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Functional Properties and *in vitro* Digestibility of Cashew Nut Flour

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Abstract We investigated the physicochemical, functional properties and *in vitro* digestibility of cashew kernel-based flour. Study was conducted on kernels of cashew nuts harvested from fields. Technological treatments have been applied to these kernels: cooking (100°C/30 min), roasting (120°C/20 min). Flours obtained after kernel grinding namely, FTA, FAC, FRA and FIA have been used for physicochemical, functional properties and digestibility analysis. Results showed that technological treatments had a significant influence on studied parameters. Protein contents of FTA (20.42 ± 0.50 %) and FAC (19.23 ± 0.02 %) are lower than those of FRA (21.85 ± 0.04 %). Total carbohydrate content showed the same trends. In addition, FAC showed the lowest lipid content. We established the decrease of sodium and zinc content in treated flour compared to raw flour: FTA (1.09 ± 0.23 % vs 1.20 ± 0.34 %), FAC (0.87 ± 0.12 % vs 1.20 ± 0.34 %), FIA (1.02 ± 0.30 % vs 1.20 ± 0.34 %) for sodium and FTA (0.80 ± 0.11 % vs 0.85 ± 0.08 %), FAC (0.50 ± 0.08 % vs 0.85 ± 0.08 %), FIA (0.49 ± 0.07 % vs 0.85 ± 0.08 %) for zinc. Functional properties showed a significant decrease of oil absorption capacity and water solubility index. In addition, total carbohydrate content showed the same trends. Digestibility results have shown that FAC has the lowest hydrolysis percentage than FTA, FRA and FIA. The study shows that different cashew flours obtained are the real sources of energy and are very digestible. These flours can be use for supplemented cereal flour.

Keywords: *cashew nut- flours- biochemical parameters- cooking- in vitro digestibility*

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1. Introduction

Cashew tree (*Anacardium occidentale L.*) is a tree native to northeastern Brazil. Portuguese introduced it in other parts of world in 1578. After the war, in 1945, global cashew production and consumption increased sharply as cashew quickly became the leading dessert nuts in the world. Indeed, global production estimated at 3953212 tons in 2010 increased by over 86% to 4552315 tons in 2012 [1,2]. Cashew appears today in Africa as a strategic culture generating significant income. Indeed, it has been experiencing strong production growth since early 2000s (almost 10% per year on average). In Côte d'Ivoire, cashew trees were introduced for ecosystem enhancement and protection. It was a response to the severe land degradation due to deforestation. Indeed, these trees allow erosion control in cropping spaces. Moreover, its bark and leaves have many medicinal properties. Rising prices of cashew kernels on the international market in 1990 will make this crop a major source of income for Ivoirian farmers. It appears today, besides cotton and livestock, as a lever for local development savannah areas (North and Centre of the country) [3]. In addition, Ivorian production of raw nuts increased from 330000 tons in 2008 to 380000 tons in 2010 and 450000 tons in 2012 [1,2]. Due to exponential growth in production of cashew nuts, Côte d'Ivoire ranks as 2nd largest world producer after India.

Although Côte d'Ivoire became first largest world producer of cashew as cash crop, she's loses added value by exporting almost all of its production to Asian countries. Côte d'Ivoire processes only 5 percent of its production. Ivoirians do not really consume these nuts compared with other produce such as coffee, cocoa and groundnuts for several reasons: for some Ivoirians, nutritional value is poorly known. In addition, the shell liquid is very corrosive. Côte d'Ivoire is facing an outbreak of chronic diseases such as diabetes, cancer and cardiovascular diseases whose these treatment led an economic problem for population. However, according to [4] cashew nuts intake reduces the risk of cardiovascular disease, type 2 diabetes, and colon cancer in women. Similarly, [5,6,7] have shown that a high intake of cashew kernels reduces the risks of cerebrovascular diseases (CVD). In addition, [8] in Brazil have shown that cashew kernels are a major source of fat, protein and fiber. In 2008, a survey undertaken by National program on Nutrition and Health (PNNS) revealed an overall prevalence of chronic malnutrition of 30.6 percent in north of Côte d'Ivoire and 15.2 percent in Abidjan. In response to this food crisis, cashew kernels could be used in food formulation. Indeed, in Malaysia, [9] were studied the rheological properties, sensory properties and oxidative stability of cashew kernel spread. The overall objective of this study was to estimate the impact of technological treatments on physicochemical, functional properties and to assess in vitro digestibility of cashew flour.

