

Full Length Research Paper

Physico-chemical and sensory characterisation of three traditional functional dishes made from maize flour and wild *tomi* (*Tamarindus indica*), *baobab* (*Adansonia digitata*) and *néré* (*Parkia biglobosa*) fruit pulp consumed in Côte d'Ivoire

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Received 25 April, 2024; Accepted 27 June, 2024

The aim of the study was to determine the biochemical and sensory characteristics of dishes made from maize and baobab, tomi, and néré pulp. To this end, *Badégué* with *baobab*, *Badégué* with *tomi*, and *Wasséra* were prepared using traditional technologies to determine their physico-chemical composition followed by a sensory evaluation. The results showed that *Wasséra* has the highest levels of total carbohydrates (51.94 ± 0.39 g / 100 g), calcium (47.68 ± 0.52 mg / 100 g), magnesium (27.63 ± 0.22 mg / 100 g), vitamin C (34.62 ± 0.35 mg / 100 g), and total polyphenols (82.28 ± 3.77 mg EAG / 100 g). *Badégué* with *tomi* is characterized by high levels of oxalates (14.37 ± 1.37 mg / 100 g) and tartaric acid (643.40 ± 5.74 mg / 100 g). As for *Badégué* with *baobab*, high levels of potassium (45.70 ± 1.23 mg / 100 g), citric acid (1109.31 ± 89.24 mg / 100 g), and flavonoids (12.42 ± 1.41 mg EQ / 100 g) were recorded. Sensory characterization showed a fairly good overall acceptability (6) of *Badégué* with *baobab*. Given their sensory characteristics, *Badégué* with *tomi* and *Wasséra* are less appreciated and rarely consumed.

Key words: Wild fruit pulp, maize flour, traditional dishes, characterisation, Côte d'Ivoire.

INTRODUCTION

The fruit pulps of wild fruit trees such as *Adansonia digitata* (Baobab), *Tamarindus indica* (Tomi), and *Parkia biglobosa* (Néré) are highly appreciated and widely

consumed in Côte d'Ivoire (Ambé, 2001; Diallo et al., 2007). Studies on the nutritional value of these pulps have highlighted their richness in vitamins (A, B1, B2, B6,

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and C), phenolic compounds (tannins, total polyphenols, and flavonoids), and essential minerals including potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca), and iron (Fe) (Cissé, 2012; Kouassi et al., 2019). Due to their significant dietary and nutritional benefits, these pulps can help address nutritional deficiencies and prevent metabolic diseases and their complications, attributed to their antioxidant, anticarcinogenic, and free radical-scavenging properties (Kouassi et al., 2018a; Konan et al., 2022b).

To integrate these nutritional benefits, the populations in the savannah regions of northern Côte d'Ivoire incorporate these pulps into cereal flours to create a variety of traditional dishes (Konan et al., 2022a, b, c). Surveys conducted by Konan et al. (2022c) identified 17 cereal-based dishes that utilize baobab, tomi, and néré pulps, including 11 millet-based and 6 maize-based dishes. Both millet and maize are widely grown and consumed in Côte d'Ivoire, with millet being particularly appreciated for its excellent organoleptic qualities, especially in the form of porridge (Tou et al., 2006; N'Guessan et al., 2014). However, despite millet's favorable qualities, maize flour is more widely consumed on a national scale (Nomel et al., 2019).

Coates et al., (2007) and DSRP (2009) explain the low consumption of millet at the national level due to its relatively high cost and limited distribution. In contrast, maize is one of the most important and widely grown cereals in Côte d'Ivoire (Siene et al., 2020). Maize has long been a well-established crop in both the northern and southern regions of the country. Its storage potential and high productivity have supported socio-economic diversification, urbanization, and the development of the food trade (Juhé-Beaulaton, 1990). As a result, the maize sector has firmly established itself throughout Côte d'Ivoire, capable of meeting more than 95% of the national consumption. Even in the forested areas of Côte d'Ivoire, maize has gradually assumed a significant role, allowing cultivation in high-altitude regions, thereby complementing rice, a traditional cereal grown in low-lying areas, and integrating well with crops like cassava, yams, and taro (Rongead-Ong, 2014). National maize production has increased steadily from approximately 700,000 tons in 2011 to 1.2 million tons in 2020, with an average yield of 2.5 t/ha, surpassing the West African average of 1.68 t/ha, thus making maize the second most cultivated cereal after rice (FAO, 2018). Consequently, maize-based dishes have gained popularity among a large segment of the Ivorian population. Maize serves as a crucial raw material for food and feed processing, allowing for the production of both semi-finished and finished food products (Charcosset et al., 2000). Despite its relatively low protein content, maize offers health benefits through easily assimilated carbohydrates and high fiber content, predominantly found in the grain's skin, which aids in regulating intestinal transit. Maize also

provides essential vitamins, particularly from the B and K groups, and according to Yapi and De Kouassi (2017), it possesses anti-haemorrhagic properties that may contribute to nervous and muscular balance. Konan et al. (2022c) have highlighted the significant association of maize flour with baobab, tomi, and néré pulps in traditional dishes native to northern Côte d'Ivoire, notably *Badégué-baca* with *baobab*, *Badégué-baca* with *tomi*, and *Wasséra*. However, the lack of scientific data on these dishes complicates their widespread adoption. Therefore, the overarching goal of this study was to characterize these three dishes, incorporating maize flour and pulps from tomi (*T. indica*), baobab (*A. digitata*), and néré (*P. biglobosa*), from both biochemical and sensory perspectives.

