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Some Biochemical and functional properties of composite flours based on Ivorian agriculture products (cassava and maize) and by-products (African oil palm heart)

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Abstract
The aim of this study was to display some biochemical and functional properties of composite flours blended from cassava flour (Cf) or maize flour (Mf) and oil palm heart flour (HP) at 10, 20, and 30 %. The codes used were: Cf (100 %), Cf10HP (90 % cassava and 10 % HP), Cf20HP (80 % cassava and 20 % HP), Cf30HP (70 % cassava and 30 % HP), Mf (100 %), Mf10HP (90 % maize and 10 % HP), Mf20HP (80 % maize and 20 % HP) and Mf30HP (70 % maize and 30 % HP). Compare to cassava and maize standard flours, results showed that at 30 % of oil palm heart blend, the protein content of the composite flours increased significantly ($p < 0.05$) from 3.5 to 6.1 % and from 8.4 to 10.7 %, when cassava or maize flour were used respectively. Likewise, ash content increased significantly ($p < 0.05$) from 3.6 to 5.5 % and from 0.5 to 2.4 %, when cassava or maize flour were used respectively. Otherwise, lipids content did not change significantly ($p > 0.05$). Meanwhile, carbohydrate content decreased significantly ($p < 0.05$) from 82.6 to 77.0 % and from 78.9 to 75.5 %, when cassava or maize flour were used respectively in composite flours. Water absorption capacity, wettability, foam capacity, least gelation concentration, dispersibility and swelling power increase significant ($p < 0.05$) in the composite flours. Concerning oil absorption capacity and apparent density, these properties decrease significant ($p < 0.05$).

Keywords: composite flours, oil palm heart, cassava, maize, chemical and functional properties

1. Introduction

Maize and cassava are respectively the third and sixth most important food crops in the world [1]. With an annual production in tonnes of 53,670 million of cassava and 10,250 million of maize [2], these starchy food crops are staple foods and represent respectively the second and the fourth sources of calories in Côte d'Ivoire [3]. However, the inherent problem in the consumption of these starchy foods, which is their high perishability [4, 5], require their transformation into readily preservable flours, convenient use and good organoleptic quality, nutritional and sanitary [6]. According to Falade and Akingbala [7], cassava and maize flours are used in households to prepare new recipes such as baked goods (cookies, rolls, donuts, cakes, bread, puff pastry, pie and more). Meanwhile, these foods made from cassava and maize flours are of lower technological and nutritional quality than wheat flour products [8, 9]. To overcome these technological and nutritional shortcomings of local flours, many studies have been conducted on the possibility of formulating foods from local ingredients that can increase technological ability and nutritional value, particularly in terms of dietary fibre, protein and minerals [7, 10].

The heart of the oil palm was used for human nutrition in many countries [11, 12, 13]. It was also an excellent source of vitamin C and a potential source of vitamins A, B1, B2, B3, B6 and K [14, 15]. Minerals such as potassium, calcium, magnesium and phosphorus are found in significant quantities [13]. In addition, the heart of the palm has a strong anti-oxidant activity with a predominance of polyphenols and flavonoids [16]. All essential amino acids are present in the heart of the oil palm [12]. Generally, the heart of palm is Consumed in mixed salads, but there is a multitude of recipes derived from indigenous uses: lasagna, quiches, soups, croquettes, etc. In Côte d'Ivoire, the heart of the oil palm is sold on a small scale in local markets [13]. It is usually cut into pieces and cooked in a sauce [11]. Also, the heart of the palm is incorporated into other flours for technological purposes. This use is observed in South-East Asia where indigenous transformed palm heart into starch for mixed bread making [12].

Composite flour is the mixture of different flours of vegetables, wheat or non-wheat flour, rich in protein and starch which can be used for the production of leavened products breads, pastas, porridges, unleavened baked products, snack foods [17]. The using of composite flours for baking foods is recent around the world [18, 19, 20, 21]. In Africa, economic, social and health reasons seem to justify the development of composite flours from local products [22, 23]. In fact, the use of composite flours aims to reduce imports of wheat, enhance the value of products and by-products from local agriculture and reduce the incidence of celiac disease, which is a disease of gluten intolerance [20, 24, 25]. In addition, used composite flours aims to improve the nutritional and technological value of some local products of industrial interest [9, 6]. Composite flours blended with local plant could also be important sources of plant protein in the diet of people in tropical developing countries where animal protein is unavailable to majority of the population [26].

