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Development of a Process for Formulating Infant Flours from the Almonds of *Treculia obovoidea*, *Terminalia catappa* Linne as well as *Ipomoea batatas* Lam Leaves

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Abstract

In response to the malnutrition problem affecting children in Congo Brazzaville, we made three cooking-type infant flours from *Treculia obovoidea*, *Terminalia catappa* L. almonds and *Ipomoea batatas* L. leaves. The nutritional quality of the three infant flours we developed indicates 11.07% - 12.47% protein content, 9.92% - 14.87% fat content, 58.85% - 68.06% carbohydrate content, 1.50% - 2.18% ash and an energy intake varying between 399.84 and 439.37 Kcal. Functionally, our prepared flours have a water absorption capacity between 219.05 and 317.86 mL/g, an oil absorption capacity of 0.19 mL/g, a water solubility index varying from 29.66 - 41.03 and a swelling capacity of 250% - 320%.

Keywords

Process, Formulation, Infant Flours, *Terminalia catappa* Linne and *Treculia obovoidea* Almonds, *Ipomoea batatas* Lam Leaves

1. Introduction

Nutrition intake during the first 1000 days of a child's life is critical for long-term physical and mental development [1]. From the age of 6 months, breast milk becomes qualitatively and quantitatively insufficient for the infant whose nutritional needs are increasing [2]. It is therefore necessary to introduce into the diet of young children, food supplements in liquid or semi-solid form to boost the intake of breast milk [3]. These food supplements must therefore provide the major nutrients in balanced proportions: proteins, lipids and carbohydrates [4] [5] [6]. The months of complementary feeding constitute a period of high risk of nutritional deficiency, due to the change in the feeding of the infant accustomed to taking exclusively breast milk [2].

Micronutrient deficiencies and malnutrition are prevalent in many developing countries [7]. Childhood malnutrition is one of the main causes of public health and social welfare problems in these countries. In Africa, more and more scientific work is interested in the formulation of local infant flours that comply with international recommendations [8]-[13]. Indeed, an inadequate diet is a public health problem. Brown *et al.* [14] have shown that nutritional deficiencies are particularly severe in children aged 6 to 24 months, when their nutritional needs exceed what they can get from breast milk or traditional family meals.

Thus, supplementing the child's diet with products rich in nutrients is essential. In the Congo, complementary foods accessible to all are, for the most part, prepared from simple or compound flour from cereals and tubers, which are rich in carbohydrates and low in proteins. These are unable to meet all the nutritional needs of a child and cause problems of malnutrition and nutritional deficiencies.

However, the majority of weaning foods of high nutritional quality, in particular commercially approved infant flours available on the Congolese market are imported and sold at prices inaccessible to all social strata as specified by Kafuti *et al.* [15]. In addition, the Congo has a significant diversity of non-timber forest food products which are sometimes poorly exploited [16]. Many of these food products contribute significantly to the balanced food rations of rural and urban populations [17]. Various edible parts (fruits, seeds and leaves, etc.) of these plants are used directly or after processing. It is with this in mind that we took an interest in local products: *Treculia obovoidea*, *Terminalia catappa* Linne and *Ipomoea batatas* Lam. So, in a socio-technological context, is it not appropriate to produce infant flours of good nutritional quality and at an affordable price based on local products that are easily accessible and available in the Congo?

In addition, this study will make it possible to develop underestimated natural resources in order to manufacture products with high added value. It is in this sense that we set out to develop an infant flour, in particular from *Tréculia obovoïdea* and *Terminalia catappa* (L.) almonds mixed with the leaves of *Ipomoea batatas* (L.).

This study will also aim to provide households with infant flours obtained from local raw materials with nutrient and energy contents in accordance with recommended standards.

2. Materials and Methods

2.1. Equipment

2.1.1. Vegetable Matter

The vegetable raw materials that were the subject of our study are:

- *Treculia obovoïdea* almonds (**Figure 1(a)**) from the locality of Mayombe in the south-west of the Congo;
- almonds extracted from *Terminalia catappa* Linne (**Figure 1(b)**). These fruits are collected at the foot of the trees in two (02) locations in downtown Brazzaville, namely: the square of Marien NGOUABI and avenue Emile Biayenda. These locations were chosen because of the abundance of this species and;
- finally, the leaves of the sweet potato (*Ipomoea batatas* Lam) (**Figure 1(c)**) were bought at the Madibou market in the southwest of Brazzaville.