MATERIALS AND METHODS

Biological material

The biological materials used in the study consisted of fruit pulp from three wild fruit trees and a commonly consumed cereal in the north of Côte d'Ivoire. These were baobab fruit pulp (*A. digitata* L.), néré fruit pulp (*P. biglobosa*), tomi fruit pulp (*T. indica*), and maize flour (*Zea mays* L.).

Preparing the dishes

Biological material

Masses of 50 kg each of maize grain, tomi fruit pulp, baobab fruit pulp, and néré fruit pulp were purchased from producers in Korhogo. All these products were packed in sterile jute bags and sent directly to the laboratory for preparation and analysis of their biochemical and sensory characteristics.

Food preparation

The dishes were prepared according to the traditional production diagram for each food described by Konan et al. (2022a, b, c) for *Badégué-baca* with *baobab*, *Badégué-baca* with *tomi* and *Wasséra*, respectively. *Badégué-baca* with *baobab* is made from maize and baobab pulp. 1 kg of maize soaked in 3 L of water for 120 min was drained and ground into flour with 100 g of ginger before being transformed into granules and dried at room temperature for 5 h. The granules were cooked in 7 L of boiling water for 30 min, to which 100 g of baobab pulp macerated in 0.5 L of water and 500 g of sugar were added 15 min before the end of the cooking time. *Badégué-baca* with *tomi* is made from maize and tomi pulp. 1 kg of maize was soaked in 3 L of water for 120 min, drained and ground into flour with 100 g of ginger before being turned into granules and dried at room temperature for 5 h. The granules were cooked in 7 L of boiling water for 30 min, during which time a macerate of 250 g of tomi pulp in 0.5 L of water and 500 g of sugar were added 15 min before the end of the cooking time. *Wasséra* is made from maize and néré pulp. 1 kg of maize flour is mixed with 1 kg of néré pulp. After homogenisation, the mixture is sprayed with water to form granules which are steamed for 5 to 10 min. After cooking, the granules are relayed in 100 mL of refined vegetable oil to obtain *Wasséra*.

Biochemical characterisation of foods

Proximate analysis

Dry matter, ash content, and pH were determined using the AOAC method (1990). Proteins and lipids were analyzed using the BIPEA method (1976). Crude fiber was assessed using the Multon method (1991). Total carbohydrates were calculated by difference following the FAO/WHO guidelines (1998), and the energy value was calculated using the coefficients specified by Atwater and Rosa (1899). Mineral content was determined according to the protocol established by Brule et al. (1974).

Vitamin analysis

The analysis of Group B vitamins was conducted using high-performance liquid chromatography (HPLC) following the method outlined by Hasan et al. (2013). For each sample, 5 g was weighed and transferred to a conical flask. A mixture of 25 mL acetonitrile/acetic acid (50:10, v/v) diluted 3:5 with double-distilled water (extraction solution) was added, and the flask was placed in a water bath at 70°C for 40 min. After cooling to 25°C for 2 h, the mixture was filtered through a 0.45 µm Millipore filter (Sartorius AG, Goettingen, Germany). Throughout the extraction process, samples were shielded from direct light exposure and kept on ice to minimize vitamin degradation.

Vitamin C content was determined by HPLC following extraction with 100/80 (v/v) metaphosphoric acid/acetic acid, as described by Cissé (2012). Three grams of sample were homogenized in 30 mL of metaphosphoric acid solution under gentle agitation for 30 min and filtered through Wattman paper. For vitamin A analysis, HPLC was used after extraction with a methanol solution of retinol acetate (1 µg/µL) stored in a tinted bottle at -20°C, following the protocol by Billion-Rey et al. (1993). Five grams of sample were mixed with approximately 20 mL of methanol in a beaker protected from light with aluminum foil. The solution was stirred with a bar magnet for 2 h and 30 min at room temperature.

The determination of vitamin E content followed the protocol of Billion-Rey et al. (1993), involving extraction with an organic solvent and subsequent HPLC separation with fluorimetric detection. A mass of 0.5 g of sample was mixed with 2 mL of 1% ethanol (v/v) in a 25 mL test tube, homogenized by vortexing for 20 s, and heated in a water bath at 70°C for 2 min.

Phenolic compounds determination

Total phenols were determined using the method of Singleton et al. (1999). Tannins were measured using the method described by Bainbridge et al. (1996) and flavonoids were measured using the method described by Meda et al. (2005). Oxalates were determined using the method described by Day and Underwood (1986) and phytates were quantified using the method of Latta and Eskin (1980).

