dough fermentation (Amadou et al., 2022).

According to standard sensory analysis criteria, the acceptability of composite breads decreased from formulation F0 (0% of *Adansonia digitata* fruit powder) to formulation F4 (0% of *Adansonia digitata* fruit powder). The formulation F4 obtained the lowest scores at sensory criteria, including loaf bread appearance (2.83 ± 1.15^a), its crust texture (3.54 ± 1.27^a) and its general acceptability (3.29 ± 1.75^a). This decreasing effect of the bread acceptability can be explained by a darker crust color and drier texture, which is contrary to consumer's usual preferences. Furthermore, although the general taste of *Adansonia digitata* fruit pulp powder is judged to be more intense (7.77 ± 0.50), it seems that its persistent aftertaste (7.66 ± 0.53^c) has a negative impact on the overall appreciation. According to Gibson et al. (2011), ingredients rich in phenolic compounds such as *Adansonia digitata* can produce an undesirable taste or astringent aftertaste of the breadmaking products.

Flavonoids and tannins present in the pulp of *Adansonia digitata* fruit can cause a slight bitterness at high doses. This taste may please or displease consumers, depending on their eating habits. Indeed, formulations F0 to F3 show a good balance between sensory characteristics and nutritional enrichment. For example, formulation F2 (10% *Adansonia digitata* powder) shows a relatively high overall appreciation (7.32 ± 0.73^b), with an acceptable taste (7.06 ± 1.45^b) and odor (6.58 ± 1.66^b) of *Adansonia digitata* fruit pulp. These results demonstrate the quality of the composite bread until the formulation F2. This observation shows that the moderate incorporation of *Adansonia digitata* as an ingredient in baking is well tolerated, especially in a context that consumers value functional products rich in antioxidants in food products (Ismail et al., 2019).

Finally, the results of this study confirm that the addition of *Adansonia digitata* fruit pulp powder strongly influences the sensory attributes of bread. A moderate incorporation rate (F2: 10% of *Adansonia digitata* fruit pulp powder) of *Adansonia digitata* fruit powder appears to be a good compromise between nutritional improvement and sensory acceptability of bakery products.

IMPLICATION OF THE RESEARCH AND PRACTICE

Adansonia digitata powder holds significant potential for improving food and nutrition security. This study has developed to promote scientific research on not conventional powders and dough by partially substitution to conventional flours. It also aims to enhance the rheology of these not conventional powders, flours, and dough to understand and adapt these products in bread and dough making. They would that contributed to the fight against hunger and the ensuring of food security.

CONCLUSION

Adansonia digitata fruit pulp powder from Côte d'Ivoire have a lot of potential in the food system. This research work allowed to explore *Adansonia digitata* fruit pulp nutritional and functional potential in breadmaking through its incorporation into wheat flour to obtain composite breadmaking flours.

The general objective of this work is to contribute to the valorization of the *Adansonia digitata* fruit pulp in the bread manufacturing process. This study revealed that *Adansonia digitata* fruit pulp can be a source of enrichment for bakery products, particularly the bread, while providing an answer to malnutrition and public health challenges. Nutritionally, the addition of *Adansonia digitata* fruit pulp as an ingredient in breadmaking process increased the content of fiber, minerals, total polyphenols, flavonoids and tannins, contributing to obtain a product with functional benefits.

However, beyond a certain threshold (notably 15%), technological properties such as texture, volume and sensory acceptability are affected; imposing a limit on a possible incorporation of *Adansonia digitata* fruit pulp powder in breadmaking. So that adding 10% *Adansonia digitata* pulp powder to wheat flour in breadmaking enriches the bread at bioactive and nutritional nutrients while retaining its technological and sensory qualities. This use of *Adansonia digitata*

fruit pulp in breadmaking is a strategy to promote local resources and improve the nutritional quality of bakery products.

Futures Researches

The future focus of research will be the study of the rheological and microbiological properties of conventional substitute (wheat flour and *Adansonia digitata* fruit pulp powder) doughs and flours produced and their promotion in the food industry.

Compliance with Ethics Requirements

Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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