In this study, the main object was to evaluate biochemical and functional properties of composite flours blended from cassava or maize and oil palm heart.

2. Materials and methods

2.1 Material

The products (fig. 1), about 250 kg of sweet cassava roots (12 months old) and 25 kg of yellow maize seeds, were purchased on local market of Abidjan (Côte d'Ivoire). The by-product (fig. 2) was African oil palm heart, isolated from the stipe after sap extraction process.

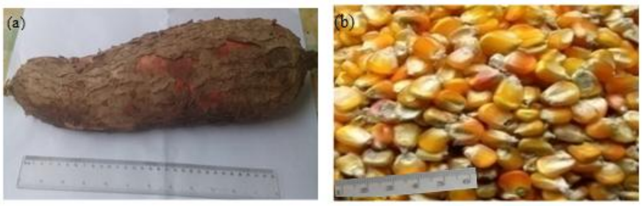

Fig 1: Product of Ivorian agriculture (a): Cassava (*Manihot esculenta* Crantz); (b): Yellow maize (*Zea mays*)

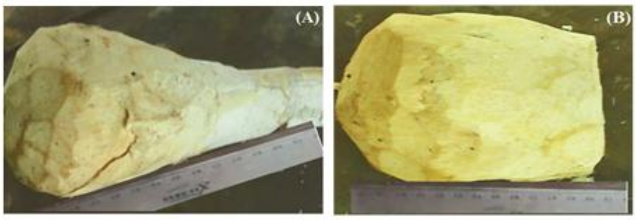

Fig 2: By-product of African oil palm (*Elaeïs guineensis* Jacq) (A): Heart before sap extraction, (B): Heart after sap extraction

2.2 Preparation of African oil palm heart flour

The fresh heart isolated from African oil palm after sap extraction were washed with tap water. Then, it was cut directly into strips about 1 mm thick. The slides were then dried at 45 °C for 72 h in a ventilated oven (UN160Plus, Memmert GmbH, D91126-Schwabach, Germany) to obtain chips. At last, the dried chips were crushed and sieved through a 25-µm diameter sieve.

2.3 Preparation of cassava root flour

For the preparation of cassava root flour, the chipped method of Aryee *et al*. [27] is used. The process started by peeling the freshly baked cassava roots. Then, peeled cassava roots were washed, sliced to 4 mm and dried for 24 hours at 70 °C in a ventilated oven (UN160Plus, Memmert GmbH, D91126-Schwabach, Germany) to obtain chips. Then, the dry chips were ground into flour with a laboratory mill, and excess fibre was removed by passing the ground material through a sieve (250-µm aperture sieve).

2.4 Maize flour preparation

The maize grains were sorted, washed properly and drained before milling with a locally fabricated attrition mill. The flour obtained were dried again for 24 hours at 45 °C in a ventilated oven (UN160Plus, Memmert GmbH, D91126-Schwabach, Germany) and sieved through aperture size 250 µm sieves to obtain fine flour.

2.5 Preparation of composite flours from cassava or maize and oil palm heart blends

For composite flours preparation, cassava flour or yellow maize flour were mixed with African oil palm heart flour. The rates of African oil palm heart flour were 10 %, 20 % and 30 % (w / w) in the composite flours (Table 1).

Table 1: Type of flours and composite flours from cassava or maize and oil palm heart

		Cassava flour (%)				**Yellow maize flour (%)**			
		100	**90**	**80**	**70**	**100**	**90**	**80**	**70**
(%)	0	Cf				Mf			
	10		Cf10HP				Mf10HP		
	20			Cf20HP				Mf20HP	
	30				Cf30HP				Mf30HP

HP = heart of the oil palm
Cf = cassava flour
Cf10HP = cassava flour containing 10 % of heart of the oil palm
Cf20HP = cassava flour containing 20 % of heart of the oil palm
Cf30HP = cassava flour containing 30 % of heart of the oil palm
Mf = maize flour
Mf10HP = maize flour containing 10 % heart of the oil palm
Mf20HP = maize flour containing 20 % heart of the oil palm
Mf30HP = maize flour containing 30 % heart of the oil palm

2.6 Proximate analysis

Moisture content (on dry weigh basis) was determined on samples after oven drying at 105ºC for 24 h according the 925.10 standard of AOAC [28]. Ash content was determined by measurement of residues left after combustion in a furnace at 550 ºC for 8 h according the 920.87 standard [28]. Crude fat was determined exhaustively extracting sample of flours in a soxhlet apparatus using anhydrous hexan as solvent [29]. Nitrogen was determined by the Kjeldahl method reported by the 984.13 standard of AOAC [28] and crude protein content was subsequently calculated by multiplying the nitrogen content by a factor of 4.2. Total sugars were calculated using differential method [30].