Assimilation indicators

The mineral uptake indices (Ca, Na, Fe, K, Mg, P and Mn) of different feeds were determined using different molar ratios of phytate, oxalate and minerals (Ca and Fe) (Norhaizan and Faizadatul, 2009; Ellis and Lieb, 2015). The molar ratio of the ANF (Anti-Nutritional Factor) and the molar ratio (X) were given by Equations 1, 2 and 3 respectively:

$$\text{Molar ratio (ANF)} = \frac{\text{Mass (ANF)}}{\text{Molar mass (ANF)}} \quad (1)$$

$$\text{Molar ratio (X)} = \frac{\text{Mass (X)}}{\text{Molar mass (X)}} \quad (2)$$

$$\text{Molar ratio (ANF/X)} = \frac{\text{Molar ratio (ANF)}}{\text{Molar mass (X)}} \quad (3)$$

where Molar mass (Phytates = 660 g/mol); (Oxalates = 128.097 g/mol); (Ca = 40 g/mol) and (Fe = 56 g/mol).

The different molar ratios were calculated and compared with threshold values of phytate / Calcium > 0.24; phytate / Fe > 1 (Ma et al., 2007; Yewelsew et al., 2007) and oxalate / Calcium > 2.25 (Tchiégang and Aissatou, 2004).

Sensory characterisation of dishes

The sensory evaluation focused on the 3 foods or samples: *Badégué-baca* with *baobab*, *Badégué-baca* with *tomi* and *Wasséra*. The sensory properties of the foods were determined using a hedonic test with a panel of 60 untrained tasters. These tasters, who were all students at Nangui Abrogoua University, assessed colour, smell, astringency, texture in the mouth, taste, viscosity and general acceptability according to the method described by (Ngono eyenga et al., 2018).

Thus, these judges were asked to look, taste, smell and rate the degree of appreciation for each descriptor on a 9-point linear rating scale ranging from 1 (lower bound: very poor) to 9 (upper bound: very good) with 1- very poor; 2- too poor; (3) somewhat-poor; (4) poor; (5) neither good nor poor; (6) somewhat-good; (7) good; (8) too good; (9) very good. The samples were coded to three digits and presented one by one to the panellists in a randomised fashion. Each panellist was given water to rinse their mouth between samples.

Statistical analysis

All experiments for the various analyses were conducted in triplicate. One-factor analysis of variance (ANOVA) was performed using Statistica 7.1 software on all the results obtained to determine if there were significant statistical differences between the calculated means. Differences were assessed using Tukey's test at a 95% confidence level.

RESULTS

Macronutrient composition

Table 1 shows the macronutrient composition of *Badégué-baca* with *baobab*, *Badégué-baca* with *tomi*, and *Wasséra*. Significant differences ($P < 0.05$) were observed in lipid, ash, total carbohydrate, crude fiber, protein content, and pH among the samples.

Table 1. Macronutrient content of maize flour-based foods and baobab, tomi and néré pulps.

Parameter	Dry matter	Total carbohydrate	Ash	Lipids	Crude fiber	Protein	Reducing sugar	Total sugar	Energy (Kcal/100 g of food)	pH
	(g/100 g of food)					(g/100 g of food)				
<i>Wasséra</i>	62.23 ± 0.25 ^a	51.94 ± 0.39 ^a	1.04 ± 0.00 ^a	5.60 ± 0.19 ^a	11.37 ± 0.13 ^a	3.65 ± 0.01 ^a	19.39 ± 0.27 ^a	34.53 ± 0.22 ^a	272.78 ± 0.96 ^a	4.96 ± 0.01 ^a
<i>Badégué with tomi</i>	24.93 ± 0.31 ^b	22.94 ± 0.27 ^b	0.17 ± 0.00 ^b	0.17 ± 0.00 ^b	1.39 ± 0.12 ^c	1.66 ± 0.04 ^c	9.44 ± 0.05 ^b	13.51 ± 0.19 ^b	99.90 ± 1.22 ^b	3.94 ± 0.01 ^b
<i>Badégué with baobab</i>	24.20 ± 0.87 ^b	22.50 ± 0.27 ^b	0.16 ± 0.00 ^b	0.08 ± 0.00 ^b	1.72 ± 0.02 ^b	1.79 ± 0.03 ^b	8.43 ± 0.16 ^c	14.59 ± 0.33 ^b	97.88 ± 1.22 ^b	3.75 ± 0.02 ^c

In the same column, the average contents assigned the same letter are not significantly different at the 5% threshold according to the Tukey test.

Table 2. Mineral content of foods based on maize flour and baobab, tomi and néré pulps.

Parameter	Ca	K	Mg	Na	P	Fe	Mn
	(mg/100 g of food)						
<i>Wasséra</i>	47.68 ± 0.52 ^a	56.52 ± 0.21 ^a	27.63 ± 0.22 ^a	28.80 ± 0.10 ^a	38.60 ± 0.16 ^a	3.49 ± 0.02 ^a	0.01 ± 0.00 ^c
<i>Badégué with tomi</i>	20.40 ± 0.27 ^c	27.88 ± 0.36 ^c	9.58 ± 0.21 ^c	5.72 ± 0.07 ^c	8.47 ± 0.23 ^b	0.27 ± 0.01 ^b	0.88 ± 0.03 ^a
<i>Badégué with baobab</i>	22.12 ± 0.69 ^b	45.70 ± 1.23 ^b	10.70 ± 0.22 ^b	8.42 ± 0.38 ^b	7.52 ± 0.29 ^c	0.27 ± 0.03 ^b	0.56 ± 0.01 ^b

In the same column, the average contents assigned the same letter are not significantly different at the 5% threshold according to the Tukey test.

