American Journal of BioScience
2023; 11(5): 111-121
http://www.sciencepublishinggroup.com/j/ajbio
doi: 10.11648/j.ajbio.20231105.11
ISSN: 2330-0159 (Print); ISSN: 2330-0167 (Online)

Effect of Cooking Time on Biochemical Parameters and Some Functional Properties of Lima Bean Seed Flours (White, Red and Black) Consumed in Côte d'Ivoire

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To cite this article:

Tchumou Messou, Oupoh Bada Bedos, Dembele Syndoux, Tano Kablan. Effect of Cooking Time on Biochemical Parameters and Some Functional Properties of Lima Bean Seed Flours (White, Red and Black) Consumed in Côte d'Ivoire. *American Journal of BioScience*. Vol. 11, No. 5, 2023, pp. 111-121. doi: 10.11648/j.ajbio.20231105.11

Received: July 27, 2023; **Accepted**: August 31, 2023; **Published**: September 15, 2023

Abstract: Meeting the world's food needs requires efforts to promote the cultivation and use of underutilized and neglected plants, which have the potential to improve food and nutritional security. *Phaseolus lunatus* (L.), is one of them can serve as a promising potential food crop. This study aims to contribute to food security throught he valorization of *P. lunatus* (L.) beans seeds, with a view to their more rational use indifferent diets. Seeds obtained at stage 4 (52days) of maturity after harvesting were cooked for 45, 60 and 75 minutes at 100°C. The results showed an increase in moisture content (29.68 to 36,27%), carbohydrates (64.16 to 71.56%) and fiber (4.62 to 6.05%), followed by a reduction in protein (4.62 to 6.05%), ash (4.62 to 6.05%) and lipids (4.62 to 6.05%). The results also showed a non-significant decrease in essential and non-essential aminoacids during cooking. Similarly, cooking increased water absorption capacity (WAC) (230.00 to 322.60%), oil absorption capacity (OAC) (190.36 to 250.36%), swelling power (SP) (2.26 to 23.33gwater/gDM) and solubility (1.80 to19.90%) at temperatures ranging from 50 to 90°C. The study provides useful information for consumers and food manufacturers that lima bean flour has great potential to increase the nutritional value of foods.

Keywords: Cooking, Neglected Plants, Underutilized, Food Security, Food Manufacturers

1. Introduction

According to [1], dry beans are one of the main legumes that are an essential source of nutrients and dietary protein for over half a billion people worldwide [2]. Dried bean seeds are good source of energy, complex carbohydrates (dietary fiber, starch and oligosaccharides), proteins, minerals and vitamins as well as polyphenols and antioxidants necessary for human health [3]. *Phaseolus lunatus* is a species of dry bean, belonging to the Fabaceae family and the *Phaseolus* genus. Its seeds are an important source of protein (21-26%), carbohydrates (55-64%), fiber (3.2-6.8%), lipids (12.3%) and minerals such as potassium, zinc, calcium, iron with small amounts of sodium and phosphorus [4]. They are used in many preparations as food supplements with cereals such as rice, maize, sorghum or with plantain. *P. lunatus* is grown in association with tubers, plantain and vegetables in the forest zone, but also with sorghum and millet in the savannah zone [5]. High consumption of *P. lunatus* seeds reduces the risk of developing diabetes, hypertension and hypercholesterolemia, according to [6]. They are also particularly rich in essential aminoacids such as lysine [7]. Various mechanisms involved in food preparation can affect the nutritional value and bioavailability of nutrients and minerals. Previous studies have shown that technological processes such as soaking and cooking have an impact on the nutritional value of foods. The aim of this study was to evaluate the effects of different cooking times on the biochemical parameters and some functional properties of *P. lunatus.*

2. Material and Methods

2.1. Materials

Seeds of the three *Phaseolus lunatus* (L.) cultivars (white, red and black) were obtained from pods harvested at full withering in a field created in Tomasset, 38.7 km from Abidjan, during 2013-2014 [8].

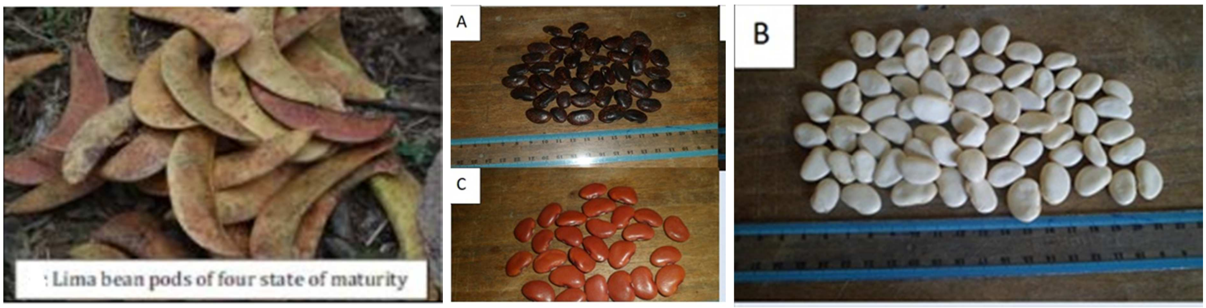

Figure 1. *Lima bean pods of four state of maturity, A=black seeds, B=white seeds and C=red seeds.*

2.2. Methods

2.2.1. Preparation of Lima Bean Powder

Three hundred (300) grams of each sample of, lima bean (*Phaseolus lunatus*) white, red and black bean seeds at maturity stage 4 (52 days) were mixed in an ivory pot with 2 liters of pre-boiled water (100°C) Cook together. On a hot plate (RELPE, Spain). Precook to determine different cooking times. The 45minutes time was marked by removing the seed membrane by rubbing with two fingers. Fifteen (15) minutes are considered the cooking interval. Therefore, three cooking times (45, 60, 75 minutes) were determined. Put the seeds in the IVOIRAL, pot. As soon as cooking starts, the timer starts. After each cooking time (45, 60 and 75 minutes), remove the seeds and drain for a few minutes. After draining, the seeds were dried in a ventilated oven at 45°C for 72 h. They are ground with a Moulinex grinder. The powder obtained was sieved with an AFNOR 300 µm sieve. The flour obtained was stored in glass bottles for laboratory analysis, previously washed and dried in an oven at 45°C [8].

