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Research Article

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Physico-chemical and Functional Qualities of *Vigna subterranea* (L.) Verdc. Seeds Powder Compared to those of its Starch

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Abstract The aim of this study was to study some physicochemical and functional properties of *Vigna subterranea (L.) Verdc*. seeds powder and starch cultivated in Ivory Coast in order to develop their using in the foods and industries. The starch extraction percentage of Vigna subterranea (L.) Verdc. seeds were 33.77%. The ash of its powder and starch were 2.183 ± 0.15% and 0.083 ± 0.03%, respectively. The pH was 5.22 ± 0.01 and 6.2 ± 0.01 for powder and starch, respectively. The average water absorption capacity was 224.146±1.42% for the powder and 92.208±1.09% for the starch. The both samples have perfect water solubility index in ordor of 35.50 ± 0.35 for the starch and 31.17 ± 0,17 for the powder. Their apparent density and lowest gelling concentration were 4% for starch and 8% for powder. *Vigna subterranea (L.) Verdc*. seeds powder and starch have boths good bulk density, good porosity, good dispersibility and acceptable oil absorption capacity. They have a greater affinity for water than refined oils. But the starch has greater affinity for crude palm oil than the water. The clarity of the powder and the starch decreases when the concentration of their gel, increases from 1% to 6%. The swelling power and solubility of the powder and starch increased when the temperature increases from 0°C to 95°C.

Keywords powder, starch, *Vigna subterranea (L.) Verdc*., physicochemical, functional, quality

1. Introduction

Legumes are important and valued foods because of their health, environmental and economic benefits. They are an essential and inexpensive source of vegetable protein, vitamins, and minerals [1]. *Vigna subterranea (L.) Verdc*., also called bambara groundnut or ground pea, is a minor food legume because its cultivation has remained within the limits of Sub-Saharan Africa areas. It has adapted to various climatic and ecological conditions by its tolerance to drought and its ability to germinate on poor soil [2]. In Ivory Coast, the culture extends from the center to the north [3]. Globally *Vigna subterranea (L.) Verdc.* occupies the 3rd important place in terms of production and consumption after groundnuts and cowpeas, with world production estimated at 160,378 tonnes [4]. Thus, around 70% of *Vigna subterranea (L.) Verdc*. of the world is produced in West Africa [5]. The seeds are used for human consumption, alone or mixed with other foods. The seeds of *Vigna subterranea (L.) Verdc*. are mainly used as a snack or a dietary supplement food [6, 7]. They can be eaten raw, boiled, dried as food. *Vigna subterranea (L.) Verdc*. has many medicinal [1], agronomic [8] and nutritional [9] advantages. Despite its nutritional potential, the physico-chemical and functional properties of *Vigna subterranea (L.) Verdc*. powder and starch of Ivory Coast are poorly understood, which limits its using. These proofs hinder the satisfaction of the food needs of the populations and the gain of the producers. The general objective of this work is to contribute to the development and promote the using of *Vigna subterranea (L.) Verdc*. powder and starch in the food industry through a thorough knowledge of some of its physico-chemical and functional properties.

2. Material and Methods

2.1 Plant Material

Vigna subterranea (L.) Verdc. seeds were bought at Adjemé market in Abidjan. They are transported to the Laboratory of Biocatalysis and Bioprocessing (LAB) of Nangui Abrogoua university for physicochemical and functional analyzes.

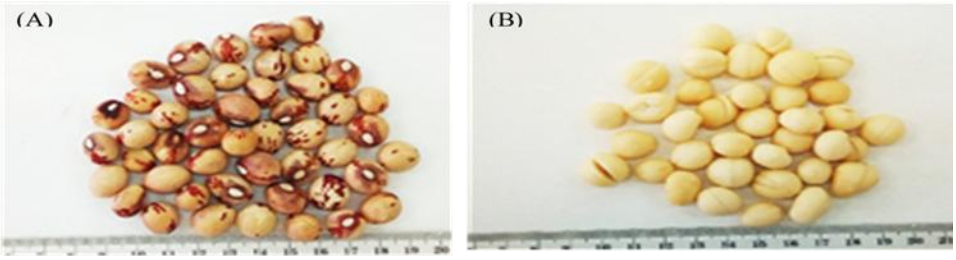

Figure 1: Grains of Vigna subterranea (L.) Verdc. (A): grains with coat film; (B): skinned grains.

2.2 *Vigna subterranea (L.) Verdc*. powder

The powder of *Vigna subterranea (L.) Verdc*. was obtained according to the method described by Rita and Sophia [10]. One (1) kg of *Vigna subterranea (L.) Verdc*. seeds was sorted in order to eliminate the defective seeds. The sound seeds were soaked in water for 24 h, skinned manually, dried at a temperature of 45°C in an oven during 12 hours and then grinded with a mixer. The milled grains were sieved with a mesh sieve of 250 µm and then stored in hermetically closed boxes.