Wasséra exhibited higher lipid (5.60 ± 0.19 g / 100 g of food), ash (1.04 ± 0.00 g / 100 g of food), total carbohydrate (51.94 ± 0.39 g / 100 g of food), crude fiber (11.37 ± 0.13 g / 100 g of food), protein (3.65 ± 0.01 g / 100 g of food), and pH (4.96 ± 0.01) compared to *Badégué with tomi* and *Badégué with baobab*, where no significant differences ($P > 0.05$) were observed between their contents of total carbohydrates (22.94 ± 0.27 and 22.50 ± 0.27 g / 100 g of food), ash (0.17 ± 0.00 and 0.16 ± 0.00 g / 100 g of food), and lipids (0.17 ± 0.00 and 0.08 ± 0.00 g / 100 g of food). However, the respective contents of crude fiber (1.72 ± 0.02 g / 100 g and 1.39 ± 0.12 g / 100 g of food), protein (1.79 ± 0.03 g / 100 g and 1.66 ± 0.04 g / 100 g of food), and pH (3.75 ± 0.02 and 3.94 ± 0.01) in *Badégué with baobab* and *Badégué*

with tomi were lower compared to *Wasséra*.

Composition in minerals

The mineral composition of the different foods (Table 2). These results showed that there was no significant difference ($P > 0.05$) observed between the iron content of *Badégué with tomi* (0.27 ± 0.01 mg / 100 g of food) and *Badégué with baobab* (0.27 ± 0.03 mg / 100 g of food), but these contents were significantly lower ($P < 0.05$) than that of *Wasséra* (3.49 ± 0.02 mg / 100 g of food). However, the manganese content of *Badégué with tomi* (0.88 ± 0.03 mg / 100 g of food) was higher ($P < 0.05$) than that of *Badégué with baobab* (0.56 ± 0.01 mg / 100 g of food), although

both were significantly higher ($P < 0.05$) than that of *Wasséra* (0.01 ± 0.00 mg / 100 g of food). *Wasséra* had significantly higher levels ($P < 0.05$) of calcium (47.68 ± 0.52 mg / 100 g of food), potassium (56.52 ± 0.21 mg / 100 g of food), magnesium (27.63 ± 0.22 mg / 100 g of food), sodium (28.80 ± 0.10 mg / 100 g of food), and phosphorus (38.60 ± 0.16 mg / 100 g of food) compared to *Badégué with baobab* and *Badégué with tomi*, which had respective levels of calcium (22.12 ± 0.69 mg / 100 g and 20.40 ± 0.27 mg / 100 g of food), potassium (45.70 ± 1.23 and 27.88 ± 0.36 mg / 100 g of food), magnesium (10.70 ± 0.22 mg / 100 g and 9.58 ± 0.21 mg / 100 g of food), sodium (8.42 ± 0.38 mg / 100 g and 5.72 ± 0.07 mg / 100 g of food), and phosphorus (7.52 ± 0.23 and 8.47 ± 0.23 mg / 100 g of food).

Table 3. Vitamin content of maize flour-based foods and baobab, tomi and néré pulps.

Parameter	Vitamin E	Vitamin A	Vitamin C	Vitamin B1	Vitamin B2	Vitamin B3	Vitamin B6
	($\mu\text{g}/100 \text{ g of food}$)			(mg/100 g of food)			
<i>Wasséra</i>	30.58 ± 0.37^a	22.86 ± 0.25^a	34.62 ± 0.35^a	0.15 ± 0.01^a	0.05 ± 0.00^a	0.88 ± 0.01^a	0.19 ± 0.00^a
<i>Badégué with tomi</i>	24.66 ± 0.32^b	0.00 ± 0.00^b	5.77 ± 0.11^c	0.07 ± 0.00^c	0.02 ± 0.00^b	0.08 ± 0.00^c	0.00 ± 0.00^b
<i>Badégué with baobab</i>	11.73 ± 0.13^c	0.00 ± 0.00^b	24.75 ± 0.30^b	0.10 ± 0.00^b	0.01 ± 0.00^c	0.19 ± 0.00^b	0.00 ± 0.00^b

In the same column, the average contents assigned the same letter are not significantly different at the 5% threshold according to the Tukey test.

Composition in vitamins

Table 3 presents the vitamin contents of the different foods. These results showed significant differences ($P < 0.05$) in the vitamin contents of *Badégué-baca with baobab*, *Badégué-baca with tomi*, and *Wasséra*.