2.2. Methods

In this part of the study, we discussed on the one hand the manufacture of flour from three elements: almonds of *Tréculia obovoidea*, almonds of *Terminalia catappa* L. and leaves of *Ipomoea batatas* L. and on the other hand, the formulation of infant meals. Then, we determined the physico-chemical composition of the raw materials as well as those of the composite flours.

2.2.1. Preparation of Raw Materials

Preparation of almond flour *Treculia obovoidea*

A good quantity of *Treculia obovoidea* fruit was sorted to remove stones, foreign material, insects and damaged fruit. After washing by immersion in water, the fruits are cut to extract the almonds which are dried in a solar dryer (35˚C) for 72 hours. The dried almonds were then finely ground using a domestic electric grinder (VORWERK brand, France); then a fine flour is obtained after sieving (250 microns).

Preparation of *Terminalia catappa* almond flour

As with the fruits of *Treculia obovoidea*, the almonds of *Terminalia catappa* were first sorted, washed, crushed to extract the almonds which are dried in a solar dryer (35˚C) for 72 hours. After manual skinning, the almonds were then

(a) (b) (c)

Figure 1. Tree and fruits *Treculia obovoidea* (a); Fruits *Terminalia catappa* L. (b) and Leaves of *Ipomoea batatas* L. (c).

under the same conditions as the dry almonds of *Treculia obovoidea*, crushed and sieved to obtain a fine powder.

Preparation of flour from *Ipomoea batatas* leaves

The leaves of Ipomoea batatas are first sorted, sliced and blanched in hot water at 90˚C for 15 minutes.

The leaves are then passed through a colander to get rid of excess water and then dried in a solar dryer (35˚C) for 48 hours before being finely crushed and sieved in like the other two raw materials.

All the flours obtained were packed in polythene bags and kept in a freezer for later use.

2.2.2. Preparation of Porridge Formulas

Formulating infant flour consists of determining the proportions in which the raw materials must be mixed to meet the established nutritional needs. Thus, the formulation technique of these weaning flours is carried out using a formulation system assisted by Excel software, using a calculation system based on the matrix formulation method. The formulation of infant flours was based on nutritional complementarity between the raw materials. This complementarity allowed us to test the technological suitability of the different flours obtained.

The use of this method makes it possible to establish, on the one hand, from a list of available products the formula of a flour that meets the recommendations relating to the nutrient content (carbohydrates, proteins and lipids) [18]; and on the other hand to minimize the cost price of raw materials.

Eight (08) types of flour, on the basis of a mass of 75 g of dry matter were formulated from mixtures of various proportions of individual flours of *Treculia obovoidea* almonds, *Terminalia catappa* L. almonds and *Ipomoea batatas* L. leaves.

Table 1 shows the different proportions of ingredients that go into the compositions of flours F1 to F8.

Table 1. Formulations of infant flours.

Formulation	Flour incorporation rate (%)		
	T.o flour	T.c.l flour	I.b.l flour
F_1	80	20	-
F_2	65	-	35
F_3	70	15	15
F_4	65	10	25
F_5	80	12	8
F_6	68	22	10
F_7	60	12	28
F_8	50	8	42

Legend: T.o: *Tréculia obovoïdea*; T.c.l: *Terminalia catappa* L.; I.b.l: *Ipomoea batatas* L.

2.2.3. Physicochemical Composition of Flours

1) Chemical composition of the dried flour formulas

Calculating humidity: Two (02) grams of test sample in a crucible were dried in an oven at 105˚C for 24 hours. The crucible, cooled in a desiccator, was weighed and returned to the oven for 1 hour. These drying, cooling and weighing operations were repeated until a constant mass was obtained according to the AOAC standard method [19].

Calculating ash content: A test portion of 2 g of the sample in a crucible was incinerated at 550˚C for 8 hours according to the AOAC standard method [20]. The ash represented the mass obtained after cooling.

Protein dosage: The Kjeldahl method according to AOAC [19] was used for protein amount.

A test portion of 0.2 g of flour added with 10 mL of concentrated sulfuric acid and catalysts (3.5 g of K_2SO_4 and 0.4 g of $CuSO_4$) was mineralized at 420˚C for 2 hours. The mineralized product diluted with 20 mL of distilled water and approximately 30 mL of 400 g/L caustic soda. Steam stripping is carried out in a 250 mL Erlenmeyer flask containing 20 mL of boric acid at 20 g/L and a few drops of colored indicator (mixture of equal volumes of 0.066% methyl red and bromocresol green at 0.033% in ethyl alcohol). 0.1 N sulfuric acid was used to titrate the distillate. A blank was carried out by performing the same procedure without taking the test. Each sample was assayed in triplicate.