2. Material and Methods

2.1. Source of Raw Materials and Experimental Design

Experiments were carried out on cashew nut varieties (*Anacardium Occidentale L.*) harvested in Côte d'Ivoire. Cashew fruits (apple and nuts) were picked in fields of local growers from April to June. Then the nuts are separated by a hand twist and sun-dried for 3 to 4 days in a ventilated area. These dried nuts are stored in bags and transported to the laboratory for various analyses.

2.2. Pretreatments

In order to extract almond, cashew nuts are soaked in water for 24 hours. These moistened nuts are dried for two days in the university nutrition laboratory. Dried nuts are then pound manually to recover all kernels and eliminate all traces of debris. Tesla is removed and kernels are washed and stove dried (MMM MED CENTER) at 47°C for 48 hours. They are used for making flour (FRA, FAC and FTA).

2.3. Preparation of Flour Samples

2.3.1. Flour of Cashew Nuts from Dried Almonds

Dried almonds (400g) are directly crushed using a grinder (Bomino, ItalyBI-243). The flour obtained is preserved in jars hermetically closed and named FRA (flour of raw almond).

2.3.2. Flour of Cashew Nuts from Boiled Almonds

Dried almonds (400g) are cooked to boiling in a pan containing 0.5 l of water for 30 minutes. After cooking, almonds are left to drain and then dried in a ventilated oven (MMM MED CENTER) at 47°C for 48 hours and grinded with a grinder. Flour obtained is stored in sealed jars and named FAC (flour of almond cooked at water).

2.3.3. Flour of Cashew Nut from Torrefied Almonds

Dried almonds (400g) are torrefied in a pan at 120°C for 20 minutes. These roasted almonds are cooled at room temperature for 4 hours and are subsequently grinded. Flour obtained is stored in sealed jars and named FTA (flour of torrefied almonds).

2.3.4. Flour of Cashew Nut from Industrial Almonds

Industrial almonds (400g) are purchased in a supermarket in Abidjan and grinded directly. The flour obtained is stored in sealed jars and named FIA (flour of industrial almond).

2.4. Centesimal Composition

Centesimal composition was made on four flour samples (FRA, FAC, FTA and FIA) previously prepared.

• Moisture content: Moisture was determined by drying the sample at 105°C for 24 h according to [10]. Samples were then cooled in desiccators and weighed. The loss of weight was expressed as a percentage of the initial weights of the samples give their moisture content.

• Ash content: Ash was obtained according to [10]. A 5 g sample was weighed into a previously dried and weighed porcelain crucible. The crucible with its content was placed in a furnace at 550°C for 6 h. After cooling in desiccators, the crucible with its content was weighed. The weight of the ash was expressed as a percentage of the initial weight of the sample.

• Cellulose content: The cellulose content was obtained according to [11] method. Duplicate (3.0 g) of sample was heated at boiling with sulfuric acid solutions (0.28 N) and potasium hydroxide (0.5N) in a ratio (1/1: v/v) for 30 min. After heating, the mixture was filtered through filter paper, washed, dried and weighed. The pellet was then calcined at 900°C for 30 min. Weight loss resulting from ashing of the crude cellulose was noted.

• Protein content: Protein was determined by determination of total nitrogen according to the Kjeldahl method [11]. The principle: under the action of NAOH and after sulfuric mineralization in the presence of catalyst ($CuSO4$), ammoniac formed was neutralized. The ammonia in the sample solution was then distilled into the boric acid until it changed completely to bluish green. The distillate was then titrated with 0.1 N HCl solutions until it became colorless. The percent total nitrogen and crude protein were calculated using a conversion factor of 6.25.

• Fat content: fat was determined based on the Sohxlet extraction method of [10]. Five gram (5.0 g) of the sample was introduced into a cartridge of Whatman. An empty flask reweighed and containing 60 ml of hexane was placed on the heating block of the Soxhlet apparatus and heated at 110°C. After 6 hours of extraction, the flask was removed from apparatus and then the solvent was evaporated on a Rotary Evaporator. The flask containing the fat and residual solvent was placed on a water bath to evaporate the solvent followed by a further drying in an oven at 60°C for 30 min to completely evaporate the solvent. It was then cooled in desiccators and weighed. The fat obtained was expressed as a percentage of the initial weight of the sample.