Wasséra exhibited higher levels of vitamin C ($34.62 \pm 0.35 \text{ mg} / 100 \text{ g of food}$), vitamin B1 ($0.15 \pm 0.00 \text{ mg} / 100 \text{ g of food}$), and vitamin B3 ($0.88 \pm 0.01 \text{ mg} / 100 \text{ g of food}$) compared to *Badégué with baobab*, which had levels of $24.75 \pm 0.30 \text{ mg} / 100 \text{ g of food}$ for vitamin C, $0.10 \pm 0.00 \text{ mg} / 100 \text{ g of food}$ for vitamin B1, and $0.19 \pm 0.00 \text{ mg} / 100 \text{ g of food}$ for vitamin B3. The levels of these nutrients in *Badégué with baobab* were higher than in *Badégué with tomi*, which showed lower levels of vitamin C ($5.77 \pm 0.11 \text{ mg} / 100 \text{ g of food}$), vitamin B1 ($0.07 \pm 0.00 \text{ mg} / 100 \text{ g of food}$), and vitamin B3 ($0.08 \pm 0.00 \text{ mg} / 100 \text{ g of food}$).

Additionally, the respective contents of vitamin E ($24.66 \pm 0.32 \mu\text{g} / 100 \text{ g}$ and $11.73 \pm 0.13 \mu\text{g} / 100 \text{ g of food}$) and vitamin B2 ($0.02 \pm 0.00 \text{ mg} / 100 \text{ g}$ and $0.01 \pm 0.00 \text{ mg} / 100 \text{ g of food}$) in *Badégué with tomi* and *Badégué with baobab* were significantly lower ($P < 0.05$) than those in *Wasséra*, which recorded higher levels of vitamin E ($30.58 \pm 0.37 \mu\text{g} / 100 \text{ g of food}$) and vitamin B2

($0.05 \pm 0.00 \text{ mg} / 100 \text{ g of food}$). However, the vitamin A and vitamin B6 contents were not determined for *Badégué with tomi* and *Badégué with baobab*, unlike *Wasséra*, which recorded vitamin A contents of $22.86 \pm 0.25 \text{ mg} / 100 \text{ g of food}$ and vitamin B6 contents of $0.19 \pm 0.00 \text{ mg} / 100 \text{ g of food}$.

Composition in phenolic compounds

Table 4 shows the phenolic compound composition of the different foods. The results show significant differences ($P < 0.05$) in oxalate and phytate content. *Badégué with tomi* ($14.37 \pm 1.37 \text{ mg} / 100 \text{ g of food}$) and *Wasséra* ($12.53 \pm 0.09 \text{ mg} / 100 \text{ g of food}$) did not exhibit any significant difference ($P > 0.05$) in their oxalate contents. However, the oxalate content of *Badégué with tomi* and *Wasséra* was significantly ($P < 0.05$) higher than that of *Badégué with baobab*, which recorded an oxalate content of $9.12 \pm 0.10 \text{ mg} / 100 \text{ g of food}$.

Furthermore, the phytate content ($14.47 \pm 0.17 \text{ mg} / 100 \text{ g of food}$) of *Badégué with baobab* was significantly ($P < 0.05$) higher than that of *Badégué with tomi* ($13.85 \pm 0.15 \text{ mg} / 100 \text{ g of food}$) and *Wasséra* ($13.22 \pm 0.09 \text{ mg} / 100 \text{ g of food}$).

In addition, the total polyphenol ($82.28 \pm 3.77 \text{ mg EAG} / 100 \text{ g of food}$), flavonoid ($34.38 \pm 1.57 \text{ mg EQ} / 100 \text{ g of food}$), and tannin ($30.99 \pm 0.15 \text{ mg EAT} / 100 \text{ g of food}$) contents of *Wasséra* were significantly higher ($P < 0.05$) than those of *Badégué with tomi* and *baobab*.

The latter showed no significant difference ($P > 0.05$) between their respective contents of polyphenols (26.24 ± 1.47 and $24.51 \pm 1.37 \text{ mg EAG} / 100 \text{ g of food}$), flavonoids (13.84 ± 0.82 and $12.42 \pm 1.41 \text{ mg EQ} / 100 \text{ g of food}$), and tannins (8.65 ± 0.66 and $7.72 \pm 0.50 \text{ mg EAT} / 100 \text{ g of food}$).

Anti-nutritional factors and mineral bioavailability

For *Badégué-baca with baobab*, *Badégué-baca with tomi*, and *Wasséra*, the oxalate/calcium ratios were 0.18, 0.31, and 0.12, respectively, which were below the standard limit of 2.25. Similarly, the phytate to calcium ratios were 0.04, 0.04, and 0.02, respectively, all of which were below the authorized limit of 1. Regarding the phytate to iron ratio, *Wasséra* had a ratio of 0.32, which was the authorized limit, whereas *Badégué with tomi* and *baobab* had ratios of 4.35 and 4.55, respectively, which were above the authorized limit (Table 5).

Table 4. Phenolic compound content of maize flour-based foods and baobab, tomi and néré pulps.