2.3 *Vigna subterranea (L.) Verdc*. starch

Five (5) kg of *Vigna subterranea (L.) Verdc*. seeds were sorted and 4 kg of sound seeds were soaked in distilled water during 24 h. They were then manually peeled and washed twice with distilled water. The seeds were crushed in a blender (Moulinex, France) and then diluted in distilled water. The milled grains were filtered through a sieve of 250 µm. The filtrate would settle for 5 h at 25°C on the worktable and then the supernatant was poured. The obtained starch mass was taken up with distilled water (5 times the volume of the pellet) and homogenized by manual stirring in clockwise direction for 10 min. The final solution was filtered again through a sieve of 250 µm. The filtrate obtained was left to settle once more for 5 h on the worktable at 37°C. The supernatant was then separated from the pellet. The pellet taken up with NaOH solution (0.1 M; 5 times the volume of the pellet) and was stirred manually at 25°C each 10 min during 1 heure. The supernatant was removed, and the residue was taken up twice time with NaOH solution (0.1 M; 5 times the volume of the residue). The pellet was washed several times with distilled water to remove all the NaCl residues and to bring the pellet pH to 7. The obtained starch was dried at 45°C in an oven during 12 h then ground to pass through a sieve of 60 µm and stored in sealed plastic bags at 4°C in the refrigerator before next using [11].

2.4. Starch yield determination

The starch yield extraction from *Vigna subterranea (L.) Verdc*. grains were determined by the following mathematical relationship:

$$R(\%) = \frac{M_2}{M_1}\ X\ 100 \qquad (1)$$

R: Starch yield extraction (%);
M1: Mass of grains used for the extraction of starch (g);
M2: Mass of dry starch (g).

2.5. Some physicochemical properties of *Vigna subterranea (L.) Verdc*. powder and starch

2.5.1. Organic matter and ash content [12]

This method consists of calcining the sample at 550°C in a muffle furnace until a whitish ash of constant weight was obtained. 2 g of sample (PE) was weighed in a dried porcelain container of mass M1. The sample and porcelain container both gave a mass of M2. They were placed in a furnace muffle at 550 ° C until a white ash was obtained during 5h. The sample thus cremated was placed in a desiccator for cooling. The crucible containing the calcined sample was weighed (M3).

Organic matter is calculated according to the following formula:

$$M0(\%) = \frac{(M1-M2)}{p}\ X\ 100 \qquad (2)$$

M0: Organic matter (%);
M1: Mass of the crucible containing the test portion (g);
M2: Mass of crucible and ash (g);
P: Weight of the test portion (g).
The ash content is calculated as follows: Ash (%) = 100 – M0

2.5.2. pH of the Powder and starch

The method of Medoua *et al.* [13], was used to determine the pH of the powder or starch. Ten grams (10 g) of powder or starch was dissolved in 100 ml of distilled water. The suspension obtained, was homogenized by mechanical stirring for 15 min at the room temperature (25°C). It was then centrifuged at 3000 rpm for 15 min in a centrifuge (SIGMA Aldrich 2-PK, France). The pH of the supernatant was determined using a calibrated pH meter (Model S9026, Singapore).

2.6. Some functional properties of voandzou powder and starch

Water absorption capacity (CAE), water solubility index (ISE), Apparent density (DA), porosity, wettability, lowest gelling concentration (PPCG), the gel clarity (CG), the oil absorption capacity (CAH), the hydrophilic-lipophilic ratio, the dispersibility, the swelling capacity (PG) and the solubility of *Vigna subterranea (L.) Verdc*. grains powder and starch were determined.

2.6.1. Water absorption capacity (CAE) and water solubility index (ISE)

The CAE and ISE are determined according to the method of Adebowale et *al.* [14]. One (1g) gram of *Vigna subterranea (L.) Verdc*. seeds flour is dispersed in 10 mL of distilled water. After stirring for 30 min with a stirrer, the mixture is centrifuged at 5000 rpm for 15 min and the obtained wet pellet is dried at 105°C for 3h to constant weight.

2.6.2. Apparent density and porosity

The apparent density of the flour was determined according to the method of Narayana and Narasinga [15]. A 50 g of flour was placed in a 100 mL of graduated cylinder. All the flour was well adjusted in the graduated cylinder with a spatula and the volume was noted. Then, the graduated cylinder contained the flour was softly tapped on the test bench until a constant volume was obtained in the graduated cylinder.

2.6.3. Wettability

500 mL of distilled water was poured into a beaker of 600 mL container. Then, 1 g of flour sample was poured in a graduated cylinder of 25 mL and 1 cm of diameter. The flour was poured into the beaker of 600 mL containing distilled water until a height of 10 cm [16]. The wettability was determined to be the time (second) required for the flour sample to become fully wetted.

2.6.4. Lower gelling concentration (PPCG)

Floury suspensions of 1, 2, 4, 6, 8 and 10 % (w / v) were respectively homogenized by manual stirring for 2 min at 25°C. They were heated in a boiling water bath at 100°C for 1 h. They were then cooled at 4°C for 1 h. The

PPCG has been defined as the minimum concentration of gel that cannot dislocate when the test tube containing the suspensions has been tilted horizontally or overturned [17].

2.6.5. Clarity of the gel

A 1% (w / v) of floury suspension prepared in a centrifuge tube was homogenized using a vortex for 30 min at 25°C. The homogeneous solution obtained was heated in a boiling water bath for 30 min. During this heating, the tube was homogenized every 5 min. After this heating time, the tube was cooled for 10 min at 25°C. The clarity of the gel of this tube was determined at 650 nm at a spectrophotometer (JASCO V530) compared to distilled water [18]. The effect of the concentration of the powder or starch on the clarity of each dough obtained was also determined by repeating the procedure described above for the concentrations of 2, 4, 6, 8 and 10 % (w / v).