2.2.2. Proximate Analysis of Samples

Moisture, ash, crude protein, crude fat, crude fiber and total sugar were determined respectively by standard method [9,10], and carbohydrate content was determined by difference equation ([100- (protein + crude fat + ash + crude fiber)]) [11]. In addition, energy value (EV) was calculated by applying the calorie coefficient from [12] according to the following equation: EV (Kcal/100g) = (4x protein%) + (4x carbohydrate%) + (9x fat%). Analyses values are triplicate values.

2.2.3. Mineral Analysis

Minerals were analyzed using the method described in [10]. Take 1 g of ash obtained from the sample, dissolve it in10% HCl, filter it with filter paper and delute to the standard volume with deionized water. The content of sodium and potassium in the samples were determined by flame photometry described method in litterature [13]. Calcium, Iron, Magnesium, Zinc and Cooper were determined using Atomic Absorption Spectrophotometry (AAS). Phosphorus content was estimated colorimetrically using spectrophotometery (UV-visible spectrophotometer, Mode lDR 2800/United States).

2.2.4. Amino Acid Analysis

The amino acid contents of the samples were determined using an automatic amino acid analyzer (BIOCHROM30, serial number103274), according to the method described in literature [14].

2.2.5. Functional Properties Evaluation

(i). Water Absorption Capacity (WAC) and Water Solubility Index (WSI)

The water absorption capacity (WAC) and water solubility index (WSI) of flour were determined according to [15] using a simple (modified) technique. Dissolve one gram (1 g) of flour (M0) in 10 mL of distilled water in a centrifuge tube. The mixture was stirred with a shaker for 30 minutes, and then kept in a water bath at 37°C for 30 minutes. Then, centrifuge at 3000 rpm for 15 minutes with a centrifuge (ORTOAL RESAR). Weigh the resulting pellet (M2) and then dry it in a 105°C oven for 24 h until a constant mass (M1) is reached. CAE and ISE are calculated according to the following relationship:

$$\text{CAE}\ (\%) = \frac{(\text{M2}-\text{M1})}{\text{M1}} \times 100$$

$$\text{ISE}\ (\%) = \frac{(\text{M0}-\text{M1})}{\text{M0}} \times 100$$

(ii). Oil Absorption Capacity

The oil absorption capacity (OAC) of lima bean flours was evaluated using the method of [16] methods. Mix1g of sample (M0) with 10 ml of oil. The slurry was stirred on a vortex mixer for 2 minutes, allowed to standat room temperature (28°C) for 30 minutes and then centrifuged at 15,000 rpm for 10 minutes. Weighed the sediment (M1). The oil holding capacity is calculated according to the following formula:

$$\text{CAH}\ (\%) = \frac{(\text{M1}-\text{M0})}{\text{M0}} \times 100$$

(iii). Swelling and Solubility

Swelling and solubility tests were performed according to the technique of [17] with slight modifications. A suspension of 1% (w/v) flour was placed in a centrifuge tube and then agitated maximally for 30 min in a water bath at different temperatures (50, 60, 70, 80 and 90°C). Centrifuge the suspension in the tube at 3,000 rpm for 15 min. Aliquots of the pellet and supernatant were then collected in separate containers and the supernatant was incubated at 105°C for 24 hr and the pelletfor 48 hr. The supernatant was used to determine solubility and swelling:

$$PG = \frac{(M1-M2)}{M1} \times 100$$

PG: swelling power (gwater/g starch);
M1: wet mass of aliquot (g)
M2: aliquot dry mass (g)

$$S\,(\%) = \frac{M_S}{M} \times 100$$

S: solubility expressed as a percentage (%)
Ms: sample mass after drying (g)
M: mass of sample taken (g) to prepare1%(w/v) solution

2.3. Statistical Analysis

The analysis of variance (ANOVA) was used to determine the differences between treatments. When a difference was observed, the multiple range tests of Newman-Keuls at 5% were performed to separate treatment means. Statistical tests were performed using the STATISTICA soft ware version 7.1.

3. Results

3.1. Effet of Cooking Time on the Biochemical Composition of Phaseolus lunatus (L.) Bean Seeds

The determination of biochemical components of P. lunatus bean seeds showed that with the prolongation of cooking time, the contents of total sugar, reducing sugar, protein, lipid and ash all decreased significantly (P< 0.05) (Table 1). Total and reducing sugars in cooked *P. lunatus* (L) bean seeds decreased from 4.46 ± 0.75 to 2.90 ± 0.23% of dry matter and from 0.53 ± 0.75 to 0.30 ± 0.13%%, respectively (Figures 1 and 2). Seed protein content ranged from 25.06 ± 0.13 to 18.52 ± 0.23 mg/100 g dry matter. Protein losses from cooked seeds ranged from 10.22% to 10.27%. The lipid content of P. lunatus seeds ranged from 2.16 ± 0.08 to 0.69 ± 0.01 mg/100 g dry matter. The lipid lowering rate of seeds was between 49.07% and 50.71%. The ash content of P. lunatus seeds decreased from 4.26 ± 0.05 - to 2.88 ± 0.04 mg/100 g dry matter. If the seeds were boiled for 45 minutes, there was minimal loss of protein, lipid and ash regardless of the seed. A cooking time of 45 minutes is adequate for seeds of good nutritional quality. Fiber, water and carbohydrate content increased significantly (P<0.05) during cooking. Dietary fiber values were 4.62±0.04 to 6.05±0. 13 mg/100 g dry matter, moisture 29.68±0.75 to 36.27±0.25 mg/100 g dry matter, and 64.16±0.09 to 71.56±0.04 mg /100 g carbohydrate dry matter. Red seeds are rich in carbohydrates, ranging from 69.63 ± 0.48 to 71.56 ± 0.04 mg /100 g dry matter. When *P. lunatus* seeds were boiled for 75 minutes, the water, carbohydrate and fiber content increased. Cooking time had no effect on moisture, lipid or total carbohydrate content. On the other hand, energy values increased significantly (P<0.05) up to 45 min cooking time (300.79 ± 0.59 – 374.28 ± 0. 27 Kcal / 100 g dry matter), and then decreased (374.28 ± 0.27 – 365.37 ± 0.06 mg/ 100 grams of dry matter) until the end of the cooking time. The high carbohydrate content of the red seeds gives them a high energy value with cooking time (45) minutes. With a cooking time of 45 minutes, the white seeds are very high in protein and fiber.

