Journal of Food Security, 2018, Vol. 6, No. 4, 133-140
Available online at http://pubs.sciepub.com/jfs/6/4/1

DOI:10.12691/jfs-6-4-1

Combined Effects of Fermentation, Germination and Cooking Processes on the Nutritional Profile of Cowpea (*Vigna unguiculata L*) Grown in Côte d'Ivoire

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Received September 19, 2018; Revised October 23, 2018; Accepted November 15, 2018

Abstract The aim of this study was to evaluate the appropriate technological treatments and the couple time / temperature optimizing the availability of nutrients in cowpea grains. White cowpea grains used were bought at Abobo (Abidjan) market. After germination and fermentation, these grains were heated to boiling for 1 hour (h) and 1h30 min at coal and gas fires and then crushed. The biochemical and nutritional profile was performed on the flour obtained. The results showed a significant difference on the parameters studied according to the treatment applied. The dry matter content of the flours was higher than 90%. The protein content was high on the flours from sprouted grains after cooking for 1 h on charcoal (Gfc2) and gas (Gfg2) fire with respective values of 18.31 ± 0.05% and 19, 83 ± 0.50%. On the other hand, the lipid content was less than 3%. The total carbohydrate content in all the flours is between 68 and 80 %. Fibers content varies between 23 and 31 %. Whatever the cooking method used, results showed that the mineral contents were higher after 1 hour cooking. The nutrient profile by the determination of scores SAIN > 5 and LIM <7.5 classified the cowpea in food of group 1, recommended foods for health. The flours from germinated and fermented Cowpea with a high energy value could be recommended as a local product in the formulation in infant food.

Keywords: *cowpea, germination, fermentation, cooking, proteins, antinutrients*

Cite This Article: Traoré Souleymane, Assemand Emma, Digbeu Dogoré Yolande, Kouadio Larissa Adjoua, and Brou Kouakou, "Combined Effects of Fermentation, Germination and Cooking Processes on the Nutritional Profile of Cowpea (*Vigna unguiculata L*) Grown in Côte d'Ivoire." *Journal of Food Security*, vol. 6, no. 4 (2018): 133-140. doi: 10.12691/jfs-6-4-1.

1. Introduction

The diet helps to maintain health and fight against nutritional diseases. Data from [1] showed that most countries face nutritional problems: malnutrition, micronutrient deficiencies, obesity and diet-related diseases such as type II diabetes and cancer. In this context, the availability of a stable nutritionally rich, with quality acceptable to all is proving to be a challenge. Natural products are becoming increasingly valued over synthetic products by the general public. Moreover, increasing amounts of attention are being paid to the use of vegetable proteins because low-cost dietary proteins are required around the world, particularly in low-income countries. However, the legumes, an important component of the daily diet in many countries, are often marginalized due to ignorance of thier nutritional value [2]. According to [3], plants of the family of legumes grain (peas, soybeans, lentils, chickpeas, split peas) are seeds rich in protein and oil. Among the legumes, cowpea (Vigna unguiculata L.Walp.) is the most cultivated species in Africa, South America, United States, Asia and Southern Europe [4]. Moreover, cowpea is an important staple in sub-Saharan Africa, particularly in the arid savannahs of West Africa [1,5]. Studies of [6] showed that due to the high protein content, cowpea is likely to fill many protein deficits in developing countries where food shortages are still a major news scourge. The high costs and limited availabilities of animal proteins in developing countries have caused interest to be focused on the potential uses of several types of seed, including cowpeas, as sources of vegetable proteins for use as functional ingredients in foods [7]. In addition, cowpea is also source of income for humans, as well as fodder for animals [8].

In Côte d'Ivoire, from leaves to grains, cowpeas were used in various forms, especially in the making of several dishes [9]. But this use is limited by the presence of antinutritional substances [10]. There is evident that antinutritional factors, such as phytates present in legume grains chelate minerals namely iron, zinc, and calcium limit highly micronutrients absorption and use by the body

[11]. The cowpea seeds undergo technological processes such as soaking, sprouting, fermenting and cooking before consumption. These different treatments could destroy more anti-nutritional factors which alter nutritional value of foods. In addition, physicochemical changes induced by heating could affect lipids, proteins, carbohydrates, vitamins and phytonutrients. The interaction between sugars and amino acids induces successive reactions, called non-enzymatic browning, which is considered the most important in food chemistry [12]. These non-enzymatic brownings can give rise to protein aggregations, carcinogenic compound and ultimately reduce the nutritional value of foods. Therefore, the mastery of technological processes is an important factor in the acceptance of food by consumers.

The objective of this work was to evaluate the appropiate treatments and the couple time / temperature to optimiz nutrients in cowpea based flour. The nutritional quality of cowpea flours is evaluated by physicochemical analyzes after fermentation and germination treatments combined with cooking.