• Total carbohydrate content: Total carbohydrate content is determined by difference method [100% - (% moisture + % ash + % fat + protein %)]

• Energy content: Energy is calculated with 4 kcal / g carbohydrates, 4 kcal / g protein and 9 kcal / g lipids according to [12].

$$E = \left[\left(9x\%Fat\right) + \left(4x\%Protein\right) + \left(4x\%Carbohydrates\right) \right]$$

• Mineral content: Mineral content are determined by atomic absorption spectrophotometry. Ash (0.1g) is weighed in platinum crucibles to which was added 1 ml of distilled water. In each crucible, 5 ml of hydrofluoric acid 50% and 2 drops of sulfuric acid (v / v) were added. Whole, well homogenized and heated at 100 ° C until fully evaporated. Residue obtained was dissolved in 10 ml of 50% hydrochloric acid. Solution was left to stand for 10 minutes on the bench and the final volume was brought to 100 ml.

2.5. Functional Properties Measurement

• Water absorption capacity (WAC) and water solubility index (WSI). WAC and WSI were evaluated according to [13] and [14] methods, respectively. Sample (1 g) of flour were mixed with a 10 ml of distilled water in a centrifuge tube and shaken for 30 min in a KS10 agitator. After shaking, the mixture was centrifuged (Ditton LAB centrifuge, UK) at 4500 rpm for 10 min. The resulting sediment was weighed and then dried at 105°C to constant weight. The capacity for water absorption was expressed in grams of water per g of sample.

• Oil absorption capacity (OAC) was evaluated according to [15] methods. Sample (1 g) of flour were mixed with a 10 ml of sunflower oil in a centrifuge tube and shaken for 30 min in a KS10 agitator. The mixture was kept in a water bath (37°C) for 30 min and centrifuged (Ditton LAB centrifuge, UK) at 4500 rpm for 10 min. The resulting sediment was weighed and then dried at 105°C to constant weight. The capacity for oil absorption was expressed in grams of oil per gram of sample.

• Foam capacity (FC) and foam stability (FS) were studied by the method of [16]. Three (3.0) g of flour were transferred into clean, dry and graduated (50 ml) cylinders. The flour samples were gently levelled and the volumes noted. Distilled water (30 ml) was added to each sample; the cylinder was swirled and allowed to stand for 120 min while the change in volume was recorded every 15 min. The foaming activity is the percentage of increased volume. The stability of the foam in the graduated cylinder was recorded after 2 hours of storage.

• Emulsifying activity (EA) and emulsion stability (ES) were determined following the method of [17]. One gram (1g) of sample was mixed with 3 ml of distilled water and 3 ml of sunflower oil. The mixture was stirred for 10 min in a shaker KS10 and then centrifuged at 2500 rpm for 5 min. The height of the emulsified layer and total content of tube were measured for estimation of emulsifying activity. The emulsion stability was determined by heated at 80°C for 30 min. The solution was cooled and was centrifuged at 2500 rpm for 5 min. The height of the emulsified layer before and after heating was measured for estimation of emulsion stability.

• Hydrophilic lipophilic balance (HLB) as defined by [18] is obtained by ratio of water absorption capacity and oil absorption capacity. This ratio assesses the affinity of flour to water and oil.

2.6. *In vitro* Digestibility of Cashew Nut Flour

For studies about starch digestion of cashew nut flour, α-amylase from *Bacillus licheniformis* (E.C.3.2.1.1; Megazyme, Wicklow, Ireland) supplied at a concentration of 3000 U/mL and glucoamylase from *Aspergillus niger* (E.C. 3.2.1.3; A7095, Sigma, St Louis, MO) obtained at a concentration of 300 U/mL, were used.

One percent of flour gel was obtained after heating for 10 min a mixture containing 0.5 g of flour and 50 ml of distilled water. The mixture was incubated under stirring in a water bath at 37°C for 100 min. Each 10 minutes the amount of sugars released was assayed by the method of [19]. The percentage of amylolysis or *in vitro* digestibility of the starch was calculated: Digestibility% = [(Quantity of sugars released (mg) / Quantity of starch × 100].

2.7. Statistical Analysis

Results are expressed as mean ± standard deviation from triplicate measurements. The non-parametric test of Duncan is used to analyze the difference between the means at 5% risk, using Statistica 7.1 software ANOVA analysis of variance method.

3. Results and Discussion

3.1. Results

3.1.1. Physicochemical of Flours

3.1.1.1. Moisture, Ash and Cellulose Contents

Results show that the level of physicochemical parameters (moisture, ash and cellulose) varies with thermal treatments (Figure 1). FAC flour (4.01 ± 0.07 %) and FRA (3.5 ± 0.09 %) have the higher moisture contents compared to other flours (FTA and FIA). In addition, FIA and FTA flours have the highest concentrations of ash than FRA and FAC respectively 2.86 ± 0.11 %; 2.80 ± 0.10 %; 2.26 ± 0.11 % and 1.86 ± 0.11 %. The celluloses content varies significantly whatever the flour considered (P<0.01) (Figure 1).

