

# STUDY OF THE VARIATIONS IN THE PHYSICAL-CHEMICAL, FUNCTIONAL, GRANULOMETRIC, MINERAL AND ANTIOXIDANT PROPERTIES OF THREE (3) FLOUR POWDERS FS, F40, F50 OF YOUNG SHOOTS OF ROAN (*BORASSUS AETHIOPUM* MART.) SHOOTS DEPENDING ON ACCORDING TO THE DRYING METHOD

## ABSTRACT :

The young shoot of roan (*Borassus aethiopum* Mart.) is cultivated and consumed in the cities of central Côte d'Ivoire such as Dimbokro. However, it has conservation problems, its nutritional value is not well known by the population and it is little processed by local industries. This study is a valorization of the young shoots of roan. In this study, the young shoots were dried respectively in the sun, at 40°C, at 50°C and then crushed to give respectively the FS, F40, F50 flour powders. The study of the physico-chemical properties gave, according to the flour powders, 6.47 to 7.17% for moisture; 5.71 to 6.07 for pH; 130.39 mg/100g on average for the reducing sugar content; 2.42 to 3.94% for total sugars; 0.53 to 1.07% for lipids; 6.23 to 7.57% for protein content; 2.19% on average for ash; 2.72 to 3.21% for fibre; 82.56 to 84.07% for total carbohydrates; 365.65 to 369.69 Kcal/100g for the energy value. The study of functional properties revealed 60.55 to 63.63% for dispersibility; 0.70 to 0.75 g/ml for tapped density; 143.08% on average for water absorption capacity; 118.67 to 128% for oil absorption capacity; 18.17 to 25.66% for foaming capacity. The granulometry showed that all three (3) flour powders are composed of grains whose size is lower than 1mm. In addition 62.7%, 52.9%, 47.8% of the grains of the FS, F40, F50 flour powders have sizes in the interval ]250 µm, 125 µm]. The young shoots flour powders contain 243.45 to 280.44 mg/100g polyphenols; 68.46 to 83.03 mg/100g flavonoids; 45.47 to 59 mg/100g tannins. The mineral contents are 0.04 to 0.11 ppm for sodium; 0.02 ppm on average for phosphorus; 0.07 to 0.18 ppm for potassium; 0.11 ppm on average for calcium; 0.04 to 0.07 ppm for iron. The three (3) flour powders FS, F40, F50 of young shoots contained macronutrients, high energy value, fibre, interesting functional and granulometric properties, antioxidants, minerals that are beneficial for local populations and can be used by the food industries.

**Keywords:** Young shoots, flour powder, *Borassus aethiopum*, physicochemical properties, functional properties

## INTRODUCTION

The roan palm is a dioecious tree plant (Mollet, 1999) [1]. In Africa, it is called the sentinel of the savannah because of its size. It is a tall palm tree that can grow to an average height of 20 m or even 30 m, with a diameter of up to 1 m (Mollet, 1999) [1]. The natural range of the roan palm (*Borassus aethiopum* Mart.) is the semi-arid or sub-humid part of Africa (Mollet, 1999; Ali et al., 2010) [1,2]. It grows naturally from Senegal to the Central African Republic (Ali et al., 2010) [2].

In the central regions of Côte d'Ivoire (Toumodi, Dimbokro, Didiévi, ...), roan is very important for the population. In general, more than 88% of roan is used for the well-being of the population (Ouinsavi et al., 2011) [3]. It is used as food (fruit, sap, young shoots) (Waziri et al., 2010) [4], as building material (stipe, foliage, etc.) (Akinniyi et al., 2000; Sanon et al., 2007) [5,6]. It is also used in traditional African medicine (roots, male inflorescence) (Sanon et al., 2007; Waziri et al., 2011; Sakande et al., 2013) [6,7,8]. The fibres are used to make nets for fishing. The leaves are used to make a variety of objects: brushes, baskets, fences and roofs (Mollet, 1999) [1].