2.6.6. Oil absorption capacity

The oil absorption capacity is determined according to the method of Adebowale *et al.* [14]. 1 g of *Vigna subterranea (L.) Verdc*. seeds flour is dispersed in 7 ml of refined palm oil. After agitation for 30 min, the mixture is centrifuged at 4500 rpm for 10 min. The pellet of the centrifuged mixture is collected and then weighed.

2.6.7. Hydrophilic-lipophilic ratio

The hydrophilic-lipophilic ratio of *Vigna subterranea (L.) Verdc*. seeds powder or starch was calculated according to the technique of Njintang *et al.* [19].

2.6.8. Dispersibility

The dispersibility of *Vigna subterranea (L.) Verdc*. seeds powder or starch was determined by the method described by Mora-Escobedo *et al.* [20].

2.6.9. Swelling power (PG) and water solubility (SE)

The swelling power and the water solubility were performed at temperature ranged from 55 to 95°C with 10°C intervals between each measurement using the method of Adebooye and Singh [21].

2.7. Statistical analyzes

All the measurements were carried out in triplicate. Using the XLSALT software, statistical analyzes of the data were carried out. The comparisons of the means were determined according to the TUKEY Test. Statistical significance was defined at $p \leq 0.05$.

3. Results

3.1. Yield, ash content and pH of *Vigna subterranea (L.) Verdc*. seeds powder and starch

The starch was extracted from *Vigna subterranea (L.) Verdc*. seeds at 33.77 ± 0.02%. The ash content of *Vigna subterranea (L.) Verdc*. powder was 2.18 ± 0.15% and 0.08 ± 0.03% for the starch. The pH of the powder was 5.22 ± 0.01 and that of the starch was 6.2 ± 0.01.

Table 1: The starch yield, the ash content, and the pH of the *Vigna subterranea (L.) Verdc*. powder and starch

Parameter	***Vigna subterranea (L.) Verdc*.**	
	Starch	**Powder**
Yield (%)	33.77±0.02	-
Ash content (%)	0.08±0.03	2.18±0.15
pH	6.20±0.01	5.22±0.01

3.2. Some functional characteristics

3.2.1. CAE, ISE, DA, wettability, porosity and PPCG of *Vigna subterranea (L.) Verdc*. seeds

The water absorption capacity (CAE), the water solubility index (ISE), the apparent density (DA), the porosity, the wettability, and the lowest gelling concentration (PPCG) of *Vigna subterranea (L.) Verdc*. powder and starch are shown in table 2.

Table 2: CAE, ISE, Wettability, Porosity, PPCG of *Vigna subterranea (L.) Verdc.* seeds powder and starch

Parameter	Vigna subterranea (L.) Verdc.	
	Starch	Powder
CAE (%)	92.21 ±0.09	224.15 ± 0.42
ISE (%)	35.50 ± 0.35	31.17 ± 0,17
DA (g/ml)	0.95 ± 0.02	0.61 ± 0,02
Porosité (%)	24.04 ± 0.75	32.67 ± 0,16
Wettability (s)	112.00 ± 0.29	26.00 ± 0.15
PPCG (%)	4 ± 0.01	8 ± 0.01

3.2.2. Clarity of the gel

The gel clarity of *Vigna subterranea (L.) Verdc*. seeds powder and starch vary versus the concentration of their gel from 1% to 6% (Figure 2). The starch transmittance is 13.13 ± 0.06% at 1% and 3.27 ± 0.26% at 6%. It was then observed a ratio average of 25%. Those of the powder are 5.30 ± 0.44% at 1% and 0.03 ± 0.01% at 6% with a ratio average of 0.5%.

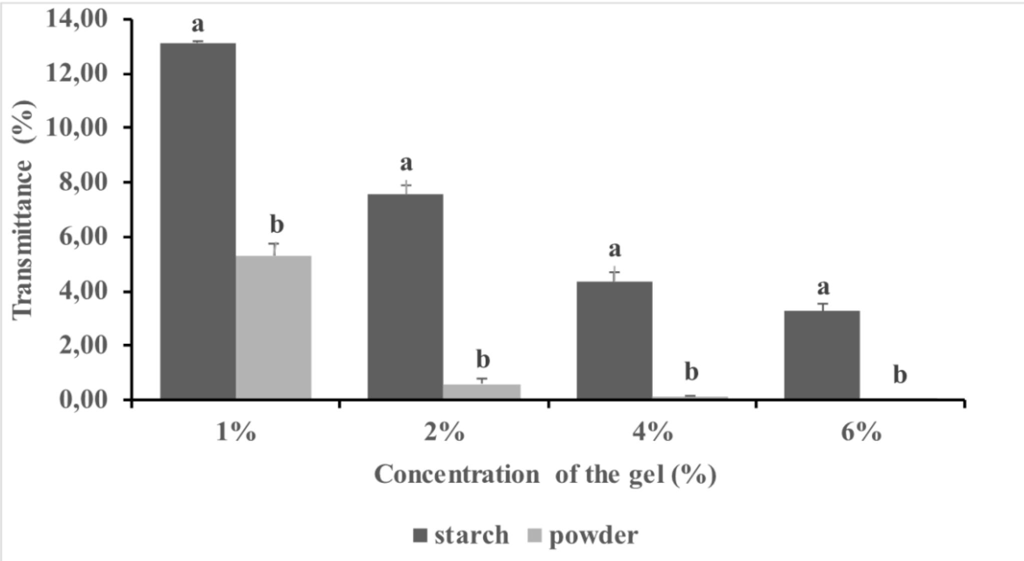

Figure 2: clarity of Vigna subterranea (L.) Verdc. powder and starch at different concentrations of their gel.

