

Research Article

Nutritional and Metabolic Profiles of Three Traditional Functional Dishes Based on Maize Flour and Wild Fruit Pulp of “Tomi” (*Tamarindus indica*), “Baobab” (*Adansonia digitata*), and “Néré” (*Parkia biglobosa*) Consumed in Côte d’Ivoire

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Received 4 June 2024; Accepted 9 April 2025

Academic Editor: Nadica Maltar Strmečki

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Badégué-baca with tomi, Badégué-baca with baobab, and Wasséra are dishes made from maize flour, and “baobab” (*Adansonia digitata*), “tomi” (*Tamarindus indica*), and “néré” (*Parkia biglobosa*) pulp were consumed by the populations of northern Côte d’Ivoire to cover their dietary and nutritional needs. This study was initiated to determine the nutritional and physiological profiles of dishes made from maize and “baobab”, “tomi”, and “néré” pulp. To this end, these foods were prepared using traditional technologies to determine the nutrient density score (SAIN) and the score of nutrients to limit (LIM), followed by the determination of glycemic indexes (GIs) and glycemic loads (GLs). The results showed that Badégué-baca with baobab (4.70), Badégué-baca with tomi (5.17), and Wasséra (0.34) had LIM values below 7.5. However, Badégué-baca with baobab (7.51) and Wasséra (8.49) have SAIN values above 5, while Badégué-baca with tomi (3.56) has a SAIN score below 5. Moreover, Wasséra has a moderate GI ($GI = 57.22 \pm 0.2$) and a high GL ($CG = 23.21 \pm 0.21$). Badégué-baca with tomi has a high GI ($GI = 76.30 \pm 0.3$) with a moderate GL ($CG = 16.45 \pm 0.09$). As for Badégué-baca with baobab, the associated GL is moderate (14.11 ± 0.1) with a moderate GI ($GI = 67.89 \pm 1.00$). Moderate consumption of Badégué-baca with baobab and Wasséra is safe for the body, they are recommended health foods (LIM below 7.5 and SAIN above 5), and could be used therapeutically to combat nutritional deficiencies. However, the consumption of Wasséra must take into account its high GL. As for Badégué-baca with tomi, a neutral food (LIM below 7.5; SAIN below 5), it would expose the diabetic patient to complications due to its high GI.

Keywords: Côte d’Ivoire; maize flour; metabolic profiles; traditional foods; wild fruit pulp

1. Introduction

Food security remains a serious problem in very many developing countries [1]. In Africa, around 30 million people go from chronic food insecurity to famine every year [2].

These problems are also encountered in Côte d’Ivoire despite the wealth of natural resources that are spread throughout the territory [3, 4]. These natural resources include *Adansonia digitata* (baobab), *Parkia biglobosa* (néré), and *Tamarindus indica* (tomi). The fruit pulps of these wild fruit trees

are appreciated and widely consumed in Côte d'Ivoire [4, 5]. Studies of the nutritional values of these pulps have shown them to be rich in vitamins (A, B1, B2, B6, and C), phenolic compounds (tannins, total polyphenols, and flavonoids), and minerals (K, P, Mg, Ca, and Fe) [6, 7]. Given this important dietary and nutritional value, these pulps could fill many nutritional deficiencies and prevent metabolic diseases and their complications due to their antioxidant, anticarcinogenic, and antiradicular properties [8, 9]. To this end, the savannah populations of northern Côte d'Ivoire incorporate these pulps into cereal flours for the preparation of several traditional dishes [9–11]. These traditional food processing technologies are aimed at adding value to local agricultural products. Many local products are processed in this region of the country. Among these products, cereals (maize and millet) occupy a prime position due to the wide range of foods they can produce. These cereals, and more particularly maize and millet, are eaten in the form of porridge, couscous, or galettes, which are the traditional dishes of these populations. These cereal products provide the necessary energy and certain proteins in the food ration [12]. Maize is the fifth most important food crop in terms of tonnage produced, after cassava, plantain, yams, and rice. Its national production has gradually risen from around 700,000 tons in 2011 to 1.2 million tons in 2020, with an average yield of 2.5 t/ha, higher than the West African average of 1.68 t/ha, making maize the second most cultivated cereal after rice [13]. As a result, the popularization of corn-based dishes could reach a large swath of the Ivorian population.