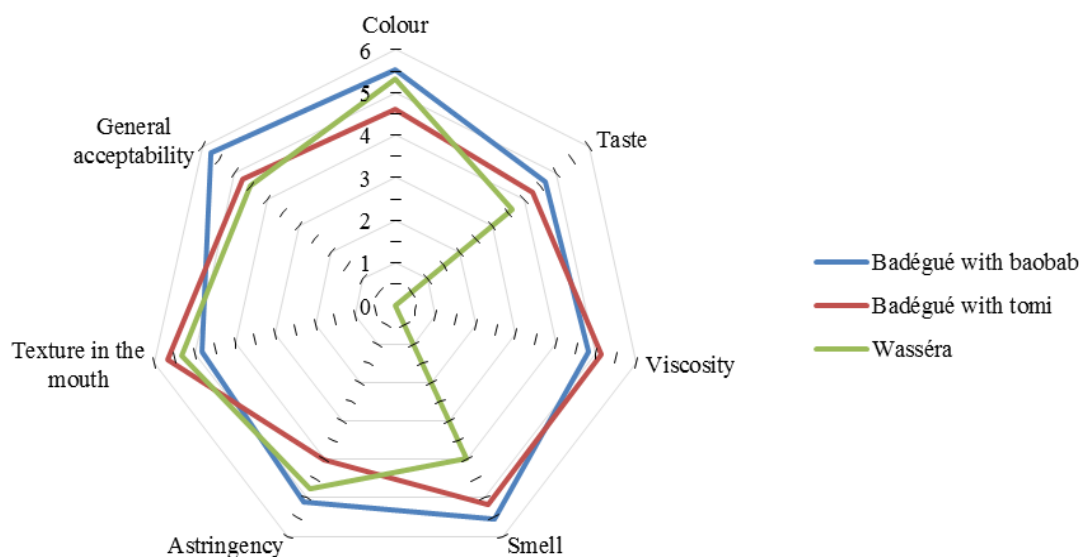
Parameter	Polyphenol (mg EAG/100 g of food)	Flavonoid (mg EQ/100 g of food)	Oxalate (mg/100 g of food)	Phytate	Tannins (mg EAT/100 g of food)
<i>Wasséra</i>	82.28 ± 3.77 ^a	34.38 ± 1.57 ^a	12.53 ± 0.09 ^a	13.22 ± 0.09 ^c	30.99 ± 0.15 ^a
<i>Badégué with tomi</i>	26.24 ± 1.47 ^b	13.84 ± 0.82 ^b	14.37 ± 1.37 ^a	13.85 ± 0.15 ^b	8.65 ± 0.66 ^b
<i>Badégué with baobab</i>	24.51 ± 1.37 ^b	12.42 ± 1.41 ^b	9.12 ± 0.10 ^b	14.47 ± 0.17 ^a	7.72 ± 0.50 ^b

In the same column, the average contents marked with the same letter are not significantly different at the 5% threshold according to the Tukey test.

Table 5. Mineral bioavailability of maize meal-based foods and baobab, tomi and néré pulps.

	Oxalates/Ca	Phytates/Ca	Phytates/Fe
<i>Wasséra</i>	0.12	0.02	0.32
<i>Badégué with tomi</i>	0.31	0.04	4.35
<i>Badégué with baobab</i>	0.18	0.04	4.55
Authorised limit	2.25 ^{**}	1 [*]	1 [*]

Source: *Ma et al. (2007); **Tchiégang and Aïssatou (2004).

**Figure 1.** Sensory characteristics of foods made from maize flour and baobab, tomi and néré pulps.

Sensory evaluation of different dishes

Figure 1 shows the sensory analysis of *Badégué-baca* with *baobab*, *Badégué-baca* with *tomi*, and *Wasséra*. The hedonic scoring test revealed significant differences ($P < 0.05$) in terms of color, taste, viscosity, smell, astringency, texture in the mouth, and general acceptability.

Badégué with baobab exhibited fairly good acceptability

(score of 6) in terms of color and neither good nor bad acceptability (score of 5) in terms of taste. In contrast, *Badégué with tomi* and *Wasséra* received neither good nor bad acceptability scores (5) for color and poor acceptability (score of 4) for taste.

Regarding viscosity, no significant difference ($P > 0.05$) was observed between *Badégué with baobab* and *Badégué with tomi*, with neither receiving a score of

neither good nor bad (5). *Badégué* with *baobab* showed fairly good acceptability (score of 6) in terms of smell, whereas *Badégué* with *tomi* received a score of neither good nor poor (5) for smell, and *Wasséra* received a poor acceptability score (4) for smell.

In terms of astringency and texture in the mouth, no significant difference ($P > 0.05$) was found between *Badégué* with *baobab* and *Wasséra*, both receiving scores of neither good nor bad (5) for astringency and texture in the mouth. *Badégué* with *tomi*, however, received a poor acceptability score (4) for astringency and a fairly good acceptability score (6) for texture in the mouth.

Overall, sensory characterization indicated significantly ($P < 0.05$) fairly good overall acceptability (score of 6) for *Badégué* with *baobab*, primarily due to its color and smell. In contrast, *Badégué* with *tomi* and *Wasséra* received an overall acceptability score of neither good nor bad (5).