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The female plants of the roan palm produce so-called fleshy fruits with stones, derived from the transformation of the sclerenchyma of the endocarp. These fruits are commonly called drupes. A mature tree can produce about 200-300 drupes annually (Davis and Johnson, 1987) [9]. Some of the naturally fallen fruits remain in the forest for the regeneration of the tree and some are collected by the rural population for food and seedlings. Each fruit gives an average of three young shoots. They are obtained after 6 to 8 months by the rural population putting the ripe fruits in the ground (Ajanvon, 2019) [10]. The young shoot roan is a perishable commodity because it contains 52% moisture (Niamke, 2014) [11] which makes its consumption periodic and a considerable loss rate hence the need to transform it into flourpowder. This alternative facilitates its storage and allows people to keep it longer and think of other uses.

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Moreover, in central Côte d'Ivoire, the young shoots are sold on-in the local market at low prices to discerning consumers for food, which does not improve the living conditions of the farmers. Transforming them into flourpowder with nutritional potential and for use in biscuit, pastry and bakery products would add value to the young shoots, which would benefit the farmers. In addition, farmers will turn away from the production of roan wine, which brings them money but destroys roan, which is an ecological tragedy. However, the method of drying the young shoots of roan is a very important operation for the good quality of the flourpowder produced. This study is therefore a valorisation of the young shoots of roan. It will consist in determining for the three (3) types of flourpowders:

- Physicochemicalproperties
- Functionalproperties
- Granulometry
- Antioxidants
- Minerals

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## 1 MATERIALS AND METHODS

### 1.1 Materials

#### 1.1.1. Young shoots of roan

The 6 to 8 months old 60 kg each young shoots of roan studied come from Dimbokro in central Côte d'Ivoire. These young shoots are 6 to 8 months old.

### 1.2 Methods

#### 1.2.1. Sampling

Samples of young shoots of roan were purchased in three (3) markets in the town of Dimbokro. For each market, 20 kg of saplings were purchased from three (3) women

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sellers, which makes 60 kg of saplings purchased per market. The total was 180 kg for all three markets. These samples of young shoots were taken to the laboratory for further analysis.

### 1.2.2. Production of young shoots flourpowder

The young shoots flourpowder was obtained in several steps. First, the tubers of young shoots were peeled, washed and cut into small pieces. These pieces were then divided into three (3) batches which were dried respectively in an oven at 40°C, at 50°C and in the sun for 4 days. Finally, the dried pieces of tubers from each batch were crushed and the crushed material was sieved using a 2mm diameter sieve. Thus, three (3) types of young shoots flourpowder were obtained: F40, F50, and FS, respectively for oven drying at 40°C, 50°C and sun drying

### 1.2.3. Determination of physico-chemical properties

#### 1.2.3.1 Moisture content

The method of moisture determination is that proposed by AOAC (1990) [12]. Moisture was assessed by drying 5 g of FS, F40, F50 flourpowders in an oven (MEMMERT) at 105 °C for 24 h.

#### 1.2.3.2 Determination of pH

The pH is-was determined according to the AOAC (1990) method [12]. Ten (10) grams of sample are-were diluted in 100 mL of distilled water for 1H. The solution obtained is-was filtered through filter paper (Whatman). The pH is measured directly by immersing the electrode of the pH meter (HANNA), previously calibrated, in the filtrate obtained.

#### 1.2.3.3 Total and reducing sugar content

##### a. Extraction of ethanosoluble sugars

Ethanosoluble sugars are-were extracted according to the method of Agbo et al (1986) [13] as follows.

One (1) gram of flourpowder is-was weighed and then diluted in 10 mL of ethanol (80%; v/v). To the resulting mixture are-were added 2 mL of zinc acetate (10%; w/v) and 2 mL of oxalic acid (10%, w/v). The mixture is-was then centrifuged at 3000 rpm for 10 min. The pellet is-was taken up with 10 mL ethanol (80%; v/v) and centrifuged again at 3000 rpm for 10 min. The supernatants are-were transferred to a 50 mL flask and the excess ethanol is-was evaporated in a sand bath for 10 min. The resulting solution is-was made up to 50 mL with distilled water.

##### b. Determination of total sugars

The total sugar content is-was determined according to the phenol-sulphuric method as described by Dubois et al (1956) [14].

One hundred (100) µL of ethanosoluble sugar extract is-was introduced into a test tube, then 0.9 mL of distilled water, 1 mL of 5% (w/v) phenol and 5 mL of concentrated sulphuric acid are-were added successively. After shaking and cooling the tube, the absorbance is-was read with a spectrophotometer (PG INSTRUMENTS) at 490 nm against a blank. The determination of the quantity of total sugars is-was carried out using a standard range of glucose stock solution at 1 mg/mL carried out under the same conditions as the test.