Although its protein content is of low nutritional value, this cereal has a number of health benefits. The carbohydrates it provides are easily assimilated by the body, and its high fiber content helps regulate intestinal transit [14]. Maize is also a valuable source of vitamins, particularly those from the B and K groups. As a result, this cereal is said to have antihemorrhagic virtues and may be involved in nervous and muscular balance [15]. Konan et al. [9–11] counted seventeen (17) cereal-based recipes incorporating “baobab”, “tomi”, and “nééré” pulps, eleven (11) millet-based and six (6) maize-based. The main maize-based dishes are Badégué with baobab and Badégué with tomi and Wasséra [9–11]. Unfortunately, no scientific data are available on these dishes, which limit their popularization. The general objective of this study was therefore to determine the nutritional potential and the impact on postconsumption health of these 3 dishes made from maize flour and “tomi”, “baobab”, and “nééré” pulps.

2. Materials and Methods

2.1. Plant Material. The biological material consists of fruit pulps from “baobab” (*Adansonia digitata* L.), “nééré” (*Parkia biglobosa*), “tomi” (*Tamarindus indica*), and maize flour (*Zea mays* L.).

2.2. Enrolling Participants. Thirty-two (32) subjects were selected from the student population at Nangui ABRO-GOUA University, in accordance with ISO [16] and FAO/

WHO [17] guidelines. Prior to the study, height was measured using a somatometer, and body weight was assessed using a bathroom scale. These measurements of weight and height were used to calculate the body mass index ($BMI = \text{weight (kg)}/\text{height (m}^2\text{)}$), while blood pressure was recorded using a blood pressure monitor. All clinical procedures were conducted at the Nangui Abrogoua University Medical Center. To be eligible for the study, participants had to be healthy, nonsmoking, nondiabetic individuals with a normal BMI ($18.5\text{--}25.0 \text{ kg/m}^2$), systolic pressure under 130 mmHg, diastolic pressure under 80 mmHg, and fasting blood glucose levels below 6.4 mmol/L [18–20].

2.3. Test Foods. The dishes were prepared following the traditional production methods for each food as described by Konan et al. [9–11]. The three test foods were made using maize flour and fruit pulp. These include Wasséra (a dish made from maize flour and “nééré” powder), Badégué-baca with baobab (a dish made from maize flour and “baobab” powder), and Badégué-baca with tomi (a dish made from maize flour and “tomi” pulp).

2.4. Macronutrient and Micronutrient Analysis. The ash content and the quantification of calcium (Ca), sodium (Na), and iron (Fe) were carried out according to the AOAC method [21]. Proteins and lipids were determined using the BIPEA method [22]. Crude fiber was determined according to the Multon method [23]. Total carbohydrates were calculated by difference [17], and the energy value was calculated using the specific coefficients of Atwater and Rosa [24]. Vitamin C content was determined by HPLC after extraction with a 100/80 (v/v) metaphosphoric acid/acetic acid mixture [6]. Saturated fatty acids (SFA) were extracted from foods according to the AFNOR standard [25], and their profiles were determined by gas chromatography [26].

2.5. Dietary Intake. Participants tested the reference food (50 g of anhydrous glucose dissolved in 250 mL of water) twice and each test food once [16]. After 12-h overnight fast, subjects arrived at the fasting room at 8 a.m. on the day of the experiment. Following a 15-min rest, fasting capillary blood samples were collected at 0-min mark, and the reference food was consumed immediately. The same procedure was applied for the test foods, with portions providing 50 g of carbohydrates from the test foods. The test foods were consumed on days 2, 3, and 4, respectively, with a consumption duration of 4 min. The test foods were served with 250 mL of water.

2.6. Glycemic Index (GI) and Glycemic Load (GL) Calculation. The GI was determined in accordance with ISO [16] and Emaleku's method [27]. Fasting capillary blood samples were collected at 0 min, followed by additional samples at 15, 30, 60, 90, and 120 min after the start of the meal. Blood glucose levels were measured using a calibrated glucometer (On Call Plus). The GI was calculated using the ISO method [16]. The final GI of the foods is the average of the GIs

obtained across all participants [28]. The GL of the test foods was determined by multiplying their GI by the amount of carbohydrates consumed [29].