DISCUSSION

Biochemical analyses showed that the macronutrient and micronutrient contents of *Wasséra* were higher than those of *Badégué-baca* with *tomi* and *Badégué-baca* with *baobab*. It is believed that the nature of the food contributes to the variation in macronutrient and micronutrient contents between *Wasséra* and *Badégué-baca* with *tomi* and *baobab*. In fact, *Wasséra* is a couscous made from maize flour and *néré* and cooked by steaming, making it a solid food, whereas *Badégué-baca* with *tomi* and *baobab* are semi-liquid foods cooked by boiling in water, commonly called *Baca* in Côte d'Ivoire. Their higher water content reduces their dry matter content, thus affecting their macronutrient and micronutrient concentration, as confirmed by Tou et al. (2006), who highlight the inadequate nutritional value of traditional porridges due to their low macronutrient and micronutrient content. The biochemical composition of the different pulps added during food preparation also contributes to this variation. Analysis of the vitamin composition of the foods showed significant differences between the levels of vitamin C, vitamin E, vitamin A, and B vitamins (B1, B2, B3, B6).

In addition, the protein (1.66 - 1.79 g /100 g) and lipid (0.08 - 0.17 g /100 g) contents of *Badégué-baca* with *tomi* and *Badégué-baca* with *baobab* were lower than those found by Tou et al. (2006), but recorded dry matter contents (24.20 - 24.93 g /100 g) higher than those found by the latter. In their work, they showed that traditional porridges would have protein contents of (7.0 - 8.9 g / 100 g DM), lipid contents of (1.5 - 3.2 g / 100 g DM) and dry matter contents of (11.3 g / 100 g). According to Tou et al. (2006), the first supplementary foods given to African children were cereal-based porridges (maize,

millet or sorghum). However, these values found by these authors in traditional porridges are very low and these traditional porridges do not have the characteristics required to be used as complementary foods. These complementary foods consumed in porridge form by infants and young children should be improved on several levels: hygienic quality, nutrient balance, energy and nutrient density, bioavailability of nutrients and organoleptic characteristics (Tou et al., 2006). Ekpa et al. (2019) make a similar point, mentioning that maize-based foods are often characterised by low nutritional quality due to the removal of certain structures from the grain such as the pericarp or germ, damage caused by processing and/or natural nutritional deficiencies in the grain. In addition, the presence of anti-nutritional substances, such as phytate in maize, reduces the nutritional quality of the food by reducing the bioavailability of minerals.

However, the high lipid content of *Wasséra* compared to *Badégué-baca* with *tomi* and *baobab* could be justified by the addition of lipids during the preparation of *Wasséra*, unlike the other two. The different conditions under which *Wasséra* is made are perfectly in line with the high dry matter and energy content of *Wasséra* compared with *Badégué* with *tomi* and *Badégué* with *baobab*. These results concur with those of Laurent and Sawadogo (2002) who state that the addition of wild fruit pulp and oil during the preparation of *Wasséra* will help to increase the energy value and improve the nutritional quality of the food. This hypothesis is confirmed by Tou et al. (2006), who report that adding vegetable oil to the porridge does not significantly alter its viscosity, but increases its energy density and provides fat-soluble vitamins and essential fatty acids.

The various analyses also revealed that all the foods studied were relatively rich in energy, with energy values ranging from 97.88 ± 1.22 kcal /100 g of food for *Badégué* with *baobab* to 99.90 ± 1.22 kcal / 100 g of food for *Badégué* with *tomi* and 272.78 ± 0.96 kcal /100 g of food for *Wasséra*. These foods are good sources of energy. These results corroborate those of (Ahokpe, 2005), who stipulates that cereal products provide the necessary energy and certain proteins in the food ration.

In the present study, only the *Wasséra* had a high level (11.37%) of crude fiber, whereas the *Badégué* with *tomi* and *baobab* had low levels (1.39 and 1.72% respectively). Consumption of these foods could be beneficial for populations as the presence of fiber facilitates digestion, increases gastrointestinal function and prevents constipation, thereby reducing the incidence of metabolic diseases such as obesity, diabetes mellitus and hypercholesterolaemia. These results corroborate those of (Ibeji et al., 2011) who state that dietary fiber has a great capacity to retain water as it passes through the digestive tract and that it constitutes an excellent digestive load facilitating gastrointestinal transit by

reducing transit time. In addition, the ash content of *Badégué* with *tomi* (0.17%) and *baobab* (0.16%) is very low compared to that indicated by Olapade et al. (2010), which is 1.2%, unlike that of *Wasséra* (1.04%), which is closer.

From these ashes, it can be seen specifically that *Badégué* with *baobab*, *Badégué* with *tomi* and *Wasséra* were rich in calcium but recorded lower values than those reported by Kouassi (2019) where the calcium contents obtained from these three pulps were respectively 84.23 mg/100 g (Néré), 310.12 mg/100g (Baobab) and 320.85 mg/100 g (Tomi).