2.7 Functional properties of samples

The apparent density (AD) of the samples was determined according to the method described by Chau and Huang [31]. A graduated cylinder (10 mL) was pre-weighed (W_0) and filled with sample for a known volume (V). Then, this specimen was re-weighed (W_1) with a scientific scale (VIC-412, ACCULAB, Heartland, USA). The apparent density was calculated by using Eq. (1):

$$AD\ (g / mL) = (W_1 - W_0) / V \qquad (1)$$

The Dispersibility (D) of the samples was determined according to the method described by Mora-Escobedo *et al*. [32]. The amount of 10 mL of distilled water was added to 1 g of sample contained in a graduated cylinder. The set up was stirred vigorously and carefully for 2 minutes and the blending volume was registered as initial (Vi). Then, the volume of the settled particles was registered when it became stable (Vs). Sample dispersibility was obtained by subtracting settled particles volume from the blending one. The difference was reported as percentage of dispersibility through Eq. (2):

$$D (\%) = [(V_i – V_s) / V] \times 100 \quad (2)$$

The wettability (W) of the samples was determined according to the method described by Onwuka [33]. To do this, 1 g of sample was added into a 25 ml graduated cylinder with a diameter of 1 cm. A finger was placed over the open end of a cylinder, it was inverted and clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. Then, the finger was removed to allow the test material to be dumped. The wettability was the time required for the sample to become completely wet.

Water and oil absorption capacities of the samples was determined according to the method described by Beuchat [34]. For this purpose, 1 g of sample (W) was mixed with 10 ml of distilled water or vegetable oil (V_0). The suspension was vortexed for 10 minutes for mi and allowed to stand for 30 minutes at room temperature (25 °C). After centrifugation (4200 rpm for 20 min), the supernatant was recovered and its volume was measured (Vs). The water absorption capacity (WAC) and the oil absorption capacity (OAC) were expressed in mL of water or oil retained per g of sample from Eq. (3):

$$WAC \text{ or } OAC (mL / g) = (V_1-V_0) / W \quad (3)$$

The method described by Robertson *et al.* [35] was used to determine the swelling capacity (SC) of the samples. The amount of 100 mg of sample (W) was wetted in 10 mL of distilled water (V_0) contained in 25 mL of graduated test tube. After 18 h time rest of the suspension at room temperature (25 °C), the final volume of the mixture was measured (Vm). The swelling capacity was calculated by using Eq. (4):

$$GC (mL / g) = (V_1 - V_0) / W \quad (4)$$

The foaming capacity (FC) of the samples was determined according to the method described by Bencini [36]. Thus, 1 g of sample was dispersed in 50 ml of distilled water to obtained initial volume (Vi). Then, the mixture was whipped vigorously with a rod for 1 min. The final volume (Vf) was measured in a graduated cylinder. The foaming capacity was calculated by using Eq. (5):

$$FC (\%) = [(V_f - V_i) / V_i] \times 100 \quad (5)$$

The minimum gelling concentration (MGC) of the flour was determined according to the method described by Chau and Cheung [37]. Suspensions of 4, 8, 12, 14, 16, 18 and 20 % of samples were prepared in distilled water. Aliquots of these suspensions (5 mL) were then transferred to test tubes (with stopper) and placed in boiling water for 1 h. After incubation, these tubes were transferred to an ice bath for 1 h and then inverted. The minimum gelling concentration was the lowest concentration of the suspension that allowed the formation of a firm gel (gel that did not sink when the tube was spilled).

2.8 Statistical Analysis

All experimental data in this study were collected in triplicates. The data analysis was done using STATISTICA version 7.1. software. Analysis of variance (ANOVA) was performed to generate treatment means and Duncan test ($P < 0.05$) values were used to separate the means.