2.7. Nutritional Profile. The nutritional profile of the samples was calculated on the basis of the nutrient density score (SAIN) and the score of nutrients to limit (LIM) [30, 31]. The SAIN score reflects the average percentage of the recommended daily intake coverage for five essential nutrients (protein, fiber, iron, calcium, and vitamin C) per 100 kcal (0.42 MJ) of food. The LIM score represents the average percentage of excess sodium, SFA, and added carbohydrates per 100 g of food.

2.8. Sensory Characterization of Dishes. The general acceptability of the foods was determined using a hedonic test with a panel of 60 untrained tasters. These tasters assessed general acceptability according to the method described by Ngono Eyenga et al. [32]. The judges were asked to observe, taste, smell, and rate the degree of appreciation on a 9-point linear scale, ranging from 1 (very poor) to 9 (very good), with the following ratings: 1 - very poor; 2 - too poor; 3 - somewhat poor; 4 - poor; 5 - neither good nor poor; 6 - somewhat good; 7 - good; 8 - too good; and 9 - very good. The samples were coded with three digits and presented one by one to the panelists in a randomized order. Each panelist was provided with water to rinse their mouth between samples.

2.9. Ethical Considerations. The research protocol for this study was approved by the National Ethics Committee for Life and Health Sciences (approval no. 00047_24/MSHPCMU/CNESVS-km).

2.10. Statistical Analysis. Data are presented as means, standard deviations, and range. Comparisons between the foods were made by using one-way analysis of variance (ANOVA) and the Tukey's multiple comparisons test. Statistical significance was set at $p < 0.05$. All Statistical analysis was performed using Statistica 7.1.

3. Results

3.1. Clinical and Anthropometric Characteristics. The study involved thirty-two (32) subjects (24 men and 8 women) who were presumed to be healthy and were all students at Nangui ABROGOUA University. These volunteer students had an average age of 22.60 ± 1.68 years, an average BMI of 20.25 kg/m^2 , and an average fasting blood glucose level of $4.65 \pm 0.08 \text{ mmol/L}$. Regarding metabolic pressures, the average systolic blood pressure was $114.7 \pm 0.99 \text{ mmHg}$, and the average diastolic blood pressure was $67.3 \pm 0.96 \text{ mmHg}$, as shown in Table 1. Notably, the BMI, fasting blood glucose, and metabolic pressures observed in these subjects were within the reference values (Table 1).

TABLE 1: Clinical and anthropometric characteristics of volunteer subjects.

Features	Study data	Reference values [20]
Number of subjects	32	≥ 10
Sex ratio (M/F)	24/8	
Age (years)	22.6 ± 1.68	
BMI (kg/m^2)	20.25 ± 1.38	< 25
Fasting blood glucose (mmol/L)	4.46 ± 0.30	$4.4\text{--}5.5$
Systolic pressure (mmHg)	114.7 ± 0.99	< 130
Diastolic pressure (mmHg)	67.3 ± 0.96	< 80

3.2. Macronutrient and Micronutrient of Badégué-Baca With Baobab and Badégué-Baca With Tomi and Wasséra. Table 2 presents the macronutrient and micronutrient composition of the different foods. These results showed a significant difference ($p < 0.05$) in the energy content of the foods. Wasséra had the highest energy content ($272.78 \pm 0.96 \text{ kcal}$), whereas Badégué with tomi ($99.90 \pm 1.22 \text{ kcal}$) and Badégué with baobab ($97.88 \pm 1.22 \text{ kcal}$) recorded the lowest energy values. Wasséra had higher contents of lipids ($5.60 \pm 0.19\%$), total carbohydrates ($51.94 \pm 0.39\%$), crude fiber ($11.37 \pm 0.13\%$), and protein ($3.65 \pm 0.01\%$) than Badégué with tomi and Badégué with baobab. However, the respective contents of Badégué with baobab and Badégué with tomi in total carbohydrates ($22.94 \pm 0.27\%$ and $22.50 \pm 0.27\%$), ash ($0.17 \pm 0.00\%$ and $0.16 \pm 0.00\%$), lipids ($0.17 \pm 0.00\%$ and $0.08 \pm 0.00\%$), crude fiber ($1.72 \pm 0.02\%$ and $1.39 \pm 0.12\%$), and protein ($1.79 \pm 0.03\%$ and $1.66 \pm 0.04\%$) were lower than the respective contents of these elements observed in Wasséra.