2. Material and Methods

2.1. Material

Legumes used in this study are the white grain of cowpea (*Vigna unguiculata*) bought at Abobo (Abidjan) market. The choice of white grains was due to their availability and high consumption in Africa and also in Côte d'Ivoire.

2.2. Methods

2.2.1. Cowpea Flours Production

2.2.1.1. Control cowpea flours

Cowpea grains (2 kg) are divided into four batches of 500 g. The batches were cleaned manually, sorted, vanned and washed. The first two batches were heated in boiling water in ratio of 1: 5 (P/V) on the gas fire at 1h and 1h30 min. The last two batches were heated in boiling water on the charcoal fire in the same conditions as previously described. The boiling temperature was 100 ± 2°C. The cooked batches were dried in a ventilated oven (Memmert) at 45°C for 48 h and grinded with a grinder. The flours obtained were stored in airtight containers and named Tfc1 (Witness flour cooked on the charcoal fire for 1h30 min); Tfc2 (Witness flour cooked on charcoal fire for 1 h); Tfg1 (Witness flour cooked on the gas fire for 1h30 min) and Tfg2 (Witness flour cooked on gas fire for 1h).

2.2.1.2. Fermented Cowpeas Flour

Cowpea grains (2 kg) are divided into four batches of 500 g for fermentation. The batches were cleaned manually, sorted, vanned, soaked in water in a ratio of 1: 3 (P/V) in the polyester bowls. The bowls are hermetically sealed and placed under the bench at room temperature for fermentation. After 4 days of spontaneous fermentation, the fermented batches are washed several times with tap water. The first two (2) fermented batches were heated in boiling water in ratio of 1: 5 (P/V) on the gas fire at 1h and 1h30 min. The last two batches were heated in boiling water on the charcoal fire in the same conditions as previously described. The boiling temperature was 100 ± 2°C. The cooked batches were dried in a ventilated oven (Memmert) at 45°C for 48 h and grinded with a grinder. The flours obtained were stored in airtight containers and named Ffc1 (Fermented flour cooked on charcoal fire for 1h30 min); Ffc2 (Fermented flour cooked on charcoal fire during 1h); Ffg1 (Fermented flour cooked on the gas fire for 1h30) and Ffg2 (Fermented flour cooked on gas fire for 1h).

2.2.1.3. Sprouted Cowpea Flours

Cowpea grains (2 kg) were cleaned manually, sorted, vanned, soaked in water in ratio of 1:3 (p/v), drained and then sterilized with 0.1 g / 100 ml in a bleach solution of 8°C for 10 min. The grains were washed with water until the smell of bleach was eliminated and then soaked in water in a ratio of 1: 3 (P/V) for 24 hours at the room temperature. The grains were spread on the white cotton sheets in a dark room. The temperature of the room was 31°C with 37% of humidity. The seeds were watered once or twice a day with tap water for three (3) days. Sprouted seeds obtained were washed several times with tap water, drained and are divided into 4 batches. The first two (2) sprouted batches were heated in boiling water in ratio of 1: 5 (P/V) on the gas fire at 1h and 1h30 min. The last two batches were heated in boiling water on the charcoal fire in the same conditions as previously described. The boiling temperature was 100 ± 2°C. The cooked batches were dried in a ventilated oven (Memmert) at 45°C for 48 h and grinded with a grinder. The flours obtained were stored in airtight containers and named Gfc1 (sprouted flour cooked on charcoal fire for 1h30 min) ; Gfc2 (sprouted flour cooked on charcoal fire during 1h); Gfg1 (sprouted flour cooked on the gas fire for 1h30) and Gfg2 (sprouted flour cooked on gas fire for 1h).

2.2.2. Physico-chemical Characteristics of Flours from cowpea Grains

Moisture content

Moisture was determined by drying the sample at 105°C for 24 h according to [13]. 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.

Protein content

Protein was determined by determination of total nitrogen according to the Kjeldahl method [14]. The principle: under the action of NAOH and after sulfuric mineralization in the presence of catalyst ($CuSO_4$), 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 [13]. 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 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 [15].

$$E = \begin{bmatrix} (9 \text{ x } \% \text{ Fat}) + (4 \text{ x } \% \text{ Protein}) \\ +(4 \text{ x } \% \text{ Carbohydrates}) \end{bmatrix}.$$

Ash content

Ash was obtained after incineration at 550°C for 6 h according to [16]. Sample (5 g) 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.

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.