The protein content (TP) was determined by formulas (1 and 2).

$$\%\text{Azote}(\%\text{N}) = \frac{V_{\text{H}_2\text{SO}_4} \times 0.07}{M_{ech}} \quad (1)$$

$V(H_2SO_4)$: volume in mL of titrating sulfuric acid.

M_{ech}: mass in grams of the sample.

Then to determine the protein content, we perform the following calculation:

$$\%\text{Proteines} = \%\text{N} \times 6.25 \quad (2)$$

with 6.25 the protein conversion factor.

Determination of lipid content: A mass of 5 g of each sample of infant flour was weighed and placed in an extraction cartridge where the lipids were extracted at boiling using petroleum ether according to the Soxhlet method (AOAC [21]) for 6 h. The measurement is carried out by gravimetry after evaporation of the solvent.

Determination of the total carbohydrate content:

The carbohydrate content (in % of dry matter) was estimated by differential calculation [22] according to the following formula:

$$\text{Taux de glucides}(\%) = 100 - \left[\text{P}(\%) + \text{L}(\%) + \text{Te}(\%) + \text{C}(\%)\right] \quad (3)$$

2.2.4. Energy Intake

To determine this value, we calculated the sum of the products of the major constituents (carbohydrates, proteins, lipids) with their thermal coefficients of Atwater [23] [24] according to formula (3):

$$\text{Valeur energetique}\left(\text{Kcal/100 g}\right) = \left[\left(\%\text{Glucides}\times 4\right)+\left(\%\text{Proteines}\times 4\right)+\left(\%\text{Lipides}\times 9\right)\right] \quad (4)$$

2.2.5. Functional Analyses

On the flours produced, we determined the water absorption capacity, the water solubility index, the oil absorption capacity and the swelling capacity.

1) Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI were determined as described by [25]. One gram of dried instant slurry samples was suspended in 10 ml of distilled water at room temperature for 30 minutes, stirred gently during this time and then centrifuged at 3000 rpm for 15 minutes. The supernatant liquid was carefully poured into an evaporator dish of known weight and dried at 110˚C to constant weight. The weight of the remaining gel was taken as WAI.

$$\text{WAI g/g} = \frac{\text{weight of remaining gel}}{\text{Weight of dry porridge sample}} \quad (5)$$

The quantity of dried solids, recovered by evaporation of the supernatant and expressed as a percentage of dry solids was taken as WSI:

$$\text{WSI \%} = \frac{\text{weight of dried solid in supernatan}}{\text{Weight of dry porridge sample}}\times 100 \quad (6)$$

2) Fill power (SP)

SP determined with the method described by [26]. One gram of dried instant slurry samples was mixed with 10 mL of distilled water in a centrifuge tube of known weight and heated at 90˚C for 30 minutes. This was continuously shaken during the heating period. After heating, the suspension was centrifuged at 1000 rpm for 15 min. The supernatant was decanted and the weight of the slurry collected. The swelling power was calculated as follows:

$$\text{SP g/g} = \frac{\text{weight of the swollen porridge sample}}{\text{weight of dry porridge sample}} \quad (7)$$

2.2.6. Statistical Analyses

The data were entered on the Excel 2007 software. Each sample was analyzed in six (06) tests for the biochemical parameters and in triplicate for the rest of the measurements. The calculation of the mean and standard deviations of the various physicochemical and functional parameters were carried out respectively with the "mean" and "standard deviation" functions of the Excel 2007 software. Multiple range tests at ($P \le 0.05$) were performed to compare mean values.

3. Results and Discussion

3.1. Chemical Composition of Instant Dried Porridge Formulas

The results obtained at the end of the biochemical analyzes of the flours entering into the composition of the formulas of the compound infant flours, are collated in Table 2. This table shows an important differentiation where the contents of proteins, lipids, ash, humidity and carbohydrates vary from 7.81% to 24.1%,

Table 2. Biochemical composition of the local plants used.