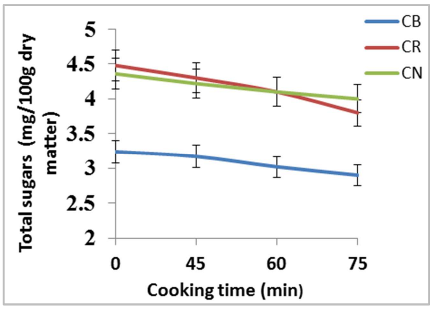

Figure 2. *Effect of cooking time on total sugars (mg/100g dry matter) in Phaseolus lunatus bean seeds.*

Table 1. *Effect of cookingime on biochemical composition of Phaseolus lunatus bean seeds (g/100gdrymatter).*

Flours	Cookingtime (min)	Moisture (%)	Proteins (%)	Fats (%)	Carbohydrates (%)	Fibers (%)	Ashs (%)	ValueEnergy (Kcal/100g)
	0	29.68±0.75^{d}	25.06±0.13^{a}	1.40±0.01^{c}	64.16±0.09^{b}	5.13±0.07^{de}	4.17±0.00^{b}	300.79±0.59^{g}
	45	30.46±0.26^{cd}	23.60±0.10^{b}	1.03±0.06^{de}	65.63±0.25^{a}	5.91±0.08^{fg}	3.88±0.07^{f}	366.67±0.14^{i}
FCW	60	31.20±0.20^{bc}	22.68±0.13^{c}	0.81±0.02^{f}	66.92±0.27^{d}	6.00±0.10^{g}	3.60±0.03^{gh}	365.60±0.20^{j}
	75	31.78±0.13^{b}	22.01±0.10^{d}	0.69±0.01^{f}	67.79±0.28^{cd}	6.05±0.13^{g}	3.42±0.07^{ch}	365.37±0.06^{j}
	0	33.30±0.34^{f}	20.63±0.20^{f}	1.60±0.01^{b}	69.63±0.48^{c}	4.62±0.04^{a}	4.26±0.05^{b}	311.25±0.33^{a}
	45	33.90±0.26^{ef}	19.59±0.10^{gh}	1.08±0.10^{e}	70.37±0.12^{efh}	5.05±0.13^{de}	3.91±0.02^{fg}	369.60±0.40^{d}
FCR	60	34.20±0.36^{ef}	18.90±0.03^{ij}	0.85±0.03^{df}	71.15±0.05g^{h}	5.50±0.20^{bc}	3.63±0.05^{h}	367.85±0.22^{h}
	75	34.63±0.21^{e}	18.52±0.23^{j}	0.70±0.03^{f}	71.56±0.04^{g}	5.83±0.15^{fg}	3.40±0.02^{cd}	366.96±0.31^{hi}
	0	35.36±0.33^{ag}	21.21±0.18^{e}	2.16±0.08^{a}	67.95±0.28^{f}	4.93±0.08^{ae}	3.74±0.05^{fg}	310.02±0.68^{f}
FCB	45	35.89±0.01^{g}	19.70±0.10^{g}	1.68±0.03^{b}	70.09±0.08^{fg}	5.32±0.07^{cd}	3.21±0.02^{de}	374.28±0.27^{a}
	60	36.10±0.34^{g}	19.22±0.06^{ef}	1.35±0.05^{c}	70.82±0.17^{egh}	5.60±0.08^{bcf}	3.00±0.10^{e}	372.31±0.40^{b}
	75	36.27±0.25^{g}	19.03±0.06^{hi}	1.10±0.10^{e}	71.12±0.11^{gh}	5.86±0.12^{fg}	2.88±0.04^{a}	370.59±0.52^{c}

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold (P < 0.05). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Flour).

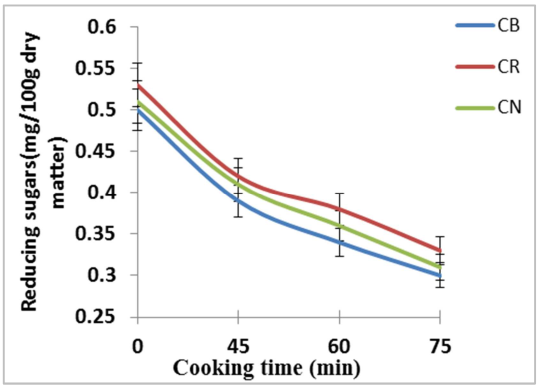

***Figure 3.** Effect of cooking time on reducing sugars (mg/100g dry matter) in Phaseolus lunatus bean seeds.*

3.2. Effect of Cooking Time on Mineral Composition of Phaseolus Lunatus Bean Seeds

Analysis of seed meal cooked for 45, 60 and 75 minutes showed a decrease in potassium, phosphorus, magnesium, sodium, calcium and iron during cooking (Table 2). Potassium (1109.3 ± 0.81-1592.27 ± 6.38 mg/100 g dry matter); phosphorus (230.18 ± 1.13-259.25 ± 1.08 mg/100 g dry matter); calcium (301.03 ± 1.00 - 359.32 ± 0.89 mg/100 g dry matter); magnesium (128.46 ± 0.35 – 140.60 ± 0.52 mg/100 g dry matter), sodium (60.80 ± 0.60 – 75.27 ± 0.72 mg/100 g dry matter) and iron (9.49 ± 0.27 - 12.56 ± 0.28 mg/100 g dry matter) of uncooked seeds (FNC) were significantly higher than cooked seeds ($P< 0.05$)**.** Mineral loss rates varied respectively from (34.71 - 46.48%) potassium, (42.05 - 46.53%) phosphorus, (35.46 - 42.31%) magnesium, (34.98 - 40%) calcium and iron (48.36- 57.40%). The mineral loss rates of cooked *P. lunatus* seeds are statistically different ($P< 0.05$). At 45 minutes cooking time for seeds of the black cultivar, the sodium, potassium and magnesium losses obtained varied by 9.29%, 34.70% and 35.46% respectively. In contrast, cooking the seeds of the black cultivar for 45 minutes resulted in calcium, phosphorus and sodium losses of 34.98%, 42.05% and 11.60% respectively. Cooking the seeds caused more iron loss with white seeds (57.40%) than with black and red seeds. Na/K and Ca/P ratios vary by (0.05-0.06) and (1.31-1.41) respectively in uncooked seeds, while the same ratios vary by (0.05-0.07) and (1.21-1.63) respectively in cooked seeds. Minerals do not have the same sensitivity to heat. After 45 minutes of cooking, seeds from all three cultivars show high mineral concentrations.