Ethano-soluble total sugars content

The ethano-soluble total sugars were measured according to the method of [17] using phenol and concentrated sulfuric acid. Extract ethano - soluble (100 µl) was put in the test tube. The (200 µl) of phenol (5% w / v) and 1 ml of concentrated sulfuric acid were added successively to the reaction medium. After homogenization, the optical density was determined at the spectrophotometer (GENESYS 5) at 490 nm against a control containing no sweet extract. Optical densities were converted to total sugars by a calibration line obtained from a glucose solution (1 mg / ml).

Ethano-soluble reducing sugars content

Ethano-soluble reducing sugars are determined by the method of [18]. The mixture was heated in boiling water bath for 5 minutes and cool for 10 minutes at room temperature. About 3.5 ml of distilled water are added to the reaction medium. The optical density was performed at 540 nm with a control. This value was converted into mg of reducing sugars by means of the calibration curve obtained from glucose solution at 1 mg / ml.

Fiber content

Fibers content were determinated according to the method described by [13]. The 50 mL of sulfuric acid (0.25 N) was added in to 2 mg of flour. The solution obtained was homogenized and boiled for 30 min under reflux. Then 50 ml of sodium hydroxide (0.31 N) were added and heated at boiling for 30 min under reflux. The extract obtained was filtered on Whatman filter paper and the residue was washed several times with hot water until complete elimination of the alkalis. After removal, the residue was dried in an oven at 105°C for 8 h, cooled in a desiccator and weighed. The residue obtained was incinerated in the oven at 550°C for 3 h, cooled in a desiccator and the ashes were weighed.

2.2.3. Nutritional Profile by the SAIN, LIM System

The nutritional profile used was the SAIN and LIM system described by [19]. The SAIN refers to the favorable aspects of the food (qualifying nutrients) and the LIM refers to the unfavorable aspects (disqualifying nutrients). A food has a good profile when its SAIN is high and its LIM is low.

SAIN calculation formula is as follows:

$$\text{SAIN} = \frac{\dfrac{\left(\begin{array}{l} \dfrac{\text{Vitamin C}}{\text{RNI Vitamin C}} + \dfrac{\text{Iron}}{\text{RNI Iron}} \\ + \dfrac{\text{Calcium}}{\text{RNI Calcium}} \\ + \dfrac{\text{Protein}}{\text{RNI Protein}} + \dfrac{\text{Fiber}}{\text{RNI Fiber}} \end{array} \right)}{5} \times 100}{\text{Energy}} \times 100$$

RNI (Recommended nutritional intake).

The LIM calculation formula is as follows:

$$\mathbf{LIM} = \frac{\dfrac{\mathbf{Na}}{3153} + \dfrac{\mathbf{SFA}}{22} + \dfrac{\mathbf{Added\,sugar}}{50}}{3} \times 100.$$

SFA= Saturated fatty acid.

These two values plotted on a graph used to classify foods into four groups. It considers two acceptability thresholds (SAIN> 5 and LIM <7.5):

1. Foods recommended for health (SAIN> 5 and LIM <7.5)
2. Neutral foods (SAIN <5 and LIM <7.5)
3. Foods recommended in small quantities or occasionally (SAIN> 5 and LIM> 7.5)
4. Foods to limit (SAIN <5 and LIM> 7.5).

2.2.4. Statistical Analyses

Results made in triplicate measurements were expressed as means with standard deviation. A one-way ANOVA was performed and means were separated using Tukey test ($p \leq 0.05$) or Dunnett test ($p \leq 0.05$) with Statistica 7.1 software. Graphical representations were made with Microsoft Word and Microsoft Excel.

3. Results

3.1. Physico-chemical Characteristics of Cowpea Flours

3.1.1. Chemical Composition of Flours

The physicochemical properties of the Different flours are presented in Table 1. The results showed that the dry matter content of the flours studied was higher than 90%. The flours from sprouted grains heated during 1h and

1h30 at the gas fires have high ash contents respectively 1.94 ± 0.09% and 2.16 ± 0.06% compared to other flours. The reducing sugars contents were lower than 0.5% in all the flours studied. On the other hand, total carbohydrate contents were higher than 68%. Results showed that the proportions of fibers ranged from 23 to 31% with the high values in sprouted and fermented grains.

The results also showed the similar protein contents ≈ 13% in control flours whatever the cooking method (gas or coal). After the application of technological treatments such as germination, the proportions of protein increased by 40% ≈ 18.31 ± 0.05% for Gfc2 and 52% ≈ 19.83 ± 0.50% for Gfg2. Furthermore, an increase of protein contents about 20% was observed in flours from fermented grains. Whatever the cooking methods, results showed that lipid contents were lower than 3%. The flours from the cowpea grains studied have energy contents ranging between 360 and 380 Kcal / 100g.