3. Results & Discussion

3.1 Proximate composition of flour blends

Table 2 highlights the effect of cassava and oil palm heart flours mixture upon some biochemical constituents. In fact, the incorporation of 30 % of oil palm heart flour in cassava one's, increased significantly ($p < 0.05$) the total protein (from 3.5 ± 0.2 to 6.1 ± 0, 2 %) and ash contents (from 3.6 ± 0.1 to 5.5 ± 0.2 %) in the result composite flours. However, for total carbohydrates, their rates decreased significantly ($p < 0.05$) from 82.6 ± 3.1 to 77.0 ± 2.4 %.

Table 3 shows the biochemical compositions of the yellow maize flour and the composite flours resulting from the mixture of yellow maize flour and oil palm heart flour. In yellow maize flour, the rates of total carbohydrate, total protein, lipid, ash and moisture were respectively 78.9 ± 2.5, 8.4 ± 1.3, 0.9 ± 0.0, 0.5 ± 0.0 and 11.3 ± 0.7 %. However, in the composite flours containing 30 % of oil palm flour, total protein and ash contents were found to be 10.7 ± 1.0 % and 2.4 ± 0.0 % respectively. At the same level of mixture, the moisture and lipid levels were not significantly ($p > 0.05$) influenced, that of the total carbohydrates significantly ($p < 0.05$) decreased from 78.9 ± 2.5 % to 75.5 ± 1.9 %.

Table 2: Proximate composition of flours blended with cassava and oil palm heart

Cassava flour and composite flours	Biochemical parameters (%)				
	Moisture	Protein	Lipid	Ash	Total sugars
Cf	9.6 ± 1.0^a	3.5 ± 0.2^b	0.7 ± 0.1^a	3.6 ± 0.1^b	82.6 ± 3.1^a
Cf10HP	10.6 ± 0.5^a	3.8 ± 0.1^b	0.8 ± 0.1^a	3.8 ± 0.1^b	80.9 ± 2.3^b
Cf20HP	10.0 ± 0.7^a	4.9 ± 0.2^b	0.9 ± 0.1^a	4.0 ± 0.1^b	80.2 ± 2.2^b
Cf30HP	10.4 ± 0.4^a	6.1 ± 0.2^a	1.0 ± 0.1^a	5.5 ± 0.2^a	77.0 ± 2.4^c

Mean ± standard deviation and number of trials = 3

On the same column, averages with the same letters were not significantly different at $P > 0.05$ according to the Duncan test.

Table 3: Proximate composition of flours blended with yellow maize and oil palm heart

Maize flour and composite flours	Proximate composition of flours (%)				
	Moisture	Protein	Lipid	Ash	Total sugars
Mf	11.3 ± 0.7^a	8.4 ± 1.3^b	0.9 ± 0.0^a	0.5 ± 0.0^b	78.9 ± 2.5^a
Mf10HP	10.7 ± 0.5^a	8.4 ± 0.9^b	0.9 ± 0.1^a	0.5 ± 0.1^b	79.5 ± 3.2^a
Mf20HP	10.2 ± 1.1^a	8.9 ± 0.8^b	1.1 ± 0.1^a	1.8 ± 0.1^b	78.1 ± 2.2^a
Mf30HP	10.2 ± 0.9^a	10.7 ± 1.0^a	1.2 ± 0.0^a	2.4 ± 0.0^a	75.5 ± 1.9^b

Mean ± standard deviation and number of trials = 3

On the same column, averages with the same letters were not significantly different at $P > 0.05$ according to the Duncan test.

3.2 Functional properties of the samples

Table 4 showed the analytical data relating to the functional properties of standard cassava flour and composite flours. From 20 % of oil palm heart flour incorporation into cassavas, some functional properties of the mixture changed significantly ($p < 0.05$), when compared to the standard. In fact, the water absorption capacity increased by more than 0.7 mL / g and the dispersibility by more than 10.8 %. Then, the wettability time moved from 80 s to 88 s, the swelling increased by 0.2 mL / g and the minimum gelling concentration increased from 4 to 7 %. By another way, at 10 % of incorporation, the mixture showed a foaming capacity that achieved 0.4 %. In contrary, from 20 % of incorporation, significant decrease ($p < 0.05$) of the crude oil absorption capacity (from 3.0 ± 0, 1 to 2.3 ± 0.1 mL / g), the refined oil absorption capacity (from 1.1 ± 0.0 to 1.0 ± 0.1 mL / g) and the apparent density (from 1.2 ± 0.1 to 1.0 ± 0.0 mL / g) were observed.