3.2.3. Oil absorption capacity (CAH) and the hydrophilic/lipophilic ratio (RHL) of *Vigna subterranea (L.) Verdc*. seeds powder and starch

Figures 3 and 4 show respectively the oils Dinor, Sunflower, Olive and crude palm oil (H. red) absorption capacity and their hydrophilic/lipophilic ratio (RHL) of *Vigna subterranea (L.) Verdc*. seeds powder and starch. The crude palm oil (H. red) CAH has the highest values 150.76 ± 0.35% for the powder and 321.500 ± 15.54% for the starch (Figure 3) than the other oils. The hydrophilic/lipophilic ratio values of starch differ with the type of oil (Figure 4). The RHL values of the powder do not show significant difference for dinor, sunflower and olive oils. However, there is a lowest RHL of crude palm oil (H. red) (Figure 4).

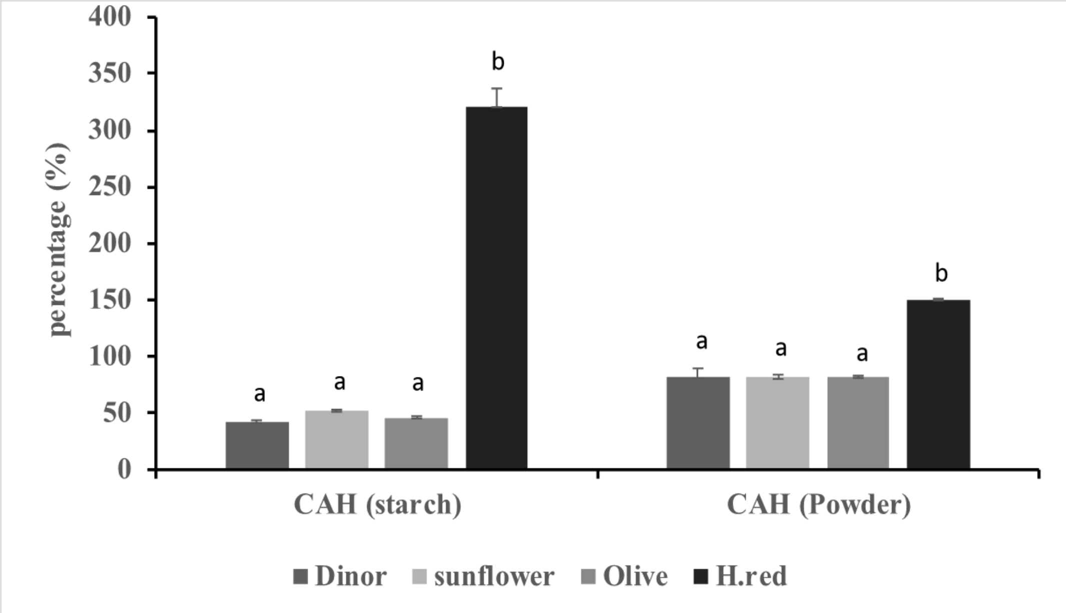

Figure 3: Oil absorption capacity (ACH) of starch and powder of Vigna subterranea (L.) Verdc. seeds for different oils (Dinor, sunflower, olive and crude palm oil (H. red)).

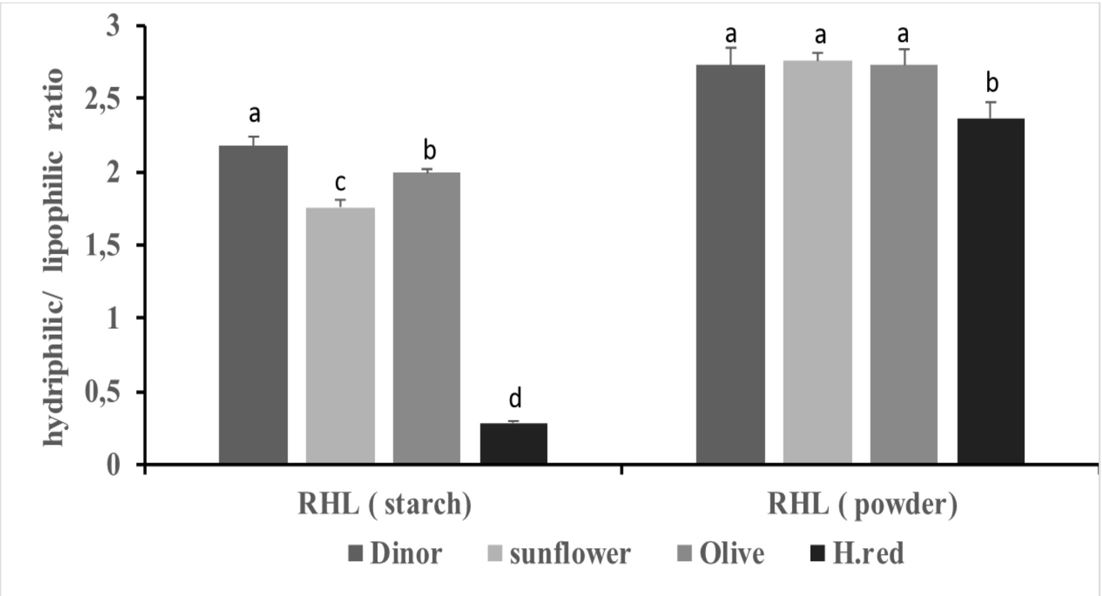

Figure 4: Hydrophilic / lipophilic ratio of starch and powder of Vigna subterranea (L.) Verdc. seeds for different oils (Dinor, sunflower, olive and crude palm oil (H. red)).