Table 1. Chemical composition of flours

Chemical parameters	**Flours**					
	Tfc1	**Tfc2**	**Tfg1**	**Tfg2**	**Gfc1**	**Gfc2**
Dry matter φ	93.79±0.52^{a}	90.97±0.20^{c}	93.60±0.01^{ab}	91.08±0.13^{c}	93.15±0.22^{ab}	92.93±0.25^{b}
Ash φ	0.91±0.06^{e}	1.56±0.06^{d}	1.44±0.01^{d}	1.47±0.01^{d}	1.76±0.03^{c}	1.80±0.01^{c}
Sugar red. φ	0.22±0.02^{e}	0.20±0.01^{f}	0.25±0.03^{d}	0.21±0.02^{e}	0.47±0.01^{a}	0.40±0.03^{b}
Sugar tot. φ	6.63±0.30^{b}	7.86±0.28^{a}	5.51±0.03^{c}	6.57±0.25^{b}	4.03±0.04^{f}	4.12±006^{f}
Glucid tot. φ	78.29±0.35^{a}	70.39±0.55^{f}	70.28±0.55^{f}	68.97±0.23^{g}	71.27±0.26^{f}	75.16±0.51^{cd}
Fibers φ	28.67±0.29^{c}	23.33±0.29^{e}	29.04±0.01^{b}	27.00±0.87^{d}	30.07± 0.29^{a}	29.50±0.01^{b}
Proteins φ	12.80±0.50^{e}	12.83±0.51^{e}	13.18±0.43^{e}	13.22±0.01^{e}	14.42±0.14^{d}	18.31±0.05^{b}
Lipids φ	1.76±0.02^{d}	2.20±0.13^{ab}	1.77±0.03^{cd}	1.96±0.05^{c}	2.03±0.03^{bc}	1.97±0.03^{c}
Energy $^{\delta}$	380.32	368.64	376.37	366.76	376.95	375.69
Chemical parameters	**Flours**					
	Gfg1	**Gfg2**	**Ffc1**	**Ffc2**	**Ffg1**	**Ffg2**
Dry matter φ	93.10±0.18^{ab}	93.00±0.15^{b}	93.38±0.35^{ab}	93.00±0.09^{b}	93.54±0.37^{ab}	93.31±0.13^{ab}
Ash φ	2.16±0.06^{a}	1.94±0.09^{b}	0.46±0.03^{f}	0.38±0.03^{f}	0.49±0.01^{f}	0.54±0.01^{f}
Sugar red. φ	0.51±0.01^{a}	0.42±0.01^{b}	0.29±0.01^{cd}	0.27±0.01^{cd}	0.32±0.01^{c}	0.27±0.02^{cd}
Sugar tot. φ	4.25±0.24^{f}	4.32±0.01^{f}	4.98±0.01^{d}	5.27±0.03^{cd}	4.38±0.20^{f}	4.53±0.13^{e}
Glucid tot. φ	75.23±0.36^{c}	75.81±0.39^{b}	74.86±0.42^{cd}	73.95±0.23^{d}	77.06±0.63^{ab}	73.43±0.37^{e}
Fibers φ	27.00±0.01^{d}	28.83±0.29^{c}	27.33±0.58^{d}	24.33±0.29^{e}	28.17±0.29^{c}	30.03±0.29^{a}
Proteins φ	14.28±0.01^{d}	19.83±0.50^{a}	15.75±0.01^{c}	16.67±0.14^{c}	15.33±1.01^{c}	16.82±0.51^{c}
Lipids φ	1.43±0.21^{e}	2.00±0.02^{c}	2.31±0.11^{a}	2.00±0.01^{bc}	2.07±0.08^{b}	2.22±0.21^{ab}
Energy $^{\delta}$	370.91	374.24	383.23	380.48	380.19	381.10

φ : Percentage (%) ; $^{\delta}$ **:** Kilocalories for 100 g (Kcal / 100g)
Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same line indicates that there is no significant difference between samples for the parameter concerned (p<0.05). **TfC1** : Witness flour cooked on the charcoal fire for 1h30 min ; **Tfc2** : Witness flour cooked on the charcoal fire for 1h ; **Tfg1** : Witness flour cooked on the gas fire for 1h30 min ; **Tfg2** : Witness flour cooked on the gas fire for 1h ; **Ffc1** : Fermented flour cooked on charcoal fire for 1h30 min ; **Ffc2** : Fermented flour cooked on charcoal fire during 1h ; **Ffg1** : Fermented flour cooked on the gas fire for 1h30 ; **Ffg2** : Fermented flour cooked on gas fire for 1h ; **Gfc1** : Sprouted flour cooked on charcoal fire for 1h30 min ; **Gfc2**: Sprouted flour cooked on charcoal fire during 1h ; **Gfg1** : Sprouted flour cooked on the gas fire for 1h30 ; **Gfg2** : Sprouted flour cooked on gas fire for 1h.
Sugar red = Sugar reducing ; **Sugar tot** = Sugar total ; **Glucid tot** = Glucid total