### c. Determination of reducing sugars

The quantification of reducing sugars ~~iswas~~ performed according to the method of **Bernfeld (1955) [15]**.

One (1) mL of ethanolsoluble extract of sugars ~~iswas~~ introduced into a test tube. To the contents of this tube, 0.5 mL of distilled water and 0.5 mL of DNS solution ~~arewere~~ added. The whole mixture ~~iswas~~ heated in a boiling water bath for 5 min. After cooling, 2 mL of distilled water ~~iswas~~ added and the absorbance of the solution ~~iswas~~ read with a spectrophotometer (PG INSTRUMENTS) at 540 nm against a blank. A standard range established under the same conditions as the test from a stock solution of glucose (1 mg/mL) ~~iswas~~ used to determine the quantity of reducing sugars.

#### 1.2.3.4. Lipid content

Lipids were quantified from 10 g of each ~~flourpowder~~ by Soxhlet extraction using 300 mL n-hexane for 7 h (**AFNOR, 1986) [16]**. The resulting hexane-oil mixture was recovered and separated with a rotavapor (Heidolph). The flask, initially tared and containing the oil, was weighed to determine the mass of oil extracted.

#### 1.2.3.5. Protein content

Crude protein was determined by total nitrogen determination according to the Kjeldhal method (**AOAC, 1990) [12]**. Thus 1g of each ~~flourpowder~~ was mineralised in the presence of Kjeldahl catalysts (potassium sulphate K<sub>2</sub>SO<sub>4</sub> and copper sulphate and concentrated sulphuric acid H<sub>2</sub>SO<sub>4</sub>). The mineralisate was purified by distillation. Nitrogen was then quantified by titration with 0.1 N H<sub>2</sub>SO<sub>4</sub>. The crude protein content of the ~~flourpowders~~ was deduced from the nitrogen content using 6.25 as a conversion factor.

#### 1.2.3.6. Ash content

The ash content (total mineral matter) was determined according to the method described by **AOAC (1990) [12]** by incinerating five (5) grams of each ~~flourpowder~~ in a muffle furnace (PYROLABO) at 550°C for 12 h.

#### 1.2.3.7. Fibers content

The determination of the fibers content was carried out according to the method of **Wolff (1968) [17]**. The determination of the crude fibers content consisted in treatment of 2 g of FS, F40, F50 ~~flourpowder~~ sample with 50 mL of 0.25 N sulfuric acid and 50 mL of 0.31 N sodium hydroxide and filtration of the resulting solution upon Whatman paper. The residue was dried for 8 h at 105 °C then incinerated at 550 °C for 3 h into ovens . The final residue was weighed as crude fibers and expressed in percentage.

#### 1.2.3.8. Total carbohydrates content and energy value

Total carbohydrates and energy values were determined using calculation formulas recommended by **FAO (2002) [18]** accounting the moisture, fat, protein, ash contents and the energy coefficients for macromolecules.  $TCC (\%) = 100 - [P(\%) + M(\%) + F(\%) + A(\%)]$   
 $CEV \quad (kcal/100g) \quad = \quad [(4 \times P) \quad + \quad (9 \times F) \quad + \quad (4 \times C)]$

With: TCC, total carbohydrates content; CEV, caloric energy value; P, protein content; M, moisture content; F, fat content; A, ash content; C, total carbohydrates content

## 1.2.4. Determination of functional properties

### 1.2.4.1. Dispersibility of the flourpowders

The dispersibility of the flourpowders was determined according to the (modified) technique described by Kulkarni et al (1991) [19]. A volume of 10 mL of distilled water was added to 1 g of flourpowder in a graduated cylinder. The mixture was stirred thoroughly with a rod for 2 min. The dispersibility of the flourpowder is was the difference between the total volume ( $V_0$ ) of the particles just after manual agitation and the volume ( $V_t$ ) of the deposited particles recorded at time t (min).