However, these foods could be appropriate for the formation of teeth and bones in young children if consumed as weaning foods. In addition, the iron concentration of these foods varied from 0.27 ± 0.01 to 3.49 ± 0.02 mg/100 g of food. These values are closer to the range indicated by OMS/FAO (2015), which recommends 4 to 8 mg of iron for infants and young children. These foods recorded high levels of magnesium and potassium, which ranged respectively from 9.58 ± 0.21 to 27.63 ± 0.22 mg /100 g of food and from 27.88 ± 0.36 to 56.52 ± 0.21 mg / 100 g of food. All these minerals are extremely important for the proper functioning of the body, especially as the assimilation indices showed that they are bioavailable after ingestion of the three feeds studied. However, the assimilation indices (phytates/iron) of *Badégué* with *baobab* and *Badégué* with *tomi* are greater than one. According to the recommendations of Ma et al. (2007), iron is not bioavailable in *Badégué* with *baobab* and *Badégué* with *tomi*. Similarly, Ekpa et al. (2019) confirm that the presence of anti-nutritional substances, such as phytate in maize, reduces the nutritional quality of the food by reducing the bioavailability of minerals.

These mineral contents are superimposed on those of Garg et al. (2005) and Anhwange (2008), who indicated that these minerals are crucial for enzymatic activities, cell protection against free radical attack and the regulation of homeostatic glucose.

Analysis of the vitamin composition of *Badégué* with *tomi*, *Badégué* with *baobab* and *Wasséra* showed that there are significant differences between the levels of vitamin C, vitamin E and vitamin B (B1, B2, B3, B6). However, *Wasséra* is richer in these vitamins than *Badégué* with *tomi* and *Badégué* with *baobab*. According to Gopalan et al. (2007) and Shah et al. (2015), maize, which is the basic component of these three foods, is not rich in the aforementioned vitamins. As a result, the vitamin C and E content of *Badégué* with *baobab*, *Badégué* with *tomi* and *Wasséra* could be justified by the richness of the different wild fruit pulps added during the preparation of these dishes. Baobab pulp (311 mg /100 g of food), *tomi* pulp (28 mg /100 g of food) and *néré* pulp (48 mg /100 g of food) are characterised by a high vitamin C content but in variable proportions (Kouassi et

al., 2018).

Levels of B complex vitamins were detected in the foods studied. Vitamin B complexes help to reduce the damage caused by free radicals in the body and degenerative diseases (Jacab and sotoudeh, 2002). Their presence would mean that these foods could be used as a dietary supplement in the prevention and treatment of B vitamin deficiency conditions such as oral and genital lesions, beri beri and pellagra, which are frequently found in rural areas (Nazmul et al., 2013).

According to the literature, vitamin C is very useful in collagen synthesis, facilitates iron absorption and participates in the biosynthesis of glucocorticoids. It is supplied to the human body through fruit and vegetables, and its recommended daily intake is 30 mg/100 g for a 65 kg adult (Olson and Hodges, 1987). It is an antioxidant involved in protecting cells against oxidative stress caused by environmental pollutants (Lauer et al., 2013; Valacchi et al., 2015, 2016) and the arteriosclerosis-type inflammatory response (Shashirekha et al., 2015).

From the point of view of phenolic compounds in foods, it emerged that all the foods studied were relatively rich in phenolic compounds, with levels ranging from 26.24 ± 1.47 mg /100 g of food for *Badégué* with *tomi* to 24.51 ± 1.37 mg / 100 g of food for *Badégué* with *baobab* and 82.28 ± 3.77 mg /100 g of food for *Wasséra*. The richness of these foods in phenolic compounds could be attributed to the high total phenol content of the pulps of these fruits as reported by Kouassi et al. (2018). This richness would be a major asset for the health of consumers as the presence of these phenolic compounds would indicate a potential antioxidant activity. According to Kouassi (2019), the pulps of these wild fruits contain a significant quantity of total phenols, which would give them a strong antioxidant activity. This could contribute to their medicinal properties.

Sensory characterisation showed fairly good overall acceptability (score of 6) for *Badégué* with *baobab*. However, the overall acceptability of *Badégué* with *tomi* and *Wasséra* was neither good nor bad (score of 5). According to the classification by Konan et al. (2022abc) based on the proportion and level of knowledge of the various dishes, *Wasséra*, with a proportion of 8.89%, tops the list of little-known foods. *Badégué* with *baobab* and *Badégué* with *tomi*, with proportions of 37.27% and 42.22% respectively, are moderately well-known foods.

This sensory characterisation shows that *Badégué* with *tomi* and *Wasséra*, given their sensory characteristics, are rarely consumed, unlike *Badégué* with *baobab*.

Conclusions

The study highlighted that *Wasséra* exhibited the highest levels of total carbohydrates, calcium, magnesium, vitamin C, and polyphenols. *Badégué-baca* with *tomi*

showed lower levels of fiber, iron, and vitamin B3, but higher levels of vitamin E and tartaric acid. *Badégué-baca* with *baobab* displayed elevated levels of potassium, citric acid, and flavonoids, yet lower levels of vitamin B2 and lipids. In terms of sensory evaluation, *Badégué-baca* with *baobab* demonstrated fairly good overall acceptability compared to *Badégué* with *tomi* and *Wasséra*, both of which were rated as neither good nor poor in overall acceptability. Thus, based on their sensory characteristics, *Badégué* with *tomi* and *Wasséra* were found to be less appreciated than *Badégué* with *baobab*.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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