Table 2. Phosphorus, potassium, calcium, magnesium and iron content

Mineral (mg/100g)	**Sample**					
	Tfc1	**Tfc2**	**Tfg1**	**Tfg2**	**Gfc1**	**Gfc2**
P	180.01±0.01^{d}	200.01±0.01^{c}	180.01±0.01^{d}	200.01±0.01^{c}	200.01±0.01^{c}	240.01±0.01^{a}
K	928.33±0.01^{c}	947.00±0.01^{c}	2170.00±0.03^{a}	1004.00±0.01^{b}	682.00±0.01^{e}	591.67±0.02^{f}
Ca	190.00±0.01^{g}	197.33±0.01^{ef}	168.33±001^{i}	195.33±0.01^{f}	196.01±0.01^{f}	236.00±0.01^{c}
Mg	124.67±0.01^{f}	125.00±0.01^{f}	130.67±0.02^{e}	109.33±0.03^{g}	149.67±0.01^{d}	163.00±0.01^{b}
Fe	0.09±002^{e}	0.07±0.01^{g}	0.09±0.01^{e}	0.08±0.02^{f}	0.19±0.02^{b}	0.23±0.01^{a}
Mineral (mg/100g)	**Sample**					
	Gfg1	**Gfg2**	**Ffc1**	**Ffc2**	**Ffg1**	**Ffg2**
P	220.01±0.01^{b}	238.01±0.01^{a}	110.01±0.01^{g}	120.01±0.01^{f}	120.01±0.01^{f}	130.01±0.01^{e}
K	816.67±0.01^{d}	703.33±0.01^{e}	362.00±0.01^{h}	383.00±0.01^{h}	622.33±0.01^{f}	497.33±0.01^{g}
Ca	272.00±0.01^{b}	350.00±001^{a}	146.00±0.01^{j}	200.00±0.01^{e}	176.00±0.01^{h}	211.00±0.01^{d}
Mg	202.00±0.01^{a}	155.33±0.01^{c}	75.67±0.01^{i}	95.00±0.01^{h}	77.33±0.01^{i}	96.33±0.01^{h}
Fe	0.19±0.01^{b}	0.24±0.01^{a}	0.11±0.01^{d}	0.11±0.01^{d}	0.10±0.01^{d}	0.14±0.01^{c}

Values are means ± standard deviations of three measures (n = 3). The same letter subscripted in the same line indicates that there is no significant difference between samples for the parameter concerned (p<0.05). **TfC1** : Witness flour cooked on the charcoal fire for 1h30 min ; **Tfc2** : Witness flour cooked on the charcoal fire for 1h ; **Tfg1** : Witness flour cooked on the gas fire for 1h30 min ; **Tfg2** : Witness flour cooked on the gas fire for 1h ; **Ffc1** : Fermented flour cooked on charcoal fire for 1h30 min ; **Ffc2** : Fermented flour cooked on charcoal fire during 1h ; **Ffg1** : Fermented flour cooked on the gas fire for 1h30 ; **Ffg2** : Fermented flour cooked on gas fire for 1h ; **Gfc1** : Sprouted flour cooked on charcoal fire for 1h30 min ; **Gfc2**: Sprouted flour cooked on charcoal fire during 1h ; **Gfg1** : Sprouted flour cooked on the gas fire for 1h30 ; **Gfg2** : Sprouted flour cooked on gas fire for 1h.
P : Phosphorus ; K : potassium ; Ca : calcium ; Mg : magnesium ; Fe : iron.

3.1.2. Mineral Composition

The mineral contents of differents flours studied are presented in **Table 2**. The results showed that whatever the mineral studied, flours from grains heated at 1 h have higher levels than their counterpart heated for 1h30 min. The potassiums contents were higher than other minerals, whatever the technological treatments applied. The highest value was 2170.00 ± 0.03 mg / 100g for Tfg2 flour. As regards of calcium and magnesium, Gfg2 flours showed the highest levels with the respective values of 350.00 ± 0.01 mg / 100g and 202.00 ± 0.01 mg / 100g. In addition, the results showed that flours from germination and fermentation treatment have the high iron contents compared to untreated flours. Among flours of sprouted grain, the higher contents were obtained from Gfc2 (0.23 ± 0.01 mg / 100g) and Gfg2 (0.24 ± 0.01 mg / 100g) comparatively to Gfc1 (0.19 ± 0.02 mg / 100g) and Gfg1 (0.19 ± 0.01 mg / 100g).

3.1.3. SAIN and LIM Score of Flours

Figure 1, Figure 2 and Figure 3 show respectively the SAIN and LIM scores of flours from control fermented and sprouted cowpea grains.