$$\text{Dispersibility (\%)} = \frac{(V_0 - V_t)}{V_0} \times 100$$

### 1.2.4.2. Tapped density

The tapped density (DT) of the flourpowders was determined using the (modified) technique of Oladele and Aina (2007) [20]. A quantity of 50 g of flourpowder (ME) was placed in a 100 mL graduated cylinder. The test tube was then gently tapped on the bench until a constant volume  $V_t$

$$\text{DT (g/ml)} = \frac{\text{ME}}{V_t}$$

### 1.2.4.3 Water absorption capacity (WAC)

The water absorption capacity (WAC) of the flourpowders was determined using the (modified) techniques of Phillips et al. (1998) [21]. Exactly 1 g of each flourpowder ( $M_0$ ) was dissolved in 10 mL of distilled water in a centrifuge tube. This mixture was stirred for 30 min by a shaker and then kept in a water bath at 37 °C for 30 min. It was then centrifuged at 14674 xg for 15 min in an ORTO ALRESAR centrifuge. The resulting pellet ( $M_2$ ) was weighed and then dried at 105 °C to a constant mass ( $M_1$ ). The WAC was calculated from the following relationships:

$$\text{WAC (\%)} = \frac{(M_2 - M_1)}{M_1} \times 100$$

#### 1.2.4.4. Oil absorption capacity

The oil absorption capacity of the [flourpowders](#) was determined using the (modified) technique of [Eke and Akobundu \(1993\) \[22\]](#). A 1 g sample ( $M_0$ ) of [flourpowder](#) was dissolved in 10 mL of oil. The mixture was stirred for 30 min at room temperature using a magnetic stirrer and then centrifuged at 11886 xg for 10 min in an ORTO ALRESAR centrifuge. The recovered pellet was weighed ( $M_1$ ). The oil absorption capacity (OAC) was calculated from the following formula:

$$\text{OAC (\%)} = \frac{(M_1 - M_0)}{M_0} \times 100$$

#### 1.2.4.5. Foaming capacity

The foaming capacity (FC) of the [flourpowders](#) was determined using the (modified) technique of [Coffman and Garcia \(1977\) \[23\]](#). Three grams of [flourpowder](#) were placed in a 50 mL graduated cylinder that had been oven dried at 50 °C. Then 30 mL of distilled water was added to the sample to facilitate dispersion of the [flourpowder](#) in the test tube and the volume was noted (volume before homogenisation). The test tube was then vigorously shaken by hand and the new volume was read off the test tube (volume after homogenisation). The volume of the foam obtained was calculated as the difference between the volume after homogenisation ( $V_{\text{after}}$ ) and the volume before homogenisation ( $V_{\text{before}}$ ). The foaming capacity (FC) was calculated from the following formula:

$$\text{FC (\%)} = \frac{V_{\text{after}} - V_{\text{before}}}{V_{\text{before}}} \times 100$$

#### 1.2.5. Determination of [flourpowder](#) grain size

The particle size of the [flourpowders](#) [iswas](#) estimated by fractionating the total mass of [flourpowders](#) through a series of sieves of decreasing mesh size (2mm, 1mm, 500um, 250um, 125um and 63um). Underneath the 63um sieve [iswas](#) a collection lid.

The sample [iswas](#) placed in a sieve with different mesh sizes and closed with a lid. The sieve [iswas](#) stirred for 30 minutes.

The grains [arewere](#) deposited one after the other according to their diameter size and the rejects and passings of each sieve [arewere](#) weighed with a technical balance (Denver instrument SI-4002) of precision.

## 1.2.6. Determination of antioxidants

### 1.2.6.1. Extraction of phenolic compounds

Phenolic compounds [arewere](#) extracted with methanol by the method of **Singleton et al (1999) [24]**.

One (1) gram of sample of FS, F40, F50 ~~flour~~powders [iswas](#) homogenised in 10mL of 70% (v/v) methanol. The resulting mixture [iswas](#) centrifuged at 1000 rpm for 10 min. The pellet [iswas](#) recovered in 10 mL of 70% (v/v) methanol and centrifuged again. The supernatants [arewere](#) collected in a 50 mL flask and made up to the mark with distilled water.

### 1.2.6.2. Determination of total phenols

The method of **Singleton et al (1999) [24]** [iswas](#) used for the determination of total phenols. One (1) mL of methanolic extract [iswas](#) introduced into a test tube. To the contents of the tube [iswas](#) added 1mL of Folin-ciocalteu reagent. The tube [iswas](#) left to stand for 3min and then 1mL of 20% (w/v) sodium carbonate solution [iswas](#) added. The contents of the tube [arewere](#) made up to 10 mL with distilled water. The tube [iswas](#) placed in the dark for 30 min and the OD reading [iswas](#) taken at 745 nm against a blank. The amount of phenol in the sample [iswas](#) determined by a standard range using a stock solution of gallic acid (1 mg/mL) under the same conditions as the test.