There was no significant difference ($p > 0.05$) between the iron content of Badégué with tomi ($0.27 \pm 0.01 \text{ mg/100 g}$) and Badégué with baobab ($0.27 \pm 0.03 \text{ mg/100 g}$), but these contents were lower than those of Wasséra ($3.49 \pm 0.02 \text{ mg/100 g}$). Wasséra had significantly higher levels ($p < 0.05$) of calcium ($47.68 \pm 0.52 \text{ mg/100 g}$) and sodium ($28.80 \pm 0.10 \text{ mg/100 g}$) compared to Badégué with baobab and Badégué with tomi, which had respective calcium levels of $22.12 \pm 0.69 \text{ mg/100 g}$ and $20.40 \pm 0.27 \text{ mg/100 g}$ and sodium levels of $8.42 \pm 0.38 \text{ mg/100 g}$ and $5.72 \pm 0.07 \text{ mg/100 g}$. The vitamin C content in Wasséra ($34.62 \pm 0.35 \text{ mg/100 g}$) was higher than that in Badégué with baobab ($24.75 \pm 0.30 \text{ mg/100 g}$), while Badégué with tomi had lower vitamin C levels ($5.77 \pm 0.11 \text{ mg/100 g}$).

The fatty acid composition of the different foods is presented in Table 3. The levels of palmitic acid ($18.79 \pm 0.17 \text{ mg/100 g}$), stearic acid ($3.14 \pm 0.02 \text{ mg}$), and arachidic acid ($0.90 \pm 0.20 \text{ mg/100 g}$) in Wasséra were significantly higher ($p < 0.05$) than in all other foods. Badégué with tomi and Badégué with baobab recorded the lowest levels of palmitic acid ($7.02 \pm 0.02 \text{ mg}$ and $5.32 \pm 0.20 \text{ mg}$, respectively) and stearic acid ($1.30 \pm 0.20 \text{ mg/100 g}$ and $0.80 \pm 0.20 \text{ mg/100 g}$, respectively).

Regarding unsaturated fatty acids, Wasséra recorded the highest levels of oleic acid ($9.80 \pm 1.73 \text{ mg/100 g}$), linoleic acid ($12.83 \pm 0.02 \text{ mg/100 g}$), and alpha-linolenic acid ($12.13 \pm 0.02 \text{ mg/100 g}$). In contrast, Badégué with baobab had the lowest levels of oleic acid ($3.53 \pm 0.17 \text{ mg/100 g}$) and linoleic acid ($4.19 \pm 0.02 \text{ mg/100 g}$), while Badégué with tomi

TABLE 2: Macronutrient and micronutrient content of test foods.

Parameters	Wasséra	Badégué with tomi	Badégué with baobab
Energy (kcal)	272.78 ± 0.96 ^a	99.90 ± 1.22 ^b	97.88 ± 1.22 ^b
Total carbohydrate (%)	51.94 ± 0.39 ^a	22.94 ± 0.27 ^b	22.50 ± 0.27 ^b
Lipids (%)	5.60 ± 0.19 ^a	0.17 ± 0.00 ^b	0.08 ± 0.00 ^b
Protein (%)	3.65 ± 0.01 ^a	1.66 ± 0.04 ^c	1.79 ± 0.03 ^b
Crude fiber (%)	11.37 ± 0.13 ^a	1.39 ± 0.12 ^c	1.72 ± 0.02 ^b
Ash (%)	1.04 ± 0.00 ^a	0.17 ± 0.00 ^b	0.16 ± 0.00 ^b
Ca (mg)	47.68 ± 0.52 ^a	20.40 ± 0.27 ^c	22.12 ± 0.69 ^b
Na (mg)	28.80 ± 0.10 ^a	5.72 ± 0.07 ^c	8.42 ± 0.38 ^b
Fe (mg)	3.49 ± 0.02 ^a	0.27 ± 0.01 ^b	0.27 ± 0.03 ^b
Vitamin C (mg)	34.62 ± 0.35 ^a	5.77 ± 0.11 ^c	24.75 ± 0.30 ^b

Note: In the same row, the means with the same letter are not significantly different at the 5% threshold according to the Tukey test.

TABLE 3: Fatty acid profile.