3.2.4. Determination of dispersibility

Figure 5 present the dispersibility of *Vigna subterranea (L.) Verdc*. seeds powder and starch versus time (min). The results show in the both cases an acceleration of the dispersibility for the first 5 min versus the time. They reache an optimum of 72.70 % for the powder and 80.35% for starch from 0 to 5 min. This corresponds to a ratio average of 0.90 %. These dispersibilities decrease slightly between 5 and 10 min, moving from 72.7 % to 71.43 % with a ratio average of 0.98 % for the powder and from 80.35% to 79.25 % with a ratio average of 0.99 % for the starch. Beyond 10 min, it was observed a stabilization of the dispersibility of the starch and the powder respectively at 71.43 % and 79.25 % with a ratio average of 0.90 % until the reach time of 45 min

(Figure 4). The dispersibility of the powder remains slightly lower than that of starch with a ratio average of 0.90 %.

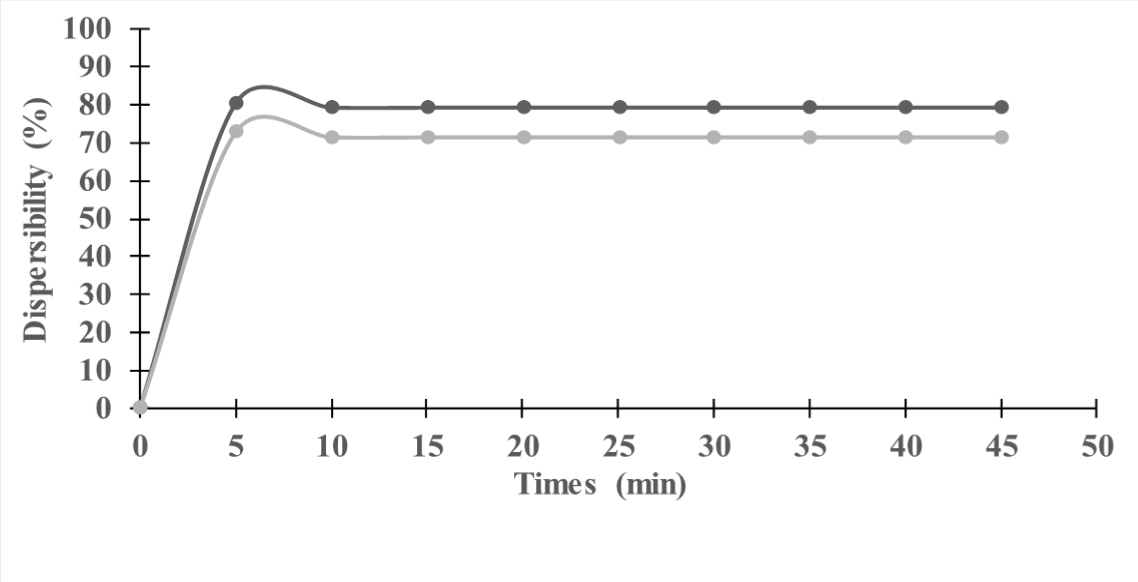

Figure 5: Dispersibility of Vigna subterranea (L.) Verdc. seeds powder and starch versu time

3.2.5. Swelling power and solubility

Figure 6 shows the swelling power of *Vigna subterranea (L.) Verdc*. powder and starch versus the temperature (°C). In the both cases, the swelling power has constant average values lower than 2% for temperatures of 0°C to 70°C. From 70°C to 95° C, the swelling power increase with a significant difference between the values of the powder and that of the starch. The swelling power of the starch is greater than that of the powder with a ratio average of 0.25%.