***Table 2.** Effect of cooking time on mineral composition of Phaseolus lunatus bean seeds (mg/100g dry matter).*

Flours	Cooking time (min)	Na	K	P	Mg	Fe	Ca	Na/K	Ca/P
	0	60.80 ± 0.60^{d}	1109.30 ± 0.81^{e}	259.25 ± 1.08^{a}	140.60 ± 0.52^{f}	10.33 ± 0.29^{b}	340.50 ± 0.51^{b}	0.05	1.31
	45	55.96 ± 0.54^{e}	804.70 ± 0.30^{j}	200.63 ± 0.35^{d}	110.34 ± 0.36^{b}	7.80 ± 0.20^{d}	272.88 ± 0.38^{c}	0.07	1.36
FCW	60	52.30 ± 0.70^{f}	716.20 ± 0.75^{k}	163.69 ± 0.31^{k}	$90.75\pm0.18g^{h}$	5.63 ± 0.15^{h}	240.23 ± 0.68^{e}	0.07	1.46
	75	50.16 ± 0.15^{g}	665.34 ± 0.41^{l}	138.60 ± 0.36^{i}	80.86 ± 0.16^{i}	4.40 ± 0.10^{g}	218.16 ± 0.77^{h}	0.07	1.57
	0	72.65 ± 0.32^{h}	1592.90 ± 6.38^{a}	250.48 ± 0.67^{b}	140.56 ± 0.20^{f}	12.56 ± 0.28^{a}	359.32 ± 0.89^{a}	0.05	1.43
	45	68.34 ± 0.43^{i}	1150.22 ± 0.23^{d}	196.57 ± 0.50^{e}	106.32 ± 1.14^{c}	9.26 ± 0.14^{c}	300.69 ± 0.27^{k}	0.06	1.52
FCR	60	66.33 ± 0.59^{b}	966.99 ± 0.01^{h}	164.09 ± 0.09^{k}	90.45 ± 0.48^{h}	7.35 ± 0.15^{de}	268.67 ± 0.29^{d}	0.07	1.63
	75	64.22 ± 0.23^{c}	852.50 ± 0.50^{i}	145.14 ± 0.15^{h}	81.12 ± 0.13^{i}	6.30 ± 0.20^{fh}	233.60 ± 0.40^{f}	0.07	1.6
	0	75.27 ± 0.72^{a}	1519.50 ± 1.40^{b}	230.18 ± 1.13^{c}	$128.460.35^{a}$	9.49 ± 0.27^{c}	301.03 ± 1.00^{k}	0.05	1.31
FCB	45	71.90 ± 0.26^{h}	1238.34 ± 0.36^{c}	185.13 ± 0.13^{f}	102.72 ± 0.23^{d}	6.97 ± 0.11^{ef}	223.84 ± 0.96^{g}	0.06	1.21
	60	69.62 ± 0.54^{i}	1100.92 ± 0.08^{f}	150.33 ± 0.15^{g}	91.97 ± 0.24^{g}	5.86 ± 0.04^{h}	203.81 ± 0.19^{i}	0.06	1.35
	75	68.27 ± 0.30^{i}	992.09 ± 0.34^{g}	132.18 ± 0.12^{j}	82.90 ± 0.13^{e}	4.90 ± 0.01^{g}	180.50 ± 0.40^{j}	0.07	1.36

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold ($P < 0.05$). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Clour).

3.3. Effect of Cooking Time on Amino Acids Composition of Phaseolus Lunatus Bean Seeds

Nine amino acids, including 6 essential amino acids (lysine, phenylalanine, tryptophan, threonine, tyrosine and methionine) and three non-essential amino acids (arginine, cystine and glutamic acid), were determined after cooking *Phaseolus lunatus* bean seeds (Table 3). Amino acids in *P. lunatus* bean seeds did not decrease significantly ($P < 0.05$) with cooking time. The most abundant essential amino acids are lysine, threonine, phenylalanine and tyrosine. Contents vary respectively from 4.44 ± 0.03 - 6.00 ± 0.10%; 6.38 ± 0.03 - 9.80 ± 0.10%; 2.90 ± 0.01 - 4.80 ± 0.01% and 3.62 ± 0.08 - 5.20 ± 0.02%. The most abundant non-essential amino acids are arginine and glutamic acid. The contents vary respectively from 5.96 ± 0.05 - 8.98 ± 0.22% and 14.61 ± 0.06 -16.90 ± 0.10%. Seeds cooked for 45 minutes from the white cultivar showed low amino acid losses.

***Table 3.** Variation of aminoacids levels in Phaseolus lunatus bean seeds as a function of cooking time (mg/100gdrymatter).*

Flours	Cooking time (min)	Cystine	Thréonine	Tryptophane	Tyrosine	Méthionine	Lysine	Phénylalanine	Arginine	Acide glutamique
	0	0.55 ± 0.01^{fg}	4.80 ± 0.01^{a}	2.89 ± 0.09^{ef}	5.20 ± 0.02^{c}	0.58 ± 0.10^{g}	5.41 ± 0.12^{fg}	9.80 ± 0.10^{g}	8.98 ± 0.22^{a}	14.53 ± 0.25^{b}
	45	0.50 ± 0.01^{fg}	4.56 ± 0.04^{b}	2.78 ± 0.01^{df}	5.15 ± 0.02^{c}	0.51 ± 0.10^{hi}	5.32 ± 0.02^{fg}	9.69 ± 0.02^{g}	8.87 ± 0.10^{a}	14.28 ± 0.01^{bf}
FCW	60	0.48 ± 0.01^{fg}	4.37 ± 0.02^{e}	2.72 ± 0.02^{d}	5.11 ± 0.01^{c}	0.46 ± 0.10^{ij}	5.21 ± 0.01^{dg}	9.61 ± 0.04^{bg}	8.76 ± 0.03^{a}	14.18 ± 0.02^{f}
	75	0.46 ± 0.01^{g}	4.27 ± 0.02^{e}	2.66 ± 0.01^{d}	5.07 ± 0.02^{c}	0.44 ± 0.10^{j}	5.11 ± 0.01^{de}	9.50 ± 0.10^{b}	8.68 ± 0.07^{a}	14.07 ± 0.06^{f}