	Wasséra	Badégué with tomi	Badégué with baobab
Saturated fatty acids (mg/100 g)			
Palmitic acid	18.79 ± 0.17 ^a	7.02 ± 0.02 ^b	5.32 ± 0.20 ^c
Arachidic acid	0.90 ± 0.20 ^a	0.44 ± 0.02 ^b	0.49 ± 0.02 ^b
Stearic acid	3.14 ± 0.02 ^a	1.30 ± 0.20 ^b	0.80 ± 0.20 ^c
Unsaturated fatty acids (mg/100 g)			
Oleic acid	9.80 ± 1.73 ^a	5.62 ± 0.20 ^b	3.53 ± 0.17 ^b
Linoleic acid	12.83 ± 0.02 ^a	5.33 ± 0.02 ^b	4.19 ± 0.02 ^c
Alpha-linolenic acid	12.13 ± 0.02 ^a	4.35 ± 0.02 ^c	7.94 ± 0.02 ^b

Note: In the same row, the means with the same letter are not significantly different at the 5% threshold according to the Tukey test.

showed the lowest level of alpha-linolenic acid (4.35 ± 0.02 mg/100 g).

3.3. Nutritional Profiles of Badégué-Baca With Baobab and Badégué-Baca With Tomi and Wasséra. The SAIN and LIM values calculated for each of the foods are presented in Table 4. Table 4 shows that Wasséra has the highest SAIN score, with a value of 8.49 ± 0.02 . This food is followed in descending order of SAIN scores by Badégué-baca with baobab (7.51 ± 0.00) and Badégué-baca with tomi (3.56 ± 0.03). The LIM score of these foods shows that Badégué-baca with tomi has a score of 5.17 ± 0.00 , which is significantly higher ($P < 0.05$) than that of Badégué-baca with baobab (4.70 ± 0.00). The latter LIM score is also higher than that of Wasséra, which has an observed LIM score of 0.34 ± 0.00 .

Graphical representations of SAIN and LIM (Figure 1) in the factorial plane show that the foods Badégué-baca with baobab and Wasséra have LIM values < 7.5 and SAIN values > 5 , which are characteristic of foods recommended for consumption for health (Group 1). Badégué-baca with tomi is characterized by a LIM value < 7.5 but a SAIN value < 5 , placing this food in the neutral food group (Group 2). According to recommendations, Badégué-baca with tomi should be combined with high SAIN foods for nutritional balance.

3.4. GI of Badégué-Baca With Baobab and Badégué-Baca With Tomi and Wasséra. The postprandial glycemic responses of subjects ingesting anhydrous glucose solution, Badégué-baca with baobab, Badégué-baca with tomi, and Wasséra

TABLE 4: SAIN and LIM parameters of mixed feeds based on maize flour and “tomi”, “baobab”, and “nééré” pulp.

Aliments	Scores SAIN	Scores LIM
Badégué-baca with baobab	7.51 ± 0.00^b	4.70 ± 0.00^b
Badégué-baca with tomi	3.56 ± 0.03^c	5.17 ± 0.00^a
Wasséra	8.49 ± 0.02^a	0.34 ± 0.00^c

Note: Data on the same column with different letters are significantly different ($p < 0.05$) as assessed by Tukey's test.

are illustrated in Figure 2. The absorption kinetics of the three foods were translated into bell-shaped curves of the same amplitude, but with a glycemic peak at 30 min for the reference food (anhydrous glucose) and at 45 min for the test foods. The highest postprandial glycemic peak was caused by anhydrous glucose (7.43 mmol/L), followed, respectively, by Badégué-baca with tomi (6.53 mmol/L), Badégué-baca with baobab (6.25 mmol/L), and Wasséra (5.60 mmol/L). After 2 h, postprandial glycemic levels fell to 5.13 mmol/L (anhydrous glucose), 5.01 mmol/L (Badégué-baca with tomi), 4.71 mmol/L (Badégué-baca with baobab), and 4.57 mmol/L (Wasséra).