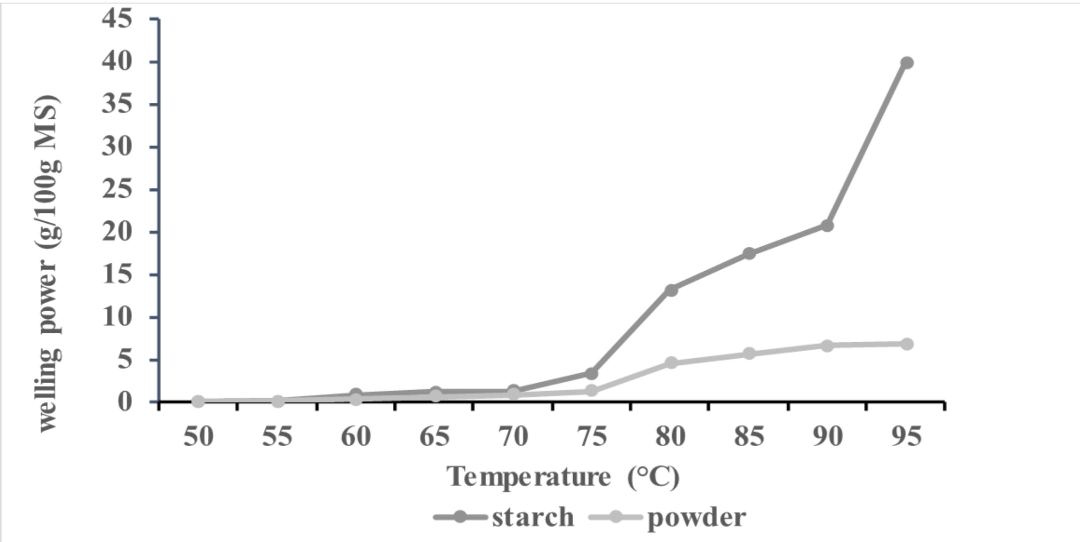

Figure 6: Swelling power of Vigna subterranea (L.) Verdc. seeds powder and starch versus the temperature

Figure 7 present the solubility of *Vigna subterranea (L.) Verdc*. seeds powder and starch versus the temperature. In the both cases, values of solubility increase slightly with the temperature, but they have similar values lower than 5% for temperatures of 0°C to 60°C. From 60°C to 95° C, the solubility increases exponentially on both sides. However, the solubility of starch is slightly higher than that of the powder, with a ratio average of 0.62%.

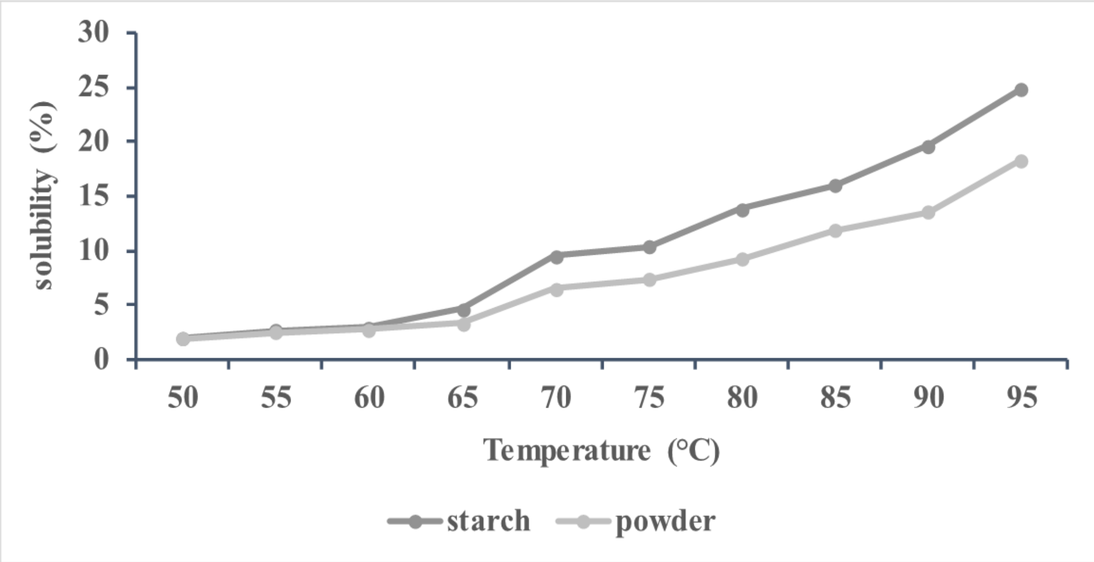

Figure 7: Solubility of Vigna subterranea (L.) Verdc. seeds powder and starch versus the temperature

4. Discussion

Physico-chemical and functional of food raw materials properties determine the different areas of application for various food products [22]. The starch yield of *Vigna subterranea (L.) Verdc*. seeds was 33.77% (g/100g of *Vigna subterranea (L.) Verdc*. seed). This value is higher than the starch yield of soybean seeds 27% described by Zitari [23]. This yield of starch improves the swelling power, solubility, and water retention capacity of *Vigna subterranea (L.) Verdc*. seeds [24]. The starch of *Vigna subterranea (L.) Verdc*. could be used for making various dishes such as porridge to childrens.

The ash of of *Vigna subterranea (L.) Verdc*. seeds powder and starch was 2.18% and 0.08% respectively. According to Trèche *et al.* [25], the ash content of biological material is an indicator of the quantity and the quality of mineral materials. The ash content of *Vigna subterranea (L.) Verdc.* seeds starch is similar to that of corn starch (a cereal) 0.08%. However, the ash of *Vigna subterranea (L.) Verdc*. seeds powder was higher than that of corn flour which was 1.4% [26]. The low value of satarch ash was due to the extraction process which delete some constituents unlike the powder [27]. The high value of *Vigna subterranea (L.) Verdc*. seeds powder ash could be justified by the presence of a significant quantity of non-leached materials confirmed by Trèche *et al* [25]. *Vigna subterranea (L.) Verdc*. seeds starch could be used in the production of various food and pharmaceutical products. Its quantity of mineral materials that is similar to that of corn, a cereal generally used in the pharmaceutical industry.