Flours	Cooking time (min)	Cystine	Thréonine	Tryptophane	Tyrosine	Méthionine	Lysine	Phénylalanine	Arginine	Acide glutamique
FCR	0	1.07±0.01^{a}	3.52±0.02^{c}	3.64±0.04^{b}	4.32±0.07^{a}	1.37±0.20^{a}	5.00±0.10^{e}	8.36±0.03^{a}	6.20±0.20^{b}	16.90±0.10^{a}
	45	0.93±0.11^{ac}	3.30±0.02^{f}	3.57±0.06^{bc}	4.21±0.01^{ad}	1.24±0.10^{b}	4.63±0.05^{h}	8.14±0.05^{c}	6.10±0.10^{b}	16.70±0.04^{ac}
	60	0.82±0.09^{cde}	3.20±0.02^{fgh}	3.52±0.02^{bc}	4.13±0.20^{ad}	1.17±0.10^{f}	4.52±0.03^{h}	8.00±0.10^{ce}	6.02±0.04^{b}	16.59±0.08^{c}
	75	0.77±0.02^{de}	3.13±0.01^{gh}	3.47±0.02^{c}	4.08±0.07^{d}	1.12±0.20^{f}	4.44±0.03^{h}	7.88±0.07^{ef}	5.96±0.05^{b}	16.53±0.03^{c}
FCB	0	0.86±0.05^{cd}	3.25±0.02^{fg}	3.09±0.01^{a}	4.03±0.15^{d}	0.90±0.03^{c}	6.00±0.10^{a}	7.72±0.02^{f}	7.30±0.10^{c}	15.44±0.03^{d}
	45	0.70±0.02^{e}	3.16±0.01^{fgh}	2.93±0.03^{e}	3.80±0.10^{b}	0.1±0.02^{d}	5.71±0.03^{b}	7.53±0.05^{h}	7.13±0.15^{c}	15.31±0.01^{de}
	60	0.61±0.01^{f}	3.07±0.06^{gh}	2.87±0.06^{ef}	3.67±0.02^{b}	0.64±0.01^{e}	5.63±0.05^{bc}	7.45±0.05^{h}	7.05±0.12^{c}	15.24±0.04^{de}
	75	0.55±0.01^{fg}	2.90±0.01^{d}	2.87±0.03^{ef}	3.62±0.08^{b}	0.54±0.02^{gh}	5.50±0.10^{cf}	6.38±0.03^{h}	6.96±0.05^{c}	15.15±0.02^{e}

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold (P < 0.05). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Flour).

3.4. Effectof Cooking Time onFunctional Properties of Phaseolus Lunatus Bean Flours

3.4.1. Water Absorption Capacity (WAC) and Water Solubility index (WSI)

The study showed a significant increase (P < 0.05) in the water absorption capacity (WAC) and water solubility index (WSI) of seed flours from the three cultivars during cooking. The water absorption capacities of the cultivar flours (white, red and black) ranged from 302.00 ± 1.00 - 324.53 ± 0.50; 246.53 ± 0.50 - 266.43 ± 0.51 and 230.00 ± 1.00 - 257.53 ± 1.00 respectively. The water solubility index (WSI) of the seed flours increased during cooking. The water solubility indices (WSI) of cultivar flours (white, red and black) range from 40.50 ± 0.50 - 43.10 ± 0.27%; 35.13 ± 0.47 - 36.66 ± 0.61% and 30.70 ± 0.65 - 32.03 ± 0.15% respectively. Seed flours baked at 45 and 60 minutes have higher absorption capacities and water solubility indices (WSI) than seed flours baked at 75 minutes. All seed flours from the three cultivars have high water absorption capacities and water solubility indices (WSI) at 45 minutes cooking time. Flour from the white cultivar retained more water, with a high solubility index at 45 minutes of cooking, than flour from the red and black cultivars (Table 4).

Table 4. *Evolution of water absorption capacity and solubility index of Phaseolus lunatus seed flours as a function of cooking time.*

Flours	Cooking time (min)	Water absorption capacity (%)	water solubility index (%)
FCW	0	302.00 ± 1.00^{b}	33.10 ± 0.43^{g}
	45	319.20 ± 1.31^{a}	40.50 ± 0.50^{c}
	60	324.53 ± 0.50^{e}	45.36 ± 0.32^{b}
	75	322..60 ± 0.52^{e}	43.10 ± 0.27^{a}
FCR	0	246.53 ± 0.50^{c}	26.30 ± 0.30^{e}
	45	262.43 ± 0.51^{g}	35.13 ± 0.47^{i}
	60	269.00 ± 1.00^{f}	38.16 ± 0.76^{i}
	75	266.43 ± 0.51^{f}	36.66 ± 0.61^{d}
FCB	0	230.00 ± 1.00^{d}	22.30 ± 0.26^{f}
	45	255.00 ± 1.00^{h}	30.70 ± 0.65^{h}
	60	260.63 ± 1.52^{h}	34.80 ± 0.80^{h}
	75	257.00 ± 1.00^{g}	32.03 ± 0. 15^{i}

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold (P < 0.05). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Flour).

3.4.2. Oil Absorption Capacity of Three Phaseolus Lunatus Cultivars Flours

The results show a significant increase (at the 5% threshold) in the oil absorption capacity of *P. lunatus* seed flours during cooking. The oil absorption capacities of uncooked *P. lunatus* seed flours are lower than those of cooked flours. The corn oil absorption capacity (CAH) of seed flours from *P. lunatus* cultivars ranged from 190.36 ± 0.40 to 228.93 ± 0.81% respectively. It is higher in the flour of the red cultivar, ranging from 207.00 ± 1.00 - 228.93 ± 0.81%. The sunflower oil absorption capacity of seed flours from *P. lunatus* cultivars ranged from 210.30 ± 0.30 - 245.36 ± 0.40% and was highest in the flour of the red cultivar. It range from 220.86 ± 0.80 to 245.36 ± 0.40%. The red oil absorption capacity of seed flours from *P. lunatus* cultivars ranged from 199.50 ± 0.50 - 240.03 ± 0.45%. Seed flour from the red cultivar showed the highest red oil absorption capacity. It range from 219.00 ± 1.00 - 240.36± 0.45%. The dinor oil absorption capacity of seed flours from *P. lunatus* cultivars ranges from 214.73 ± 0.23 - 250.36± 0.40%. It was highest in the flour of the red cultivar, ranging from 200.96 ± 0.25 - 228.93 ± 0.8%. Raw cultivar flours have a significantly (P< 0.05) lower CAH than cooked flours obtained at different cooking times. Cultivar flours have different CAHs depending on the oil studied (Table 5). At the 75 minutes seed cooking time, the oil absorption capacities of the flours are higher than at the 45 and 60 minutes times studied. The absorption of each oil is specific to a given flour. Flour from seeds of the red cultivar absorbs more dinor and sunflower oil, while flour from the white cultivar absorbs more red oil, and finally, corn oil is absorbed more by flour from the black cultivar.