3.5. Area Under the Curve (iAUC), GI, and GL of Badégué-Baca With Baobab and Badégué-Baca With Tomi and Wasséra. The GIs and GLs are summarized in Table 5. The incremental area under the curve (iAUC) of the reference food (glucose) is much higher than that of the test foods (Badégué-baca with baobab, Badégué-baca with tomi, and Wasséra). iAUCs for Badégué-baca with baobab, Badégué-baca with tomi, and Wasséra ranged from 113.67 to 151.59 mmol/L $\times$ 120 min. Badégué-baca with tomi had the

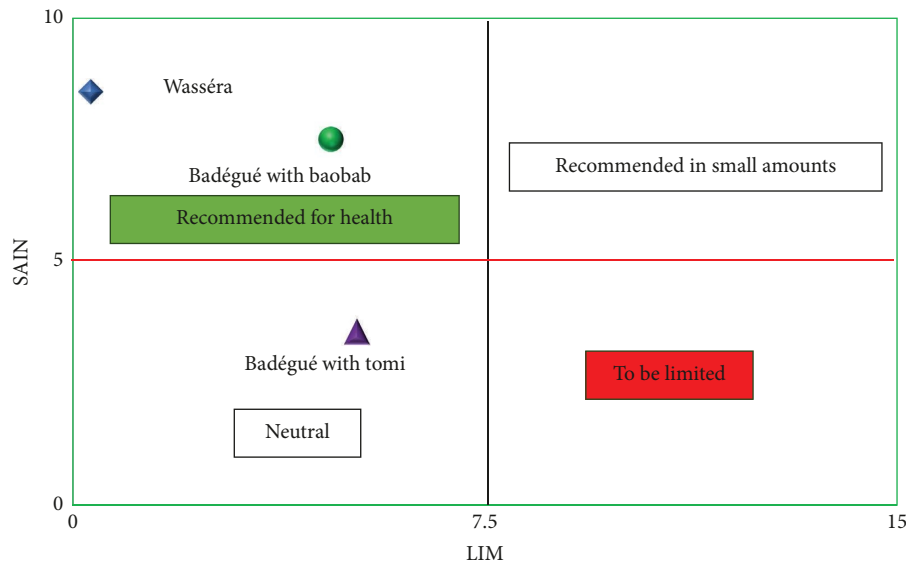


FIGURE 1: Nutritional profile of Badégué-baca with baobab and Badégué-baca with tomi and Wasséra.

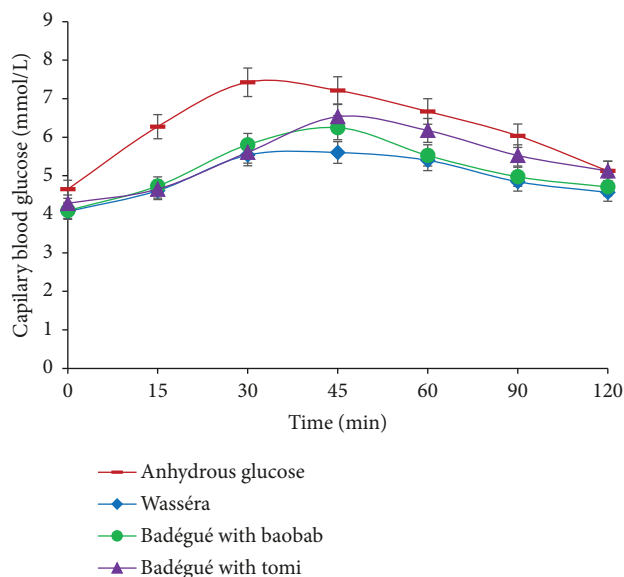


FIGURE 2: Graphs showing mean blood glucose concentrations for Badégué-baca with baobab and Badégué-baca with tomi and Wasséra.

highest iAUC (151.59 mmol/L $\times$ 120 min), followed by Badégué-baca with baobab (134.87 mmol/L $\times$ 120 min). Wasséra had the lowest iAUC (113.67 mmol/L $\times$ 120 min). The GI ranged from 57.22 (Wasséra) to 76.30 (Badégué-baca with tomi). However, the GIs of Wasséra (57.22) and Badégué-baca with baobab (67.89) are lower than those of Badégué-baca with tomi (76.30). The GL associated with Wasséra (23.21) is high (GL > 20). On the other hand, those of Badégué-baca with baobab (14.11) and Badégué-baca with tomi (16.45) are moderate (GL $\leq$ 20).

3.6. Sensory Evaluation of Different Dishes. Figure 3 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 general acceptability. Badégué-baca with baobab received a fairly good overall acceptability score (5.80). However, the overall acceptability of Badégué-baca with tomi (4.90) and Wasséra (4.50) was neither good nor bad.