The pH (6.2) of the starch tends to neutrality. This could be explicated by the successive washings with the distilled water (pH=7) during the starch extraction process described by Achy [27]. *Vigna subterranea (L.) Verdc*. seeds powder is a slightly acidic product (pH (5.2) < 7). This acidity could be explained by the presence of acidic substances contained in Vigna subterranea (L.) Verdc. raw seeds according to Achy [27]. However, this acidity is not too pronounced because the pH (5.2) > 4. This slight acidity must be adjusted for the manufacture of food and pharmaceutical products based on starch and powder. To control this acidity, it is necessary to add basic or acidic substances at the final product to make them less or more acidic.

The CAE of *Vigna subterranea (L.) Verdc*. seeds powder of this study was 224.15% and that of the starch was 92.21%. These values are lower than those of Sirivongpaisal [28] who obtained values of 227% for the powder and 167% for the starch of *Vigna subterranea (L.) Verdc*. cultivated in Thailand. However, the CAE of *Vigna subterranea (L.) Verdc*. seeds powder (224.15%) of this studiy is slightly similar of that of Sirivongpaisal [28] value (227%). This slightly strong and similar value of powder in the both cases could be attributed to the presence of high concentrations of hydrophilic constituents such as proteins obtained by Sila and Malleshi, [29] in the raw material. This value indicates that more water could be necessary added to *Vigna subterranea (L.) Verdc*. seeds powder to increase its moulding. According to Figoni [30], a high absorption of water is desirable in baking of *Vigna subterranea (L.) Verdc*. seeds powder to obtain the final bread. The increase of the sample humidity level can that reduce the its alteration speed. However, the low value of the CAE obtained with starch in this study is probably due to the starch extraction process which lead to the loss of certain molecules But it was desirable to form thin lumps of dough film for a final food dough.

The ISE of *Vigna subterranea (L.) Verdc*. seeds powder and starch are 31.17% and 35.50% respectively. These values are major importance because they are higher than those of corn powder and starch which vary of 9.7% to 15% and then those of gable powder and starch which vary of 0.3% to 2.4% according to Henriquez [31] results. However, according to Colonna *et al.* [32], these high values could be explained by the presence of the same soluble molecules in the raw material. They give information about the reducing of the starch size. A powder that has a high ISE is ideal for formulating food for infants confirmed by Altan *et al.* [33].

The DA of *Vigna subterranea (L.) Verdc*. seeds powder (0.612 g/ml) is lower than that of uncooked wheat flour (0.86 g/ml) and that of unfermented flour (0.86 g/ml) confirmed by Ijarotimi [34]. However, this value is higher than that obtained for chickpea powder (0.54 – 0.57 g/ml) by Kaur and Singh [35]. The value of its starch (0.95 g/ml) is higher than that of wheat starch (0.65-0.78 g/ml) described by Kaur and Singh [35, 36]. According to Falade *et al.* [37], the size of the particles would be at the origin of these high values because they would be inversely proportional to the apparent density. The high DA obtained with the starch would be desirable to reduce the thickness of the final dough which is an important factor in the manufacturing of diet of children according to Padmashree *et al.* [38]. Also, the low value obtained with the powder would be best suited for infants feeding because it would facilitate the digestion confirmed by Nelson-Quartey *et al* [39].

According to Shittu *et al.* [40], the porosity makes important roles during mixing, conditioning, and transport of food particles. The high porosity of *Vigna subterranea (L.) Verdc*. seeds powder obtained in this study suggests that it is important to be used in the formulation of infant foods.

The time (26 s) of *Vigna subterranea (L.) Verdc*. seeds powder wettability is lower than that of soybean powder (31 s) and that of wheat (52 s) reported by Nwosu *et al.* [41]. This time could be explained by the affinity that the different constituents of powders and starches have for water but also for the structure (porosity and capillarity) of this same water. According to Pohl *et al.* [42], the powder of this study is very wettable because its wettability time (26 s) is less than 30 seconds, the standard time. Likewise, the starch of *Vigna subterranea (L.) Verdc*. seeds starch is wettable because its wettability time (112s) is less than 120 seconds, the standard time. So that, *Vigna subterranea (L.) Verdc*. seeds powder would then be useful for infants feeding because it would ensure a rapid food manufacturing, ingestion, and digestion confirmed by Niro [43].

The PPCG of *Vigna subterranea (L.) Verdc*. seeds powder (8%) is similar to that of peanut flour (6 to 8%) described by Fékria [44] and lower than that of cowpea (16%) obtained by Fasasi *et al.* [45]. The low PPCG of *Vigna subterranea (L.) Verdc*. seeds starch (4%) was probably due to its amylose and amylopectin composition. According to Akaereue and Onwuka [46], a high PPCG value of a material powder can be explained by the variation of its various constituents' ratios such as starch, lipids, and proteins. So, the gelation process does not depend of the quantity or the quality of the protein but also of other components of the sample, such as lipids. The gelation introduced that hydrophobic components into the samples film which could be at the origin of the PPCG of the powder increasing, described by Schmitz *et al.* [47]. According to Akintayo *et al.* [48], the lower is the PPCG, the better is the protein or starch of the ingredient gelation capacity. The high PPCG of *Vigna subterranea (L.) Verdc*. seeds powder means that it cannot form thick gels at a meal formulating. However, it causes the formation of viscous dough. *Vigna subterranea (L.) Verdc*. seeds starch (a low PPCG) would be beneficial in the formation of gelatinous products. According to Obatolu and Cole [49], the starches which form a gel in small concentrations are not ideal for children's diets. They would require a lot of dilutions at their manufacturing to improve their final digestibility.