Table 5. *Oil absorption capacity of Phaseolus lunatus seed flours as a function of cooking time.*

Flours	Cooking time (min)	Oil absorption Capacity (%)			
		Maize	Sunflower	Red	Dinor
FCW	0	200.00±1.00^{i}	210.30±0.30^{g}	219.00±1.00^{h}	214.73±0.23^{d}
	45	209.70±0.75^{e}	218.50±0.50^{e}	229.40±0.52^{e}	225.60±0.52^{i}
	60	215.30±1.08^{g}	224.03±0.55^{h}	235.06±0.40^{c}	233.46±1.40^{h}
	75	220.33±0.35^{c}	230.23±0.49^{i}	240.03±0.45^{a}	240.40±0.52^{f}
FCR	0	190.36±0.40^{f}	220.86±0.80^{d}	199.50±0.50^{j}	224.60±0.52^{i}
	45	200.96±0.25^{i}	231.00±1.00^{i}	209.53±0.50^{i}	237.00±1.00^{g}
	60	206.33±0.61^{h}	238.63±0.55^{b}	214.53±0.50^{k}	243.36±0.32^{e}
	75	213.26±0.30^{d}	245.36±0.40^{a}	221.13±0.32^{g}	250.36±0.40^{a}
FCB	0	207.00±1.00^{h}	213.26±0.64^{f}	215.53±0.50^{k}	220.36±1.00^{c}
	45	216.50±0.50^{g}	223.30±0.30^{h}	225.40±0.45^{f}	230.30±0.60^{b}
	60	223.10±0.36^{b}	229.56±0.51^{i}	231.36±0.40^{d}	235.36±0.32g^{h}
	75	228.93±0.81^{a}	235.20±0.34^{c}	237.30±0.30^{b}	241.36±0.40^{ef}

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold (P < 0.05). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Flour).

3.4.3. Changes in the Swelling of Seed Flours from Three Phaseolus Lunatus Cultivars as a Function of Cooking Time

The study showed that raw and cooked seed flours from all three *Phaseolus lunatus* cultivars swell with increasing incubation temperature. Swelling is low for all flours at incubation temperatures of 50-60°C, and increases from 70°C up to 90°C. Flours from seeds cooked at times 45, 60 and 75 from the three *P. lunatus* cultivars absorb 16.50 ± 0.45 - 18.53 ± 0.20 g water / g DM; 18.56 ± 0.51-20.70 ± 0.36 g water / g DM and 21.90 ± 0.85 - 23.30 ± 0.30 g water / g DM respectively, while uncooked flour retains 14.80 ± 0.20 -15.53 ± 0.30 g water / g DM at 90°C. Cooked seed flours swell more than uncooked seed flours. At 90°C, flour from white cultivar seeds swells more than flour from red and black cultivars (Table 6).

Table 6. *Swelling of Phaseolus lunatus seed flours as a function of cooking time.*

Flours	Cookingtime (min)	Swelling (g water uptake/g DM)				
		50°C	60°C	70°C	80°C	90°C
FCW	0	2.33±0.25^{e}	5.33±0.41^{cf}	8.43±0.51^{e}	12.43±0.51^{de}	15.43±0.51^{fg}
	45	4.66±0.32^{d}	8.63±0.15^{e}	10.73±0.64^{d}	15.56±0.51^{f}	18.70±0.26^{de}
	60	6.90±0.79^{b}	10.93±0.40^{d}	13.40±0.36^{f}	17.93±0.11^{b}	20.70±0.36^{c}
	75	10.50±0.26^{c}	12.00±0.20^{bd}	15.70±0.81^{a}	20.46±0.41^{a}	23.30±0.30^{a}
FCR	0	2.26±0.30^{e}	4.43±0.40^{c}	6.53±0.50^{b}	11.60±0.52^{ce}	15.53±0.30^{fg}
	45	5.36±0.20^{d}	6.46±0.37^{f}	8.10±0.36^{be}	13.60±0.52^{d}	18.83±0.20^{e}
	60	7.80±0.26^{ab}	9.03±0.25^{e}	11.26±0.55^{cd}	14.96±0.35^{f}	19.20±0.43^{d}
	75	10.76±0.25^{c}	12.43±0.37^{ab}	12.83±0.15^{cf}	16.06±0.25^{f}	2.10±0.36^{ab}
FCB	0	3.10±0.30^{e}	5.86±0.70^{f}	8.96±0.35^{e}	10.60±0.52^{c}	14.80±0.20^{g}
	45	5.30±0.30^{d}	8.16±0.15^{e}	11.06±0.80^{d}	12.83±0.76^{de}	16.50±0.45^{f}
	60	8.63±0.30^{a}	10.63±0.65^{d}	12.76±0.68^{cf}	15.16±0.28^{f}	18.56±0.51^{de}
	75	11.53±0.50^{c}	13.83±0.97^{a}	13.86±0.73^{f}	18.40±0.36^{b}	21.90±0.85^{bc}

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold (P < 0.05). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Flour).

3.4.4. Evolution of the Solubility of Seed Flours of the Three Phaseolus Lunatus Cultivars as a Function of Cooking Time

The results of the flour solubility analysis show that the solubility of cooked Phaseolus lunatus seed flours is higher than that of uncooked flours. There was a significant difference (P<0.05) whatever the cooking temperature and time (Table 7). The solubility of flours obtained at 45, 60 and 75 minutes baked is higher at 90°C than at 50°C, 60°C, 70°C and 80°C. They range from 12.83 ± 0.20 to 15.56 ± 0.49%; 15.70 ± 0.36 to 17.83 ± 0.15% and 17.30 ± 0.30 to 19.90 ± 0.85%. The solubility of uncooked flours ranged from 10.53 ± 0.30 to 13.46 ± 0.41%. Uncooked seed flour is less soluble than cooked seed flour. Solubility increases with cooking time. Black cultivar flour is more soluble than red and white cultivar flour at 90°C.