4. Discussion

The SAIN/LIM system evaluates the quality of foods, based on their ability to promote nutritional balance, thus enabling consumers to be guided towards good-quality foods [33]. The results revealed that Badégué-baca with baobab and Wasséra both have SAIN scores above 5 and LIM scores below 7.5. Badégué-baca with baobab and Wasséra have good nutritional profiles and can be recommended to prevent cardiovascular disease [33]. These results are in line with those of Darmon et al. [34], indicating that mixed cereal-based foods belong to the class of foods recommended for good health. Masset and Martin [35] even report that these foods are rich in nutrients beneficial for the growth and renewal of the body's cells.

The SAIN score for Badégué-baca with tomi is 3.56 below 5 and the LIM score is 5.17 below 7.5. This food belongs to Group 2, the neutral food group. According to recommendations, Badégué-baca with tomi should be combined with high SAIN foods such as milk, legume flour, and vegetable proteins for nutritional balance [33]. Similarly, Koné et al. [33] still report that the nutritional quality of a food could be modified by food processing. This could explain why the nutritional scores of Badégué-baca with tomi differ from those of other foods.

On the other hand, Badégué-baca with baobab (GI = 67.89) and Wasséra (GI = 57.22) are cereal dishes belonging to the medium GI class. Badégué-baca with tomi (GI = 76.30), on the other hand, belongs to the high GI class according to the international GI classification [16]. The GI values in this study are lower than those found by Mahgoub et al. [36] for maize-based foods (GI = 91; high GI)

TABLE 5: Incremental Area under the curve (iAUC), glycemic index (GI), and glycemic load (GL) of mixed foods made with corn flour and “tomi”, “baobab”, and “nééré” pulps.

Food	iAUC (mmol/L)	GI (glucose = 100)		GL (per serving)	
	Average	Average	Classification	Average	Classification
Badégué-baca with baobab	134.87 ± 0.2 ^b	67.89 ± 0.02 ^b	Moderate	14.11 ± 0.2 ^c	Moderate
Badégué-baca with tomi	151.59 ± 0.17 ^a	76.3 ± 0.17 ^a	High	16.45 ± 0.17 ^b	Moderate
Wasséra	113.67 ± 0.2 ^c	57.22 ± 0.02 ^c	Moderate	23.21 ± 0.2 ^a	High

Note: Data on the same column with different letters are significantly different ($p < 0.05$) as assessed by Tukey's test.

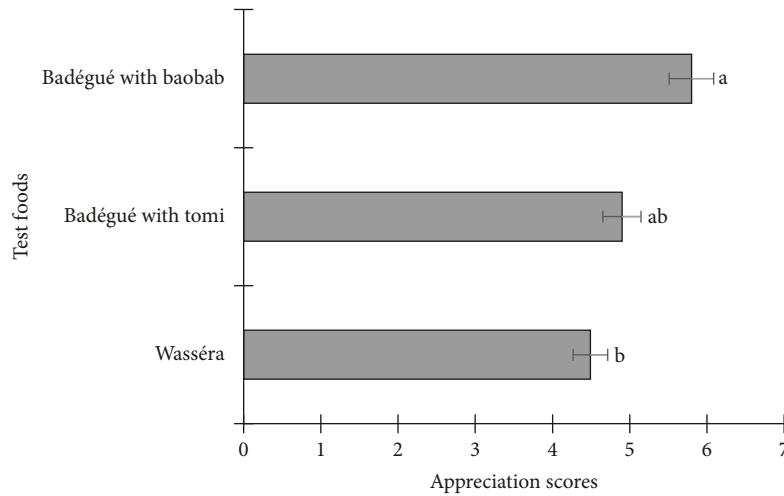


FIGURE 3: Average overall appreciation scores.