Composition (% MS)	Almonds from Treculia o.	Terminalia almonds c.L.	Leaves of *Ipomoea batatas* L.
Moisture	6.09 ± 4.13	4.3 ± 0.2	65.48 ± 1.55
Ashes	1.02 ± 0.24	3.4 ± 0.26	7.35 ± 0.13
Total lipids	3.86 ± 1.78	52.8 ± 0.56	6.26 ± 0.84
Protein	7.81 ± 0.59	24.1 ± 0.35	18.58 ± 0.98
Total carbohydrates	81.22 ± 2.03	15.4 ± 0.75	2.33 ± 0.51

The values are the means ± the standard deviations of six measurements (n = 6).

from 3.86% to 52.8%, from 1.02% to 7.35%, from 4.3% to 65.48% and from 2.33% to 81.22% respectively.

The results showed that the almond meal of *Treculia obovoidea* and *Terminalia catappa* L. gave low mean values of 6.09% and 4.3% respectively. This last value is very close to that obtained by [27]. On the other hand, the humidity of the leaves of *Ipomoea batatas* Lam is very high and relates to 65.48%.

This high water content is a limiting factor in the preservation of a product. Indeed, it exposes these sheets to various alterations and gives them a short lifespan.

Ash is the residue from the incineration of flour. Their content is a means of assessing the purity of the flour. They also define the commercial types of flour. The ash content of the kernels of *Treculia obovoidea* is 1.02%. That of *Terminalia catappa* L. almonds is 3.4%. This value is greater than those found by [27] [28]. The leaves of *Ipomoea batatas* Lam, on the other hand, have an ash content of around 7.35%. Indeed, this high value shows that these leaves are richer in minerals than the almonds studied.

As for the fats, their extraction reveals a low content for the almonds of *Treculia obovoidea* and the leaves of *Ipomoea batatas* L. corresponding respectively to 3.86% and 6.26%. On the other hand, the lipid content of *Terminalia catappa* L. almonds is very high and represents nearly 52.8%. This value is close to that obtained by [28]. In addition, *Terminalia catappa* L. almonds draw our attention to the need for good storage. If so, rapid lipolysis to free fatty acids would occur and thus lead to short-term damage. In addition, the deep grinding promotes intimate contact between lipolytic enzymes and fats.

In the light of the results grouped in **Table 2**, we note that the almonds of *Treculia obovoïdea* have 7.81% protein content; and the almonds of *Terminalia catappa* L. have 24.1%. This content is lower than that found by Ndebolo [27] but higher than that obtained by Massamba [28]. That of the leaves of *Ipomoea batatas* L. is at 18.58%. It appears from the literature, that the almonds of *Terminalia catappa* L. and the leaves of *Ipomoea batatas* L. have a good nutritional quality; because they are quite rich in proteins, vitamins and certain minerals. They also contain in quantity amino acids and essential fatty acids.

The almonds of *Treculia obovoïdea* are very rich in total sugars because their content is 81.22% compared to that obtained for the almonds of *Terminalia catappa* L. where it is around 15.4%. This result is not far from that obtained by Ndebolo [27] *i.e.* 13.73%. Finally, the leaves of *Ipomoea batatas* L. contain very few total sugars where the content is of the order of 2.33%.

3.2. Biochemical Quality of Formulated Infant Flours

The use of the matrix method made it possible to generate infant formulas with the chemical compositions presented in **Table 3**.

The analysis of these formulas reveals similar macronutrient compositions although we can sometimes notice significant differences.

The formulations adopted (flour 1, 5 and 6) have an average water content which varies between 10.05% and 11.93%. The highest water content is that of flour 6. The values obtained do not comply with the standard composition of an infant flour which requires 5%. This high water content is the limiting factor in the preservation of flours. These high values would promote the proliferation of microorganisms capable, using enzymes such as amylases, of hydrolyzing starch and thus facilitating the acidification of the flour. And this is surely the reason why artisanal flours have a shorter shelf life than instant or industrial flours.

The various analyses of the infant flours produced reveal a variation in ash content of 1.50% to 3.87%. These values, which are lower for F1 and F5 flours, whose average contents, respectively 1.50% and 1.81%, are lower than that of a standard infant flour (2%) proposed by Sanogo *et al.* [29] cited by Nago, 2012 [30]; Sanogo *et al.* [29]). These values, although slightly below the standard value for infant flour, do not show a significant difference. On the other hand, the flours (2, 3, 4, 6, 7 and 8) have average ash contents higher than the reference set by Sanogo *et al.* [29]. The increased ash content of improved flours is due to the higher incorporation rates in *I. batatas* L. compared to other flours. Indeed, these high ash contents show that the infant flours produced contain significant amounts of minerals. These high contents also define the commercial types of

Table 3. Biochemical composition of formulated infant flours.