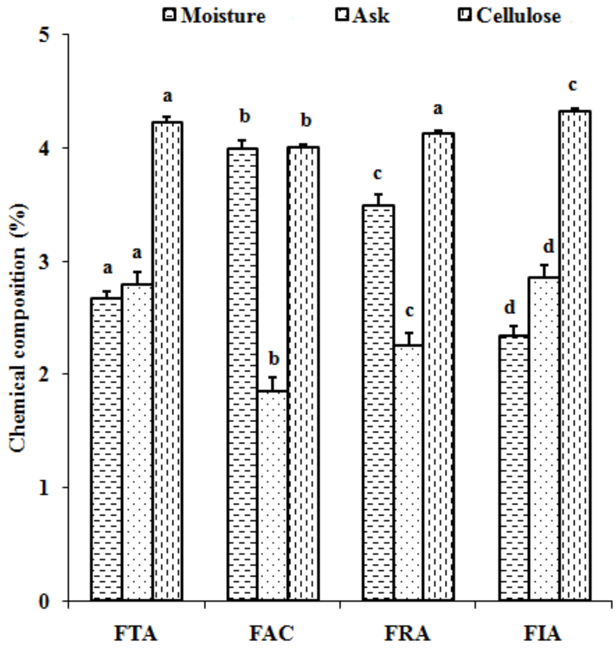

Figure 1. Rate moisture, ash and cellulose

3.1.1.2. Contents of Total Carbohydrates, Protein and Fat

Total carbohydrates, protein and fat content are presented in Figure 2. Results showed that industrial flours (34.13 ± 0.63 %) have higher total carbohydrate content than the other three FRA (34.14 ± 0.63 %), FTA (32.96 ± 0.09 %) and FAC (31.19 ± 1.83 %). In addition, protein levels were significantly different in each flours (P<0.05). Heat treatments were decreased protein contents in FTA, FAC and FIA than those of the raw FRA flours. As for as lipids content, the flour resulting from kernels cooked with water FAC has the lowest content compared with other types of flour.

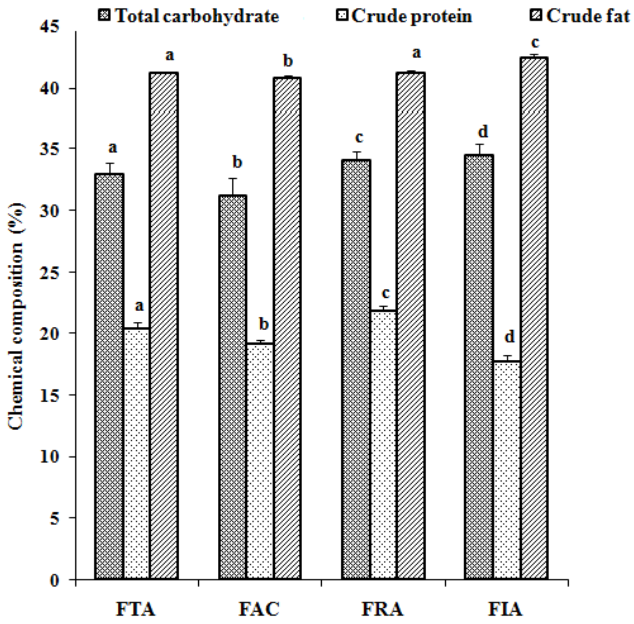

Figure 2. Carbohydrate, protein and fat content

3.1.1.3. Energy Value of Different Flours

The total energy contents in different flour are presented in Figure 3. Results showed that FIA (591.45 ± 3.7 Kcal) has the highest energy value compared to FTA (583.79 ± 3.02 Kcal), FRA (582.30 ± 3.1 Kcal) and FAC (580.36 ± 2.28 Kcal).