Table 7. *Evolution of Phaseolus lunatus seed flours solubility as a function of cooking time.*

Flours	Cooking time (min)	Solubility (%)				
		50°C	60°C	70°C	80°C	90°C
FCW	0	1.80±0.20^{e}	3.33±0.41^{g}	5.23±0.30^{b}	8.16±0.15^{h}	11.10±0.17^{b}
	45	3.80±0.10^{d}	6.63±0.15^{de}	7.30±0.30^{e}	10.90±0.85^{ef}	13.36±0.32^{e}
	60	5.90±0.79^{b}	8.26±0.25^{h}	9.40±0.36^{d}	12.60±0.52^{bc}	15.70±0.36^{d}
	75	8.50±0.26^{ac}	9.50±0.30^{bc}	10.86±0.55^{c}	14.46±0.41^{b}	17.30±0.30^{c}
FCR	0	1.90±0.10^{e}	3.63±0.15^{fg}	4.53±0.50^{b}	7.03±0.25^{h}	10.53±0.30^{b}
	45	4.33±0.15^{d}	5.90±0.10^{e}	6.93±0.11^{e}	9.40±0.40^{g}	12.83±0.20^{e}
	60	6.00±0.20^{b}	8.76±0.25^{ch}	9.63±0.55^{d}	12.30±0.30^{cd}	15.86±0.15^{d}
	75	7.76±0.25^{c}	10.43±0.37^{a}	11.83±0.15^{ac}	14.03±0.25^{b}	17.76±0.25^{c}
FCB	0	1.96±0.15^{e}	4.4±0.26^{f}	6.30±0.30^{e}	9.80±0.20^{fg}	13.46±0.41^{e}
	45	4.53±0.32^{d}	7.16±0.15^{d}	8.86±0.15^{e}	11.16±0.28^{de}	15.56±0.49^{d}
	60	7.63±0.30^{c}	8.30±0.30^{h}	11.10±0.17^{c}	13.73±0.25^{bi}	17.83±0.15^{c}
	75	9.26±0.30^{a}	9.83±0.20^{ab}	12.53±0.20^{a}	15.73±0.25^{a}	19.90±0.85^{a}

Mean ± SD, n = 3; in columns, means marked with different letters indicate significant differences at the threshold (P < 0.05). FCW (White Cultivar Flour), FCR (Red Cultivar Flour) and FCB (Black Cultivar Flour).

4. Discussion

The present study focused to investigate effect of cooking time on some biochemical parameters and functional properties of *Phaseolus lunatus* (L.) bean seeds. Firstly, some biochemical parameters were carried out.

Concerning water content of cooked *Phaseolus lunatus* (L.) bean seeds, it increased with cooking time. This is due to the nutrient dilution effect caused by the absorption of water by the seeds during cooking [18].

Levels of total and reducing sugar contents of cooked *P. lunatus* (L.) bean seeds decreased with increasing cooking time. The decrease in total and reducing sugars may be due to simultaneous hydrolysis and gelatinization of the seeds during cooking. Indeed, under the action of heat, starch granules well and rupture toreleaset heir contents, composed mainly of amylose and amylopectin [19]. These molecules are then hydrolyzed in to total and reducing sugars, which are then dispersed in the cooking water, resulting in their depletion. The decrease in sugars during seed cooking was reported by [20], who observed a drop in reducing sugars after cooking chickpea (*Cicerarietinum*) seeds. The total and reducing sugar contents of *P. lunatus* bean flours are higher than those observed by [21] in soybeans. They obtained total sugar contents of between 0.05 and 0.4% in uncooked and cooked soybean flours respectively, and also reducing sugar contents of between 0.03 and 0.04% of solids.

The drop in protein content during cooking of *Phaseolus lunatus* (L.) bean seeds is only significant after a cooking time of 45 min. This result can be explained by the effective denaturation of proteins after 45 min of cooking, i e. a break in peptide bonds and certainly in protein disulphide bridges [22]. These results are consistent with those of [23], who reported that the crude protein content of cooked millet is lower than that of uncooked millet. According to [24], the protein needs of infants are estimated at 9g/day. The protein content of *P. lunatus* bean flours ranged from 19.03 to 25.06%, which may partially meet the protein requirements of infants.

The decrease of lipid content during cooking of *Phaseolus lunatus* (L.) bean seeds may be due to the leaching of lipids into the cooking water [25]. This results are consistent with those of [26], who observed fat loss in cooked Mucuna spp seeds. [27] observed the same similarities in their work on Vigna sesquipedalis beans.

Ash content decreases in *Phaseolus lunatus* (L) bean seeds during cooking. This could be explained by the leaching of minerals in boiling water. Similar results have also been reported for soybean (glycine maximum) and lima bean (P. lunatus), when samples were subjected to the autoclave sterilization process [28].

Crude fiber contents increase in *Phaseolus lunatus* bean seeds during cooking. This may be explained by the formation of protein-fiber complexes following the chemical modification induced by cooking of lentils (*lens culinaris*) [29]. Also, this increase in fiber in cooked *P. lunatus* bean seeds is similar to the work of [30, 31], who showed that cooking increases soluble fiber content and decreases insoluble fiber content. Consumption of *P. lunatus* seeds may help reduce the risk of hypertension, constipation, diabetes, colon cancer and breast cancer.

The carbohydrate content of *Phaseolus lunatus* bean seeds increases during cooking. This is due to the mathematical difference used to determine carbohydrate levels. This carbohydrate content of *P. lunatus* bean seeds may make this bean an energy food that can contribute to food security in developing countries [32], particularly in Côte d'Ivoire.

The energy value of *Phaseolus lunatus* bean seeds increases with cooking time as carbohydrates. This increase is similar to that observed in *Dioscorea alata* raw and cooked for 90 min (357.65 and 370.01Kcal/100g dry matter respectively) [33]. *Phaseolus lunatus* bean seeds could be used in part as an energy food in porridges for infants and children whose energy requirements range from 547 to1092 kcal/day [34].

Phaseolus lunatus bean seeds cooked at 45 as cooking time contain most minerals. In general, minerals decreased significantly (P<0.05) with cooking time. The loss of minerals is due to the degradation of anti-nutritional factors such as phytate, which traps 60-80% of these minerals in seeds, compared with 20-34% in fruits and tubers [35], with iron being trapped by tannin [36]. The findings [37, 38] have shown that the denaturation of anti-nutritional factors by heat during cooking of *P. lunatus* bean seeds will release minerals into their matrices, which will then diffuse into the cooking water [39], resulting in their reduction. The Na/K and Ca/P ratios of *P. lunatus* bean seeds are less than or greater than 1. The Na/K ratio is very important for the body, as sodium and potassium regulate high blood pressure and muscle contraction. A food product is a good source of Ca and Fe if the Ca/P ratio is greater than1 [40]. The iron content of *P. lunatus* bean seeds can be recommended in the human diet because, according to [41], the recommended level for human consumption is 1.37mg/day (men) and 2.94mg/day (women). *P. lunatus* bean seeds can be recommended as a dietary supplement.