Formulations	Moisture (% MS)	Ashes (% MS)	Protein (% MS)	Lipids (% MS)	Total carbohydrates (% MS)	A.E (Kcal)
Flour 1	10.05	1.50	11.07	13.65	68.06	439.37
Flour 2	10.50	3.2	11.58	4.70	53.61	303.8
Flour 3	10.82	2.33	11.87	11.56	59.51	389.56
Flour 4	10.35	2.84	12.13	9.35	54.92	352.35
Flour 5	10.72	1.81	10.63	9.92	67.01	399.84
Flour 6	11.93	2.18	12.47	14.87	58.85	419.11
Flour 7	10.22	3.08	12.78	10.40	51.23	349.64
Flour 8	10.48	3.87	13.64	8.78	42.82	304.86
WHO standard	<12	2	11 - 12	7 - 8	60 - 70	400

flour [31] [32]. Thus, as the ash content of our processed flours is greater than 1.4%; we can classify them in the category of whole type flours (T 150) and can also be used in the manufacture of whole breads.

The protein contents of the processed flours vary on average from 10.63% to 13.64%. Thus, the incorporation of *T. catappa* L. flour and *I. batatas L* flour, known for their high protein content, was of considerable importance on the nutritional quality of the final flours. The results reported in **Table 3**, allow us to note that the majority of the formulated flours comply with the WHO criteria with the exception of flour 5 whose protein content (10.63%) is below that recommended. Compared to these results, we can say that the flours studied have acceptable protein contents and can be qualified as infant flours of good nutritional quality. In fact, four of the different flours produced (flours 4, 6, 7 and 8) comply with or are close to the value recommended by Trèche *et al.* [5] or 13%. On the other hand, three flours (1, 2, and 3) have protein contents that approach this recommendation. Then the rest of the formulas have lower contents, the difference ($P > 1\%$) of which is significant.

Fat remains an important factor in the spoilage of flour. Uncontrolled storage can generate a series of physico-chemical transformations that can affect the nutritional and organoleptic value of flours and their derived products [33]. The flours studied have lipid contents of between 4.70% and 14.87% depending on the rate of incorporation in flour of *T. catappa* L. or *I. batatas* L. Thus, the higher the rate of incorporation in flour *T. catappa* L. is high, the more the fat content increases in the final flours. We note that the flours F4, F5 and F8 having a very low rate of *T. catappa* L. flour have respective contents of: 9.35%; 9.92% and 8.78%. These contents are generally close to that of standard flour (7%) estimated by Sanogo *et al.* [29]. Indeed, these same formulas are closer to the regulatory criteria set by the WHO. Flour 2 contains less fat, *i.e.* 4.70%, which is lower than the WHO standard and not recommended for infants (especially malnourished) because it does not cover the nutritional needs of the latter. Furthermore, formulations 1, 3, 6 and 7 are very rich in lipids, ie 13.65% respectively; 11.56%, 14.87% and 10.40%. Although very energetic for infants, these high lipid contents could expose these different flours to rapid deterioration, reducing the shelf life but also deteriorating the nutritional and organoleptic quality.

Total carbohydrates, composed mainly of starch, are the most important chemical components in flours. We notice that the average total sugars contents differ from each other. Statistically, this difference was found to be significant ($p < 0.05$). The WHO recommendation for infant flours is 60% - 70%, while that for standard flour is 68% [29]. The contents found in flours 2, 4, 7 and 8 submitted to our analysis do not comply with this reference (53.61%; 54.92%, 51.23% and 42.82% respectively); except those of F1 (68.06%) and F5 (67.01%) flours, which have carbohydrate contents approaching the standard composition of infant flour [5]. In addition, only flours 3 and 6 have carbohydrate values that comply with the guidelines given by the WHO for infant flours. In addition, the carbohydrate intake of flours mainly plays an energy role. Carbohydrates are therefore a rapidly usable source of energy by the body and are involved in the anabolism of proteins. Some carbohydrates have a role called "constitution", they are part of the composition of fundamental tissues of the body: cartilage, nucleic acids, mucus, antigenic substances [10].

The energy contributions of improved flours vary between 303.8 to 439.37 kcal/100g. The highest calorific values correspond to flours 1 and 6. These flours have all the more energy due to the fact that *Terminalia catappa* L. has been incorporated at a rate greater than 10%, thus showing that it is a rich source of lipids. Flours 3 and 5 have an energy intake very close to the WHO recommendations of 400 kcal/100g for weaning flours. In addition, the energy intake of these flours (3 and 5) is also close to the standard calorific value (387 kcal/100g) of infant flour according to [34].