The values of *Vigna subterranea (L.) Verdc*. seeds powder and starch clarity could be explained by the swelling of amylopectin granules. The swelling causes significant leaching of the amylose which increase the concentration of the solution and that making it concentrated. So, the final dough appears cloudy or opaque described by Craig *et al.* [18]. Thus, it would reflect the maximum of light that would be in contact of the environment or the sample according to Tetchi *et al.* [50]. The size, the degree of dispersion of macromolecules (amylose and amylopectin) and the presence of lipids would influence the clarity of the starch solution described by Craig *et al.* [18]. *Vigna subterranea (L.) Verdc*. seeds powder and starch cannot be used as ingredients in sauces and soups because they require intense clarity. However, they can find an application in food products where opacity is important (i.e. production of noodles and salad dressing).

The value of the CAH obtained with crude palm oil for *Vigna subterranea (L.) Verdc*. seeds starch is high than the other oils used. This value could be explained by the imprisonment of the molecules of the crude palm oil in the molecular film during the establishment their structure due to the apolar grouping confirmed by Abou *et al.* [51]. These high values of crude palm oil CAH could also be explained by its composition in triglyceride, phytosterol, vitamin E unlike other refined oils. Besides the crude palm oil, the CAH of the other oils (dinor, sunflower and olive oils) powder is higher than that of the stach. However, the values of *Vigna subterranea (L.) Verdc*. seeds powder CAH are lower than those of northern beans (3.29 ml / g) described by Chel *et al.* [52]. *Vigna subterranea (L.) Verdc*. powder and starch would therefore be useful in the design and manufacture of bakery and meat products confirmed by Otegbayo *et al.* [53].

The values obtained with the RHL are higher than those reported by Njintang *et al.* [19], on the cowpea study with a ratio of 1.2. These results show that *Vigna subterranea (L.) Verdc*. seeds powder has a better affinity for water than the refined oils and crude palm oil. Also, the RHL of the starch has a better affinity for water and crude palm oil than for other refined oils (dinor, sunflower and olive oils). It would then be desirable to use *Vigna subterranea (L.) Verdc*. seeds powder and starch to the formulation of products requiring a high-water absorption capacity.

The dispersibility of *Vigna subterranea (L.) Verdc*. seeds powder (71.43%) is higher than the raw chickpea powder (25.3%) and that of the powder of two groundnut cultivars (48.4% and 53%) obtained by Milan-carrillo *et al.* [54]. That of *Vigna subterranea (L.) Verdc.* seeds starch (79.25%) is lower than that of wheat (90%) reported by Adeleke [55]. The high value of the starch dispersibility compared to the powder is probably due to the absence of fat and its finer size of the structure described also by Kulkarni *et al.* [56]. These authors have indicated that, the higher value of the dispersibility increase the capacity of the powder to reconstitute its network structure in the water to give a fine and coherent final dough.

The swelling power and solubility of *Vigna subterranea (L.) Verdc*. seeds powder and starch have a similar variation. The swelling and solubility models presented by Vigna subterranea (L.) Verdc. seeds powder and starch are similar to the typical model of legume starch reported by Oates [57]. These values are higher than those of the powder and starch of *Vigna subterranea (L.) Verdc.* cultivated in Thailand described by Sirivongpaisal [28]. The higher solubility and swelling values of *Vigna subterranea (L.) Verdc*. starch could be explained by the size of its granules and the amylose content. When an aqueous suspension of starch is heated at a critical temperature, the hydrogen bonds responsible of the granules structural integrity begin to weaken. They allow then water penetration and linear hydration of amylopectin. However, all those reactions depended of the type of starch and various other factors (pH, constituents, initial structure). They also lead to the release of amyloidosis described by James [58]. In the both cases, values of *Vigna subterranea (L.) Verdc*. seeds starch swelling power and solubility are higher tan those of the powder. These lowest values of the powder swelling power and solubility could be explained by the probable presence of lipids. According to Amani *et al.* [59], the long chains of amylose would complex the lipids and thus reduce the swelling of the starch granules. *Vigna subterranea (L.) Verdc*. seeds powder and starch could find their applications in noodle production reported by McComick *et al.* [60], in bakery products and as thickener in liquid and semi-liquid foods due to their capacity to absorb water. They will thus improve the consistency of food, results approved by Fasasi *et al.* [45].

5. Conclusion

This study was performed to promote *Vigna subterranea (L.) Verdc*. seeds by exploring its applicability in the food and industry. Few physicochemical and functional properties of its powder and starch have been determined and compared. The results of the analysis have shown that they are full of great potential. This study revealed that *Vigna subterranea (L.) Verdc.* seeds powder has a better capacity to absorbing water and oils (refined and crude oils), a good hydrophilic / lipophilic ratio, better porosity, a high apparent density, an acid pH and an appreciable quantity of ash (minerals) than its starch. *Vigna subterranea (L.) Verdc*. seeds powder would be recommended in breadmaking, pasta manufacturing and baby food production. However, *Vigna subterranea*

(L.) Verdc. seeds starch has a good capacity of absorption in crude oil, an agreeable clarity, high dispersibility and apparent density, a good small gelling concentration, a good capacity of swelling, an appropriate solubility, and a slightly acidic pH. It could also be used, as an improvement of emulsions products, thickener to sauces and soups and then to dressings confession.

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