In general, cooked *Phaseolus lunatus* seeds show low aminoacid losses. Specifically, seeds of white cultivar cooked at 45 min showed low aminoacid losses compared with those from the red and black cultivars. Essential and non-essential amino acids decreased non-significantly (P>0.05) during cooking. The rate of reduction of essential aminoacids (Lysine, phenylalanine and tryphtophan) in *P. lunatus* bean seeds during cooking is similar to the work of [42] in lentil seeds (*lens culinaris*). The lysine content of raw and cooked *P. lunatus* bean flours ranging from 4.44 to 6.00 mg/100g dry matter is lower than that of raw and cooked lentil (*lens culinaris*) seeds (6.9 to7.00mg/100g dry matter [42]). Non-essential aminoacids (methionine and arginine) were slightly reduced during cooking of *P. lunatus* bean seeds. Our results are similar to those of [43] who showed the reduction of sulfur aminoacids during cooking of faba bean seeds. The essential amino-acid/total amino acid ratios of uncooked and 45 minute cooked seeds of the three *P. lunatus* cultivars ranged from 0.51 to 0.54 and 0.46 to 0.50%. Therefore, uncooked and 45 minute cooked seeds can be incorporated into the following diets.

Secondly, functional properties of *Phaseolus lunatus* (L.) bean seeds were carried out.

Flour from the white cultivar retains more water, with a high solubility index during cooking. The EAC values of uncooked and cooked *Phaseolus lunatus* seeds flours (230-322.60%) are with in the range of the EACs of raw and pre cooked taro flours (247.5% and 562.5%) respectively [44], but higher than those of uncooked and cooked rice (225% and 250%)[45]. The high FAC values of cooked *Phaseolus lunatus* seed flours are thought to be linked to starch gelatinization, which increases water-binding capacity [46]. The high CAE values of *Phaseolus lunatus* seed flours suggest that they could be use fulinsoup formulations for easier digestion [47]. [48] has shown that EAC is an important property of flours used in pastry-making, since it enables pastry-makers to add plenty of water to the dough while improving handling and maintaining freshness in bread. The high CAE values of *Phaseolus lunatus* bean seed flours suggest that they could be useful in soup formulations for easier digestion [47]. [48] showed that EAC is an im of the starch grains contained in the flours. The water solubility index (WSI) reflects the extent of starch degradation [49]. The high WSI of uncooked *Phaseolus lunatus* bean flour may be due to gelatinization of the starch grains, which facilitates starch solubility [50]. The high ISE percentages of cooked *P. lunatus* bean flours show that cooking has had an effect on starch degradation. The ISE levels of *P. lunatus* bean flours (22 - 43.10%) are higher than those of raw taro flours (18% to 27%) [49] and those of raw and cooked yam (*Dioscorea spp*) flours (9.26% and 15.31%) respectively [51]. The oil absorption capacity of flours increases as the seeds are cooked. Oil absorption is specific to a given flour. Flour from seeds of the red cultivar absorbs more dinor and sunflower oil, while flour from the white cultivar absorbs more red oil, and finally, corn oil is absorbed more by flour from the black cultivar. Oil absorption capacity (OAC) is an important property in the formulation of a food product, as oil improves flavor and gives as mooth texture to the food [52, 53].

According to [54], CAH is influenced by proteins, but is mainly due to the availability of lipophilic groups. The ability of proteins to retain oil is an interesting property, as it enables good flavour retention during food processing, thus improving palatability [55]. The absorption capacities of maize, sunflower, red and dinor oils obtained respectively 190.36-228.93%; 210.30-245.36%; 199.50-240.03% and 214.13-250.36% are lower than those reported by [56], who observed an increase in the CAH of jackfruit flours from 280% to 310%. The CAH of *Phaseolus lunatus* bean flour is higher than that of yam flour (190%) [57]. Cooked seed flours swell more than uncooked seed flours. At 90°C, seeds flours from the white cultivar swell smore than flours from other cultivars. The increase in flour swelling following heating is thought to be due to changes in the physical state of the starch granules in the flours during hydrothermal treatment.

In fact, under the effect of heat, the granules weaken, allowing water to penetrate them. During swelling, the amylose comes out of the granule and the amylopectin is strongly hydrated. As temperature increases, granules tend to rupture, collapse and fragment, releasing polymer molecules and aggregates [58]. The swelling power (SP) of uncooked and cooked flours varies from10.53 to19.90% at 90°C. Cooking significantly (p<0.05) increased the PG of the flours. The high PG of uncooked Phaseolus lunatus bean flours is due to the fact that proteins and lipids, by forming complexes with the starch granules in the flours, prevent the penetration of water in to the granules, thus limiting the PG. This view is confirmed by [59], who reported that proteins and lipids limited the PG of rice granules during cooking. The PG of *P. lunatus* bean flours is higher than that of cassava flour (2.16%) [60] and that of flour from different rice varieties (10.76 to 12.97% at 90°C) [61]. PG is a good indication of water absorption by the granules during heating [62]. The solubility of the different P. lunatus bean seed flours increase with cooking time. Flour from black seeds is more soluble than flour from red and white cultivars at 90°C. The solubility values of cooked *P. lunatus* seed flours are higher than those of uncooked breadfruit flour. This result can be explained by the fact that cooked P. lunatus bean flours have a high PG. Granules with a high PG burst to release their contents into the reaction medium. The solubility of *Phaseolus lunatus* seed flour is higher than that of cassava flour (7.57%-10.46%) [63]. Cooked *P. lunatus* bean flours are digestible and therefore suitable for infant food formulations.

5. Conclusion

A study of the effect of cooking time on the biochemical parameters and functional properties of Phaseolus lunatus seeds in water at 100°C for 45, 60 and 75 minutes showed a decrease in nutritional factors except for carbohydrates, energy value and fiber, which increased respectively from 64.16 to 70.39%, 300.79 to 374.28 Kcal/100 g and 4.62 to 6.05% dry matter. The energy value is highest with black seeds cooked for 45 minutes, whereas 60 minutes cooking of the same seeds and white yields high carbohydrate and fiber values. Nutritional factors such as minerals and amino acids are reduced during cooking. Water absorption, oil absorption, swelling capacity and solubility improved considerably with different cooking times. In view of the results, the best cooking time for P. lunatus seeds would be 45 min for good nutritional quality. Functional properties also show that cooked P. lunatus seed flours are suitable for the preparation of baby food porridges, pastries and cakes.

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