The SAIN score of control flours Tfc1, Tfc2, Tfg1 and Tfg2 were respectively 7.07, 6.95, 9.08 and 7.43. The LIM score for these flours were 2.69, 3.36, 2.71 and 3.01 respectively.

The SAIN score for fermented cowpea flours Ffc1, Ffc2, Ffg1 and Ffg2 were 7.46, 6.62, 7.65 and 8.18 respectively. Their respective LIM scores were 3.53, 3.06, 3.17 and 3.38.

The SAIN score for sprouted cowpea flours Gfc1, Gfc2, Gfg1 and Gfg2 were 8.44, 8.37, 7.67 and 7.25 respectively. Their LIM scores were respectively 3.15, 3.01, 2.21 and 3.07.

These flours have a good nutritional profile because their SAIN were higher than 5 and LIM were lower than 7.5. The different SAIN and LIM scores obtained show that all the cowpea flours studied belong to Group 1 foods. This group contains foods recommended for health.

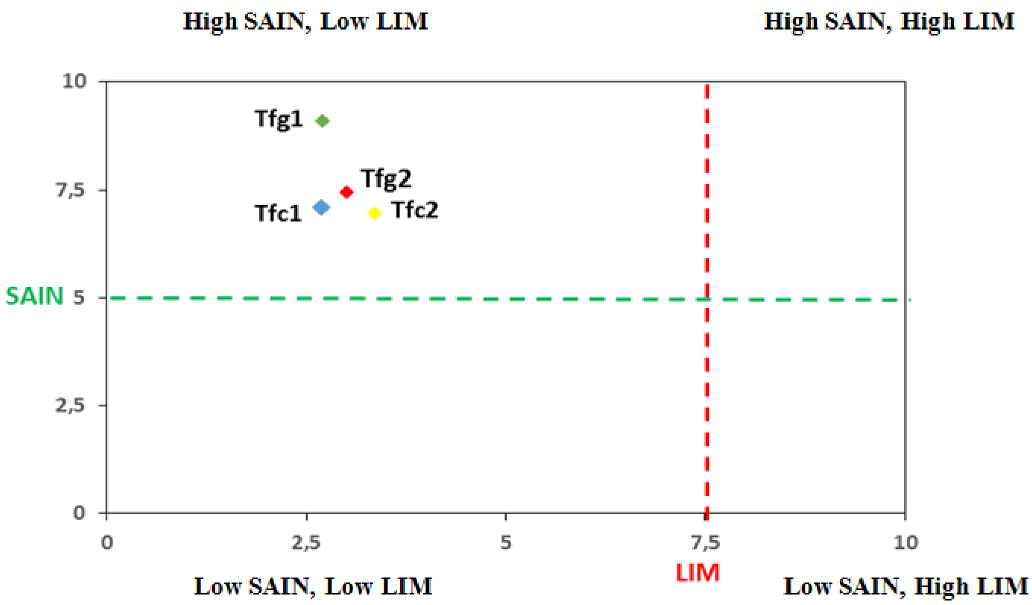

Figure 1. SAIN and LIM scores of control cowpea grains

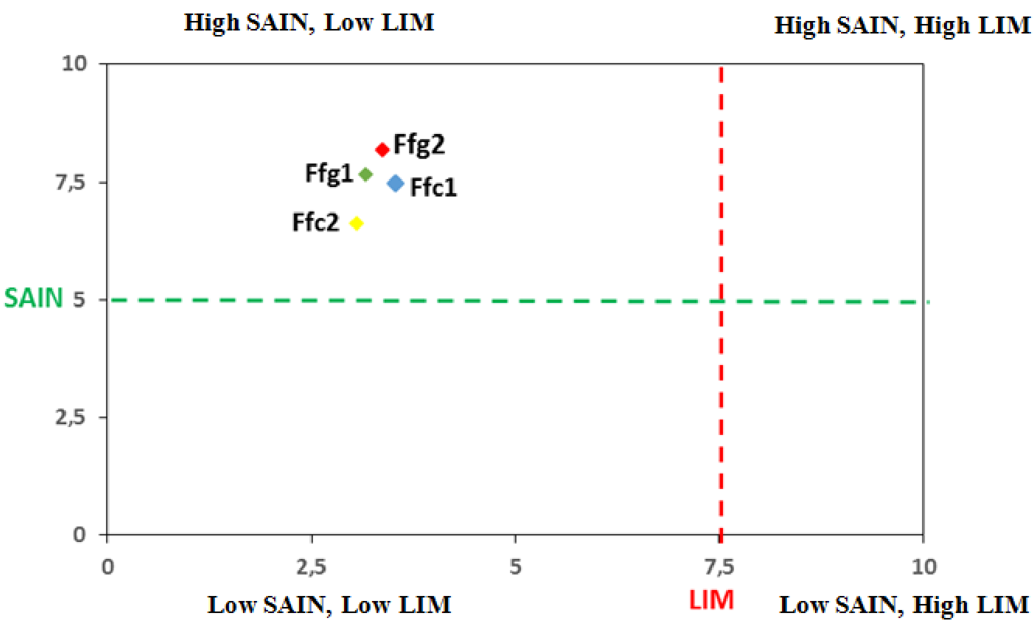

Figure 2. SAIN and LIM scores of fermented cowpea grains

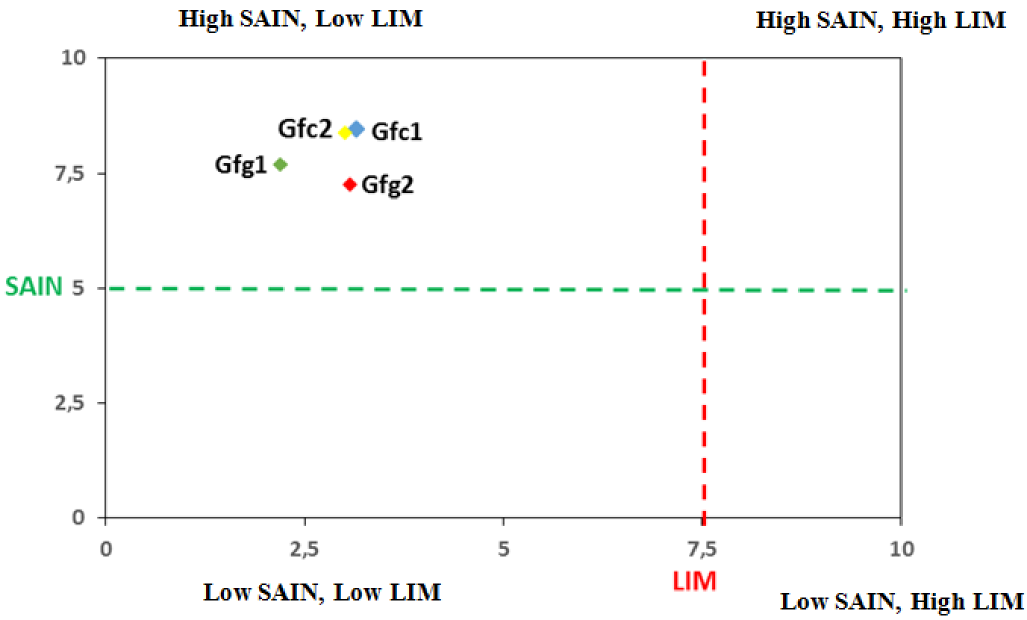

Figure 3. SAIN and LIM scores of sprouted cowpea seeds

4. Discussion

The aims of this study was to evaluate technological processes which optimize the nutritive values of flours from cowpea grains. The results showed a significant difference (p <0.05) between flours for each parameter. The proportions of dry matter in all flours was greater than 90%. The results showed that the dry matter content is very high in the different flours. These values could be explained by low moisture content. Indeed, the raw materials used for the production of these flours were from dried crops. This characteristic indicates that the resulted flours could be stored safely for long time without risk of microbial growth.