In table 5 the functional parameters of standard maize flour and it composite flours were displayed. From the 20 % incorporation level, a significant ($p < 0.05$) increase in water absorption capacity, dispersibility, swelling capacity, foaming capacity and minimum gelling concentration was recorded in composite flours, when compared to the standard. On the other hand, a significant decrease ($p < 0.05$) of the oil absorption capacity, the wettability and the apparent density was recorded in the composite flours.

Table 4: Functional parameters of standard cassava flour and composite flours

Functional parameters	Flour and composite flours			
	Cf	Cf10HP	Cf20HP	Cf30HP
WAC (mL / g)	1.3 ± 0.0^{b}	1.4 ± 0.0^{b}	2.0 ± 0.1^{a}	2.3 ± 0.1^{a}
OAC (mL / g)	3.0 ± 0.1^{a}	2.8 ± 0.1^{a}	2.3 ± 0.1^{b}	2.1 ± 0.1^{b}
W (s)	80.0 ± 3.1^{b}	78.0 ± 2.2^{b}	88.0 ± 1.8^{a}	92.0 ± 3.1^{a}
D (%)	57.5 ± 2.1^{c}	61.9 ± 3.0^{c}	68.4 ± 2.6^{b}	76.2 ± 2.3^{a}
SC (mL / g)	0.8 ± 0.1^{b}	0.9 ± 0.1^{b}	1.0 ± 0.1^{a}	1.1 ± 0.0^{a}
Da (g / mL)	1.2 ± 0.1^{a}	1.1 ± 0.1^{ab}	1.0 ± 0.0^{bc}	0.8 ± 0.1^{c}
FC (%)	0.0 ± 0.0^{d}	0.4 ± 0.1^{c}	0.8 ± 0.0^{b}	1.8 ± 0.1^{a}
MGC (%)	4.0 ± 0.0^{c}	5.0 ± 0.0^{c}	7.0 ± 0.0^{b}	**11.0** ± 0.0^{a}

Mean ± standard deviation and number of trials = 3
On the same line, averages with identical letters were not significantly different at $P \geq 0.05$ according to the Duncan test.

Table 5: Functional Properties of maize flour and composite flours

Functional parameters	Flour and composite flour			
	Mf	Mf10HP	Mf20HP	Mf30HP
WAC (mL / g)	1.4 ± 0.0^{b}	1.4 ± 0.0^{b}	1.9 ± 0.0^{a}	2.0 ± 0.0^{a}
OAC_r (mL / g)	2.6 ± 0.0^{a}	2.5 ± 0.1^{a}	2.1 ± 0.0^{b}	1.8 ± 0.1^{c}
W (s)	123 ± 3.2^{a}	119.0 ± 2.5^{a}	111 ± 3.0^{b}	103 ± 2.1^{c}
D (%)	66 ± 1.0^{b}	69 ± 1.0^{b}	75 ± 1.1^{a}	77 ± 1.0^{a}
SC (mL / g)	6.5 ± 1.0^{c}	6.5 ± 0.4^{c}	8.0 ± 0.5^{b}	11.3 ± 0.6^{a}
Da (g / mL)	0.5 ± 0.0^{a}	0.5 ± 0.0^{a}	0.4 ± 0.0^{b}	0.2 ± 0.0^{c}
FC (%)	3.5 ± 0.1^{c}	3.6 ± 0.1^{c}	4.1 ± 0.4^{b}	4.9 ± 0.1^{a}
MGC (%)	13 ± 0.0^{b}	14 ± 0.0^{b}	16 ± 0.0^{a}	17 ± 0.0^{a}

Mean ± standard deviation and number of trials = 3
On the same line, averages with different letters were significantly ($p < 0.05$) different, according to Duncan's test.

4. Discussion

The incorporation of 30 % of oil palm heart flour into cassava and yellow maize flours increased significantly ($p < 0.05$) the protein and ash contents of these foods. In the contrary, carbohydrate content decreased and that of lipids remained constant.

The moisture content of composite flour samples in the present study ranged from 10.6 % to 10.7 %. It was closed to Onuegbu *et al.* [20] value (10.8 %) found in composite flour blended with 80 % of wheat and 20 % of maize. The levels of moisture content in the composite flours were lower than the CODEX STAN 178-1991 (Rév. 1-1995) recommended moisture level of 14.5 % for safe storage [38]. For Shahzadi *et al*. [39], microbial growth and chemical changes in flour could be prevent during storage, when the moisture was below 14 %.