consumed in Botswana. However, they are close to the values reported by Kouamé et al. [18] with rigid maize porridge (GI = 74, high GI) consumed in Côte d'Ivoire. According to Mahgoub et al. [36], there are considerable variations between the GIs of foods formulated with the same cereal. These differences can, in part, be attributed to the method of food preparation. It has been established that cooking foods can affect starch digestibility, which has some implications for the GI values of these foods [37]. It can affect both the gelatinization process, thus influencing starch's resistance to digestion [38]. It should be noted that Badégué-baca with baobab and Wasséra is characterized by moderate GIs ($57.22 \leq \text{GI} \leq 70$) [39]. In contrast, Badégué-baca with Tomi has a high GI ($\text{GI} \geq 70$). This can be explained by the low protein, lipid, and fiber content of Badégué-baca with Tomi, as opposed to Badégué-baca with baobab and Wasséra, which are characterized by high levels of protein, lipids, and fiber. The presence of dietary fiber in foods delays the glycemic response. Indeed, when dietary fiber is present in carbohydrate food, it slows stomach emptying and slows down the movement of the initial part of the intestine, thus slowing down the absorption of assimilable carbohydrates and producing a hypoglycemic effect [40, 41]. Fiber also plays a role in protecting the body against diabetes and cardiovascular disease. Giacco et al. [42] concur, claiming that a high-fiber diet (50 g/day) improves glycemic control and reduces the risk of hypoglycemia, compared to a low-fiber diet (15 g/day).

The absorption of carbohydrates can also be slowed by lipids. The addition of lipids and proteins to high-

carbohydrate foods could considerably reduce their GI [43]. Similarly, the GI values of Badégué-baca with baobab and Wasséra may also be explained by the presence of polyphenols, tannins, flavonoids, and oxalates, which may result in strong inhibition of α -glucosidase and pancreatic amylase [18, 44–47]. Indeed, proanthocyanidins, phenolic acids, flavonols, and saponins are the most common compounds in “baobab” fruit pulp [48]. According to Ismail et al. [49], several flavonoids, particularly quercetin, as well as proanthocyanidins B1 and B2, are highly bioaccessible in “baobab” fruit pulp. Consequently, “baobab” fruit pulp is a good source of bioaccessible polyphenols that could be used as ingredients in functional foods [49].

The results obtained in this study show that Wasséra and Badégué-baca with baobab, although having an average GI, have respectively high GLs for Wasséra (23.21) (CG above 20) and low for Badégué-baca with baobab (14.11). Badégué-baca with tomi has a high GI but a moderate GL (16.45) (CG ≤ 20). The high load of Wasséra shows that there is a large quantity of carbohydrates in the portion of the Wasséra test used [18]. These results are corroborated by those of Mendosa [50]. According to this author, foods that have an intermediate or high GI can have very low GL or very high GL. Therefore, people who are more concerned about their postprandial glycemic response should be very careful about their food portion size, as high GL foods can increase the postprandial glycemic response. In addition, several studies have demonstrated that chronic consumption of a diet with a high GL is associated with an increased risk of developing type 2 diabetes or cardiovascular disease [51, 52].

However, the moderate loadings of Badégué-baca with baobab and Badégué-baca with tomi show that there are low proportions of carbohydrates in the test food portions used [18]. Badégué-baca with baobab and Wasséra could therefore be recommended to healthy or diabetic people but in moderation [53]. However, the consumption of Badégué-baca with tomi must be limited. This food would expose the patient suffering from diabetes to complications due to its high GI.

5. Conclusion

In this study, Badégué-baca with baobab and Wasséra presented the best nutritional profiles, based on their respective SAIN and LIM scores. Badégué-baca with tomi, belonging to the group of neutral foods, must be combined with high healthy foods for nutritional balance. In addition, Badégué-baca with baobab and Wasséra have GIs classified in the category of foods with medium GIs and Badégué-baca with tomi, in the category of foods with a high GI. As a result, Badégué-baca with tomi could expose diabetic patients to complications due to its high GI.

Data Availability Statement

The data used to support the findings of this study are available from the corresponding authors upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Kouakou Nestor Kouassi, Kouame Aristide Kouakou and Yapo Hypolithe Kouadio proposed the methodology, validated the study, investigated the study, curated the data, performed formal analysis, visualized the study, wrote the original draft, and wrote, reviewed, and edited this study. Kouadio Benal Kouassi proposed the methodology, validated the study, investigated the study, and curated the data. Gbè Aya Jacqueline Konan proposed the methodology, supervised the study, wrote, reviewed, and edited the study, and administered the project. Yao Denis N'dri and N'Guessan Georges Amani: conceptualized the study, proposed the methodology, investigated the study, curated the data, performed formal analysis, supervised the study, wrote, reviewed, and edited the study, and administered the project.

Funding

This research did not receive any funding.

Acknowledgments

The authors express their gratitude to the Nangui Abrogoua University Medical Center for their support during all clinical procedures and to the subjects for their assistance.

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