As for as the nutritional characteristics of cowpea flours, the results showed that the flours from germinated and fermented cowpeas are the true sources of protein ranged from 14.28 to 19.83% compared to flours from untreated cowpeas. The increase in the protein content after germination could have been caused by the metabolic pathways in the seeds being modified. The consumption of carbohydrates and the release of water and carbon dioxide will have led to a slight loss of dry matter, increasing the relative protein content (percentage protein on a dry matter basis). These results were in agreement with those of [20] who showed that fermentation can increase the contents of vitamins, proteins and amino acids. In addition, during the fermentation stages, [21] demonstrated significant proliferation of microorganisms, resulting in the formation of biogenic amines. According to the treatments applied, the results showed that, flours from cowpea grains heated for 1 h have the high protein contents compared to those of 1h30. The low protein content in flours from the grains heated at 1h30 could be explained by the degradation and denaturation phenomena during heating. The protein contents obtained in this result were lower than that obtained by [8] in cowpea in Algeria, which varied between 23.65% and 29.98%. Also, according to [22], legumes are rich in proteins with the content ranged from 20 to 50%. The difference of protein content obtained in this result and those of the literature could be explained either by the different varieties studied or by the technological treatments applied. Consumption of protein-rich foods may be involved in cell growth in children, in maintenance and regeneration of cells in adults. Due to the high protein content, cowpeas could be used to replace animal protein in certain region and during the lean season in the diet. Also, adding legumes to cereals could be contributes strongly to increase protein content in the final flour of cerals.