The proteins content was on contrast significantly higher in composite flours, especially in Cf30HP (6.1 %) and Mf30HP (10.7 %) (Table 2 & 3). The results showed that the proteins content increases significantly ($p < 0.05$) in composite flours blended with 30 % of oil palm heart flour. In fact, oil palm heart was rich in proteins which content close to 17.1 % according to Aboa [40]. So, adding oil palm heart flour to cassava or maize contributes strongly to increase protein content in the final flour. In this way, Fosto *et al*. [41] and Tharise *et al*. [42] reported an increase in protein content of composite flours blended with maize and 15 to 25 % of soybeans or 20 % of quinoa. This improvement of protein content in the composite flours could help to overcome the protein calorie malnutrition problem occurred in low income populations [43].

The ash content of the composite flours increased with increasing substitution with oil palm heart flour. The increase could be due to the fact that oil palm heart have high mineral content [13]. Composite flours Cf30HP and Mf30HP with 30 % oil palm heart flour substitution had the highest ash content. The ash content of Mf30HP (2.4 %) was similar to composite flours blended with 50 % cocoyam / 20 % wheat / 30 % soybean (2.6 %) and 50 % cassava / 20 % wheat / 30 % soybean (2.5 %) reported by Liymo *et al*. [44]. While, the ash content of Cf30HP (4.0 %) was high than that found in the composite flour produced from maize-soy flour (2.9 %) and in the malted sorghum-soy flour with 30 % soy flour substitution (2.6 %), reported respectively by Bolarinwa *et al*. [45] and Edema *et al*. [46]. The increasing of ash content in our composite flours will aid in the metabolism of other compounds, nutritionally [47].

Total sugars decreased when the proportion of the oil palm flour increased in the blends. These results may be attributed to the lower sugars content of oil palm heart than cassava and maize flours. Fosto *et al*. [41] observed such a decrease of sugars content in the composite foods based on maize, cassava and yam with soy substitution ratio of 25, 15 and 25 % respectively. Also, Al Shehry [25] reported the same results when blending 25 % of quinoa and 75 % of maize flours. The low total sugars contents of the cassava and maize blended with 30 % of oil palm heart indicated that products from these composite flours will be acceptable to patient with diabetics and other related health problems (Bolarinwa *et al*. [45].

In this study, lipids content of composite flours did not change significantly ($p > 0.05$) when increasing oil palm heart flour in the mixtures. Meanwhile, Fosto *et al*. [41] and Al Shehry [25] observed an increasing of lipids content when soy or quinoa flours ratio increased in their composite flours based on cassava and maize flours**.** For these authors, the increasing of lipids content in the composite flours were due to the soybean and quinoa flours highest lipids content compared to cassava and maize flours. In this study, the composite flours which lipids content exhibited week value may be commended in foods baking for hypolipedemic diets.

The mixture of the oil palm heart flour and cassavas or yellow maize flour influenced significantly ($p < 0.05$) the functional parameters of an issue composite flours. On the one hand, from 20 % of oil palm heart flour blended with cassava or maize flour, the water absorption capacity, the dispersibility, the wettability, the swelling and the minimum gelling concentration of the composite flour increased, when compared to the standards. In addition, the composite flours have acquired foaming capacity that was less in standard flours. Such an improvement in the functional properties of these composite flours could make it's used in food industries. Indeed, according to Farooq and Boye [48], among The main functional properties sought in food industries, hydration parameters, gelling and foaming capacities were found to be very important.

5. Conclusion

The results in this study showed that oil palm heart flour had varying effects on the biochemical and functional characteristics of composite flours. Compared with the cassava and maize standard flours, the composite flours that contained 30 % of oil palm flour had their protein and ash content improved, when carbohydrate content decreased and lipid content did not change. Concerning functional properties, it from 20 % of oil palm flour incorporated that hydration parameters and foam capacity of composite flours increased. Meanwhile, oil absorption capacity and apparent density decreased in composite flours compared with cassava and maize standard flours. Because of its ability to improve other foods nutritional quality, the oil palm heart flour could be commended to the detriment of import nutrient sources, in the setting of composite flour for baking trails.

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