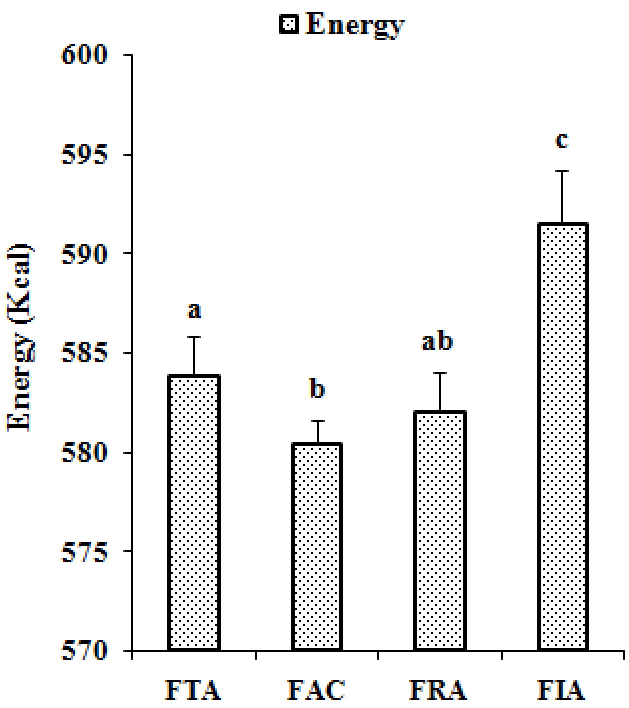

Figure 3. Total energy content

3.1.1.4. Minerals

Mineral results are presented on Table 1. The results showed that thermal treatments have an influence on minerals content of each flour studied. FAC presents low potassium (22.34 ± 0.58 %), magnesium (10.39 ± 0.14 %), sodium (0.87 ± 0.12 %) and zinc (0.50 ± 0.12 %) content compared with FTA, FIA and FRA. Fat and FIA presented the lowest contents of calcium and copper content respectively (0.44 ± 0.07 %); (0.16 ± 0.03 %). In addition, it was established that cooking increases significantly iron contents in flour heated.

Table 1. Effect of treatment on minerals (%)

flours	FTA	FAC	FRA	FIA
Potassium	22,51 ± 0,12 ^{a}	22,34 ± 0,58 ^{b}	22,72 ± 1,3 ^{c}	22,99 ± 0,64 ^{d}
Magnesium	10,95 ± 0,53 ^{a}	10,39 ± 0,14 ^{b}	10,70 ± 0,02 ^{c}	10,80 ± 0,40 ^{ac}
Sodium	1,09 ± 0,23 ^{a}	0,87 ± 0,12 ^{b}	1,20 ± 0,34 ^{c}	1,02 ± 0,30 ^{d}
Calcium	0,44 ± 0,07 ^{a}	0,52 ± 0,05 ^{b}	0,55 ± 0,14 ^{c}	0,61 ± 0,08 ^{d}
Iron	0,79 ± 0,06 ^{a}	0,69 ± 0,08 ^{b}	0,61 ± 0,03 ^{c}	0,89 ± 0,07 ^{d}
Zinc	0,80 ± 0,11 ^{a}	0,50 ± 0,08 ^{b}	0,85 ± 0,08 ^{c}	0,49 ± 0,07 ^{b}
Copper	0,29 ± 0,02 ^{a}	0,34 ± 0,03 ^{b}	0,29 ± 0,03 ^{a}	0,16 ± 0,03 ^{c}

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row indicates that there is no significant difference between samples for the parameter concerned (p<0.05).
Noted: FRA= flour of raw almond; FAC = flour of almond cooked at water; FTA = flour of terrified almonds; FIA = flour of industrial almond

3.1.2. Functional Properties of Flour

Water absorption capacity (WAC), water solubility index (WSI), oil capacity absorption (OCA) and hydrophilic lipophilic balance (HLB) were significantly differs in the four types of flours (Table 2). However, foam stability (FS), foaming capacity (FC), emulsifying stability (ES) and emulsifying activity (EA) did not differ whatever the technological treatments applied. The WAC content was lower in FAT compared to FRA respectively (99.27 ± 0.2 %) and (106.42 ± 0.15 %). In addition, WSI, were lower in FAC (35.87 ± 0.23 %), FTA (46.38 ± 0.22 %) and FIA (63.76 ± 0.17 %) than those of FRA (74.44 ± 1.55 %). We established that heat treatments decreased significantly the OAC content. As for as HLB, FRA flour (1.14 ± 0.09 %) the results showed the lowest value compared to FTA (1.34 ± 0.01 %), FAC (2.21 ± 0.12%) and FIA (3.38 ± 0.03 %).