Indeed, taking into account the lower energy values, flours 2, 4, 7 and 8 cannot therefore be retained as a weaning food for the child. However, out of the eight (08) flours improved according to the matrix plan, we have chosen three formulations because of their nutritional richness which approaches the O.M.S standard or the standard composition of infant flours. These are: flour 1, 5 and 6. Flour 1 could be a staple food for the child because of its high energy value (439.37 kcal/100g). Fasonorm [35] recommends that weaning foods be high in energy. This recommendation is important because the low energy density of some porridge tends to limit the total amount of energy consumed necessary for the proper functioning of the body of the young child as well as the use of other essential nutrients. Given the small size of their stomachs (30 to 40 g/kg) of body weight (150 to 200 mL), children need high-energy foods to meet their energy needs [36]. According to [37], the daily energy requirements for an infant of the second age (06 - 12 months) amount to 950 Kcal; to cover them, the latter should consume an average of 235.61 g of infant flours per day, which is difficult knowing that this amount of flour could lead to the preparation of 1 liter of porridge hence the importance of enriching weaning foods.

3.3. Functional Quality of Formulations

The analysis of the functional quality of the infant flours studied made it possible to determine the Water Absorption Capacity (CAE), the Water Solubility Index (ISE), the Swelling Capacity (CG) and the Capacity Oil Absorption (ACH). The results obtained are presented in **Table 4**.

The CAE measures the volume occupied by starch after swelling in excess

Table 4. Functional composition of the infant flours produced.

Formulations	Water absorption capacity (mL/100g)	Water solubility index	Oil absorption capacity (mL/g)	Swelling capacity (%)
Flour 1	219.05 ± 18.28	29.66 ± 7.98	0.19 ± 0.02	311.25 ± 34.25
Flour 2	276.28 ± 23.57	41.03 ± 10.76	0.19 ± 0.01	320 ± 35.59
Flour 3	317.86 ± 27.04	38.23 ± 9.48	0.19 ± 0.02	250 ± 0.01

water and indicates the integrity of the starch in aqueous dispersion. Formulated infant flours have a water absorption capacity of between 219.05 and 317.86 mL/100g of flour. However, flour 6 has the highest CAE (317.86 mL/100g flour) and flour 1 has the lowest CAE (219.05 mL/100g flour). We also notice that the more the *T. obovoidea* incorporation rate increases, the more the CAE increases in our formulated flours. Water Absorbency Capacity (ACE) is a useful indicator to determine because it allows us to know whether flours can be incorporated into aqueous food formulations [38].

The Water Solubility Index of the three formulations ranges from 29.66 to 41.03. It is higher in flours 5 and 6, *i.e.* 41.03 and 38.23. This index gives a flour the affinity to disperse in water and gives a homogeneous solution.

The Oil Absorbency Capacity of our three formulations is 0.19 mL/g of flour. The values obtained are very low, this could be explained by the size of the particles of the flour. Indeed, the oil absorption capacity is of capital importance since it allows retaining the flavor of food [39].

Our formulations have a significantly different swelling capacity ranging from 250% to 320%.

4. Conclusion

This study consisted of exploring another way of using *Treculia obovoidea* and *Terminalia catappa* L. almonds, as well as the leaves of *Ipomoea batatas* L. for making infant flour. It was therefore important to note the characterization of these almonds and leaves. The first results found show to what extent the almonds of *Treculia obovoidea* are very rich in carbohydrates, those of *Terminalia catappa* L. in lipids and proteins; and that the leaves of *Ipomoea batatas* L. are rich in protein and minerals. In addition, these almonds and pulses have been transformed into powders and mixed in order to have infant flours. By varying the rates of incorporation, three formulations (1.5 and 6) were selected due to their nutritional balance, but above all taking into account the energy value. The biochemical study revealed a protein level (11.07% and 12.47%) in accordance with the O.M.S standard for formulations 1 and 6; as well as a carbohydrate level of formulations 1 and 5 being at 68.06% and 67.01% respectively. In addition, these formulations have lipid content above the WHO standard. This reinforces the energy capacity of our studied infant flours. However, these lipid contents could be a limiting factor to the phenomenon of flour rancidity. We note that these formulations could be a source of minerals given their ash content. Fitness for service reveals that all three formulations have low flavor retention capacity and that these can be mixed into aqueous solutions such as porridge. In addition, these formulations have a high swelling capacity.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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