Carbohydrates content in this result were higher than 68%. Similar results were found by [23] in cowpea flour. Carbohydrates are essential compound for all living organisms and represent the most abundant biological molecules. The results establihed by [24] showed that 40 to 50% of calories brought by human nutrition come from carbohydrates. In this study, the lipid contents obtained in the various flours are less than 3% whatever the treatments applied. These results were similar to those obtained by [4,25] on other varieties of cowpea. The high levels of macronutrients in cowpea flours result in a good energy content (≈380 kcal / 100g). These result were in accordance with those of [26,27]. These authors explained the Sprouted seeds are natural sources of α-amylases that could be used to reduce porridges viscosity and, consequently allow to increase their energy density. Due to the high energy value, cowpea could be recommended in children and athletes diets.

Germinated cowpeas flours had the high ash content of 1.95%. These values were between 1.5%-2.5%, values recommended by [28] in the diet. These results were lower than those obtained by [23] in cowpea seed germinated for three days (3.54 ± 0.07 / 100g DM). This difference values could be explained either by the germination conditions applied (couple time / temperature) and by the varieties of raw materials used. The results also showed that cowpea were an important source of minerals. Minerals are extremely important because they are responsable to several metabolic reactions in body. Our results showed that phosphorus was abundant in flours Gfc2 and Gfg2 with the respective values of 240 ± 0.01 mg / 100g and 238 ± 0.01 mg / 100g. These phosphorus content were relatively higher than those obtained by [29] on other varieties of sprouted cowpea. The difference of these values can be explained by the germination conditions applied and by the different heating methods used. The potassium content was higher in flour from the control cowpeas Tfg2 (2170.00 ± 0.03 mg / 100g). This content was higher than those of roasted cowpeas (1269.00 ± 32.00 mg / 100g) cowpeas cooked after soaking (665.00 ± 36.00 mg / 100g) raw cowpea (1233.00 ± 19.00 mg / 100g) and roasted chickpea (1121.00 ± 12.00 mg / 100g) reported by [30].

The studies carried out by [24] have showed that the minerals were important for their absolute involvement in vital physiological functions such as the regulation of osmotic pressure, regulation of electrolyte flows between the intra-and extracellular medium (by Na / K pump). Due to the high potassium content, these germined and fermented cowpeas flours could be recommended in diet. For calcium, flours from sprouted seeds have significant contents. In contrast, the results were showed the low content of iron in the flours studied. This low iron content could be explained by the high content of antinutritional factors such as polyphenols and phytates which can complex iron. These results were in accordance with those obtained by [31,32]. These authors demontrated that the contribution of minerals to human nutrition was however limited due to the presence of anti-nutritional factors. Indeed, the high content of phytate in the diet could be responsible for the unavailability of certain minerals such as iron, Zinc, magnesium and calcium. These anti-nutritional factors could also influence the activity of certain enzymes such as pepsin, trypsin and amylases.

From a dietary point of view, dietary fibers have several health benefits including increased fecal bolus, decreased cholesterol, blood glucose and postprandial insulinemia [33,34]. The fiber content of the different flours studied (23 to 30%) was higher than those obtained by [25] on seven species of Vigna. The differences between these levels could be explained either by the extraction techniques or by the different species used.

As far as the nutritional profile, results showed that cowpea grains have a good nutritional profile because their have a high score SAIN higher than 5 and a low score LIM lower than 7.5. These score SAIN and LIM have classified cowpea in the group 1 food. This group contains foods recommended for health. The use of the SAIN and LIM system help to choose the best food for children and also help to reduce malnutrition. These results were in accordance with those obtained by [35]. These authors demonstrated that beans and peas have LIM scores below 7.5 and SAIN scores above 5. Beans and peas belong to the group of foods recommended for health. Our results also corroborate with those obtained by [36] which showed that beans and peas are low in calories, rich in minerals and protein.

5. Conclusion

The aim of this study was to optimize cowpea nutrients through the application of appropriate technological treatments. It follows from this study that: Cowpea grains are a good source of protein, fiber and minerals. Germination has a positive effect on protein and minerals content. Cowpea flours from grains heating in gas fire for one hour lead to preserve better cowpea nutrients. The nutritional profile of cowpea flours has shown that cowpea is healthy food for consumption. So it can be recommended for the health and growth of children.

Acknowledgements

Authors would like to thank all the farmers for their generosity, technical assistance and documentation. Their also thank the Nutrition and Technology teams of the Nangui Abrogoua University for their contribution in this study.

Statement of Competing Interests

The authors have no competing interest in relation to their work.

List of Abbreviations

RNI (Recommended nutritional intake)
SAIN: favorable aspects of the food
LIM: adverse aspects of the food
h: hour
DM: Dry matter

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