Table 2. Functional properties of flour from cashew kernel

flours	FTA	FAC	FRA	FIA
% WAC	99,27 ± 0,21 ^{a}	147,99 ± 0,5 ^{b}	106,42 ± 0,15 ^{c}	186,19 ± 0,2 ^{d}
% WSI	46,38 ± 0,22 ^{a}	35,87 ± 0,23 ^{b}	74,44 ± 1,55 ^{c}	63,76 ± 0,17 ^{d}
% OAC	73,96 ± 0,91 ^{a}	66,97 ± 3,41 ^{b}	92,88 ± 0,90 ^{c}	55,04 ± 0,62 ^{d}
% FS	100 ± 0,00 ^{a}	100 ± 0,00 ^{a}	100 ± 0,00 ^{a}	100 ± 0,00 ^{a}
% FC	0,66 ± 0,00 ^{a}	0,66 ± 0,00 ^{a}	0,66 ± 0,00 ^{a}	0,66 ± 0,00 ^{a}
% ES	35,47 ± 1,04 ^{a}	37,24 ± 0,30 ^{b}	36,45 ± 0,58 ^{ab}	37,50 ± 0,58 ^{b}
% EA	36,75 ± 1,16 ^{ab}	36,26 ± 0,29 ^{ab}	35,32 ± 0,83 ^{a}	38,03 ± 1,45 ^{b}
% HLB	1,34 ± 0,01 ^{a}	2,21 ± 0,12 ^{b}	1,14 ± 0,09 ^{c}	3,38 ± 0,03 ^{d}

Values are mean ± standard deviation of three measurements (n = 3). The same letter in the same row index indicates that there is no significant difference between samples for the parameter concerned (p<0.05).

2.1.3. *In vitro* Digestibility of Different Cashew Flour

In vitro digestibility of the various flours studied varies depending on treatments applied (Figure 4). The digestibility of these flours (FRA, FTA and FIA) increases with time and temperature until first 70 min and remains constant whatever the cooking duration. Results showed that FAC digestibility was lowest than those of FRA, FTA and FIA. In addition, between 0 to 35 min, it was established that digestibility of FRA was superior to other flours.

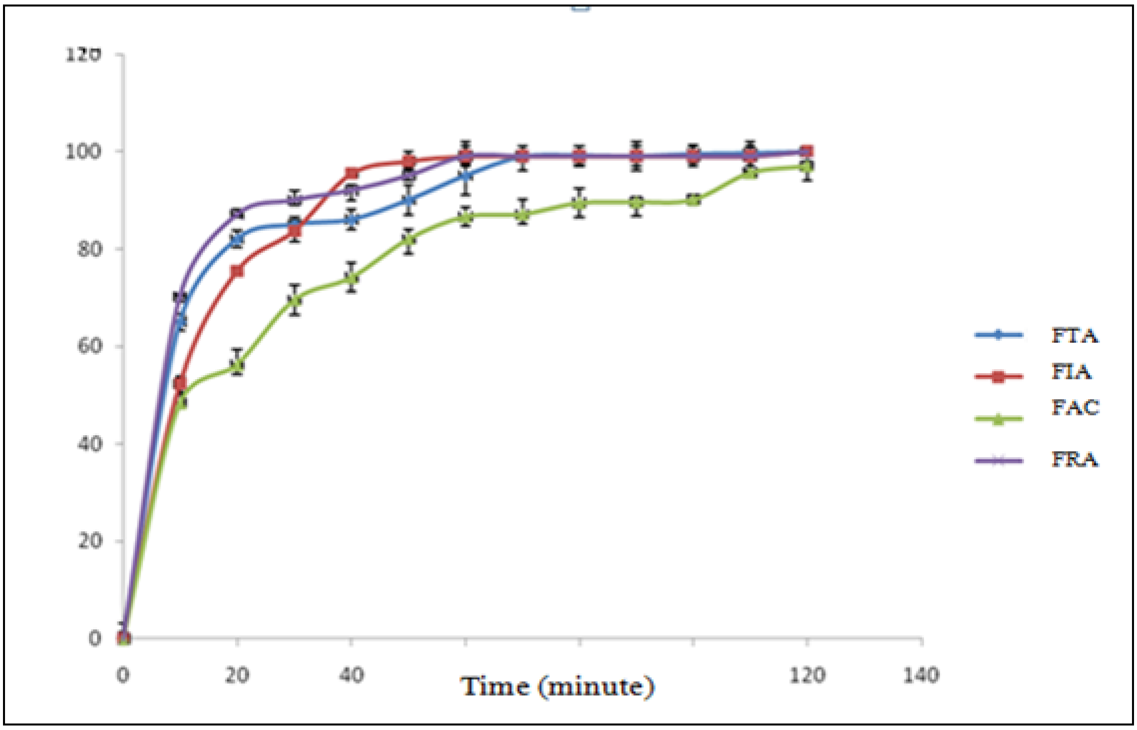

Figure 4. The *in vitro* digestibility of cashew flour

3.2. Discussion

Treatments technological led to 50% modification of physicochemical parameters of flours studied (FTA, FAC, FRA and FIA). These flours were showed an average moisture content about 3.5%. This value reflects the relative standard of cashew nut established by [20], which indicates that the water content of cashew kernels did not exceed 5%. Values obtained in this study were lower than those found by [21] and [22], which are about 6%. The fact of their lowest moisture content, these flours could be keep for a relatively long time without risk of microbial proliferation. Ash contents of different flours vary significantly whatever the treatment technological applied. The lower ash content in flour of cashew cooked at water (1.86%) may be due to solubilisation of some of these minerals in cooking water. In addition, high ash content obtained in FTA (2.80%) and FIA (2.86%) could be due to concentrated nutrients following water loss in the roasting process. The four types of flours studied have an average ash content of about 2.3%. This value is in the range of 1.5% - 2.5% which are values recommended by [23]. Below these values, flour is not recommended in diet. This value obtained (2.3%) in this study is comparable to those of [24] and [22] obtained with cashews from Asia and Nigeria respectively. Moreover, these values are lower than those obtained by [21], which is 4.4%. These variations of ash content could be explained by the geographical locations, cashew species used and their intrinsic characteristics. Results have shown a low cellulose content in kernel flour cooked in water compared with FTA and FIA. This low cellulose content could be explained by the cellulose degradation during cooking. These results are in agreement with those of [25] who showed that cooking leads to an alteration of nutrients such as dietary fiber. Average levels of cellulose (4.01%) obtained in our results are superior to those obtained by [26], [22] and [21] with respective values of 1.42%; 3.2% and 3.8%. Due to their high cellulose contents, consumption of these flours could facilitate digestive transit and prevent constipation at the root of some diseases such as colon diseases: hemorrhoid, cancers, appendicitis. It has been established that dietary fibers are involved in digestive tract and prevent the absorption of excess cholesterol [27]. Technological treatments such as cooking and roasting led to decrease significantly the total carbohydrate content in FTA and FAC flours. This decrease may be due to the solubilisation of soluble sugars in cooking water and also to caramelization phenomena due to Maillard reaction at elevated temperatures. Maillard reaction is a set of interactions resulting from an initial reaction between a reducing sugar and an amino group. This reaction is an important in food chemistry which accounts for the production of scents, flavours and pigments characteristics in cooked food.

Low total carbohydrate contents obtained in FAC and FTA flours could be explained by the time/temperature couple used for heating. The total of carbohydrates contents (32.5%) obtained in all flour was superior to those obtained by [26] which are about 25.39%. The difference between these results may be due to heating techniques and also to the couple time/temperature used during processing. Protein content of the raw flour is higher than those of flours which were undergone heat treatments. This low protein from kernels heated could be explained partly by the distribution of these macronutrients in cooking water and also by the Maillard reaction. Protein content obtained in FRA (21.85%) is comparable to those obtained by [24]. In addition, the average protein content (20.3%, approximately) of these cashew flour is higher than those of oilseeds (17.3%) mentioned in the report of the French Agency for Food Safety (AFSSA) [28]. Concerning to fat, flour resulting from almond cooked in water has a low content compared with the other three flours (FTA, FIA and FRA). This low content can be due to the fact that fat, mainly short chain fatty acids, was extracted during cooking. The Average fat content (41.5%) obtained is similar to those obtained by [29]. Industrial flour had a high-energy value compared to other three meals. This high energy was proportional to the high content of fat contained in that meal. Energy values obtained in all flours studied (580.36-591.45 Kcal) are consistent with those nuts and seeds in the range of 566-700 Kcal [30].

As far as minerals are concerned, low potassium levels (22.34 ± 0.58 %), magnesium (10.39 ± 0.14 %), sodium (0.87 ± 0.12 %) and zinc (0.5 ± 0.08 %) obtained in the flour from kernels boiled in water can be explained by solubilisation phenomena. In effect, when cooked, micronutrients are dissolved in cooking water. These results are in agreement with those of [31] and [32] which showed an influence of cooking methods leafy vegetables. Increasing iron content in flours (FTA, FAC and FIA) could be due to the lower levels of anti-nutrients during cooking. Indeed, polyphenols and phytates can make iron complex. The Applied thermal treatments could promote their destruction and promote iron bioavailability. This idea is consistent with that of [33] who worked on the contribution to the study of on iron and zinc bioavailability in millet seed.

WAC indicates the extent of starch gelatinization indeed WSI reflects the extent of starch degradation. OAC and HLB significantly differ in the four types of flours. The FTA had lower WAC content than the other three flours. This low level of WAC in FTA could be explained by the loss of some volatile constituents during this treatment, which leaves open more lipophilic functions. However, the high WAC content in FAC may be due to the denaturation of some proteins and the formation of an irreversible gel during this treatment and this phenomenon could increase water absorption capacity of flour. The extreme values of WAC (99.27% - 186.19%) of these different flours are higher than those reported by [34] who obtained values between 35 and 50%. WAC is an important property in flours for pastries. It allows addition of a lot of water to the paste while improving handling.

The treated flours (FTA, FAC and FIA) have revealed the low levels of WSI compared to FRA. These low values could be explained by the time/temperature use for the treatments technological. Our results are similar to those of Aboubakar [35]. Thermal treatments promote exposure of thiol groups and exteriorization of hydrophobic residue, which leads to breakdown in hydrogen bonds and the formation on disulfure bridges. This phenomenon could increase the breakdown of starch granules and solubilisation of amylose molecules.

The heat treatment leads to decrease significantly the OAC content. This decrease could be explained by the reduction of lipophilic groups as mentioned above. The average OAC content obtained (72%) is superior to that obtained by [34] which is about 30%. The ability of proteins to retain oil is an interesting property because it allows good retention of flavour in food processes thus improving palatability [36]. There were no treatments effect on foam stability (FS), foaming capacity (FC), emulsifying stability (ES) and emulsifying activity (EA). This stability of emulsions could be explained by reduction in droplet size [37]. The result showed the high value of EA (35.32% - 38.03%) than those reported by [38] which varies between 12.5% and 24.6%. This difference could be explained by different types of sampling used. Ogunwolu et al. [38] worked on functional properties of concentrates and cashew protein isolates. This high EA content of flour could be explained by the richness in phospholipids of these flours. Furthermore, previous studies established that phospholipids contribute to formation and stabilization of food emulsions [36]. These emulsions help bring desirable properties to foods. FC content obtained are lower than those of [34] and [38] respectively 45% and 3%. Foam formation is governed by three factors; including transportation, penetration and reorganization of the molecule at the air–water interface. The FS content obtained are lower than those [34] and [38] with the respective values of 55% and 2%. Foam stability tended to decrease with the passage of time at room temperature. This result may be due to collapsing and bursting of the formed air bubbles [39]. This could be explained by short observation time foam. About HLB, studied flours have an average value (2%). This result shows that these FTA, FAC, FRA and FIA flours have a greater affinity for water than oil. This suggests that flour should preferably be designed in formulation of products that require a high capacity for water absorption.

The increase of the digestibility parameters of flours (FTA, FIA and FRA) in the first 70 minutes could be explained by the increase in the rate of enzymatic hydrolysis. After 70 minutes of treatment, the rate of digestibility is constant, this phenomena can be explained by full hydrolysis of the sugar. In the first 35 minutes, enzymatic digestibility of the raw meal (FRA) is greater than the three other types of flour. This increase can be explained by the prehydrolysis reaction of sugar during nuts soaking. The digestibility of flour derived kernels boiled in water (FAC) is low compared to other flours. This low content could be explained by a slow enzymatic hydrolysis due to downgrading phenomena in water-boiled kernels which after heating and these kernels are cooled and dried. During cooling, starch is gelatinised and amylose and amylopectin macromolecules reorganize and tend to adopt a new conformational equilibrium, which leads to a retrogradation phenomenon which leads, in its turn, to the formation of a composite gel that is not hydrolyzed or resistant.

4. Conclusion

The study of physical and chemical characteristics and *in vitro* digestibility of different flour cashew kernels obtained after technological treatments showed a significant decrease in protein, sugars and some minerals. Industrial flour derived from kernels (FIA) presents low levels of protein, magnesium, zinc and copper. The study showed an increase in speed of hydrolysis in all flours studied during the first thirty-five minutes. Furthermore, digestibility of water-cooked flour is much lower compared with other flours. It emerges from this study that despite reductions in some nutrients due to application of technological treatments, these various cashew flours could be used for formulating meals for consumption. Thus, taking account of the functional and nutritional properties of cashew flour, this use as a complement to cereal flour can be considered because promote better nutrition and health.

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