### 1.2.6.3. Determination of tannins

The determination of tannins was carried out according to the method described by **Bainbridge et al. (1996) [25]**.

One (1) mL of methanolic extract [iswas](#) introduced into a test tube. To the contents of the tube [iswas](#) added 5 mL of vanillin reagent. The tube [iswas](#) left to stand for 20 min in the dark and the optical density (OD) [iswas](#) read at 500 nm against a blank. The amount of tannin in the samples [iswas](#) determined using a standard solution of tannic acid (2 mg/mL) under the same conditions as the test.

### 1.2.6.4. Determination of flavonoids

The flavonoid assay was performed as described by **Meda et al. (2005) [26]**.

A volume of 0.5 mL of methanolic extract was introduced into a test tube. To the contents of the tube [arewere](#) successively added 0.5 mL of distilled water, 0.5 mL of 10% aluminium chloride, 0.5 mL of 1M potassium acetate and 2 mL of distilled water. The tube [iswas](#) allowed to stand for 20 min in the dark and the optical density (OD) [iswas](#) read at 415 nm against a blank. The amount of flavonoids in the sample [iswas](#) determined using a standard solution of quercetin (0.1 mg/mL) under the same conditions as the test.

## 1.2.7. Determination of minerals

The determination of the minerals was carried out by atomic absorption with an air-acetylene flame AAS 20 type VARIAN.

The FS, F40, F50 flourpowders were ground to a particle size of 0.1mm. A mass of 0.3 g of each flourpowder ~~iswas~~ calcined at 600°C for 5h in an oven until a white ash ~~iswas~~ obtained. After cooling, 5 mL of 1N nitric acid was added and evaporated to dryness on a sand bath. To the residue ~~iswas~~ added 5mL of 1N hydrochloric acid and the whole ~~iswas~~ fired again at 400°C for 30 min. Once the calcined product ~~iswas~~ recovered from the furnace, 10mL of 0.1N hydrochloric acid ~~iswas~~ added to the crucible to recover the product. The resulting mixture ~~iswas~~ poured directly into a 50 ml volumetric flask. The operation (washing the crucible with 10 ml of 0.1 ml HCL) ~~iswas~~ repeated three times and the flask ~~iswas~~ filled to the mark. Allow to decant and take the supernatant for filtration with 0.45 µm wattman paper or with a 0.36 syringe filter. The elements contained in the solution ~~arewere~~ then determined by AAS.

**NB:** To avoid interference from the elements Ca, K, 5 ml of lantane chloride ~~iswas~~ added.

### 1.2.8. Statistical study

All statistical analyses were carried out with R software. The physicochemical and functional properties, the determination of antioxidants and minerals of the three flourpowders were compared using the ANOVA test. The null hypothesis (H0) ~~iswas~~ that all the means are equal and that the properties are equal between the 3 flourpowders and for the alternative hypothesis (H1) there ~~iswas~~ a significant difference between the 3 flourpowders. The significance level was set at 0.05 for all analyses.

To perform the ANOVA test, the Shapiro-Wilk and Bartlett tests were performed a posteriori to test normality and equality of variances respectively. When the conditions of normality and/or equality of variances of certain parameters were not met, the non-parametric Kruskal-Wallis test was applied.

## 3. RESULTS AND DISCUSSION

### 3.1. Physico-chemical properties (Table I)

The results of the physicochemical analyses of the different flourpowders, show that the moisture content of FS flourpowder (7.17%) ~~iswas~~ higher than that of F40 flourpowder (7.1%) and F50 flourpowder (6.47%). These levels ~~arewere~~ lower than that of flourpowder from the uncooked pulp of breadfruit (*Artocarpus altilis*) which ~~iswas~~ 10.7%±0.36 (Oulai, 2014) [27]. These moisture contents ~~arewere~~ below the maximum level of 15.5% defined by the Codex Alimentarius Commission (CAC, 1985) [28]. Indeed, when the moisture content ~~iswas~~ high, aggregation of the flourpowder particles occurs, thus reducing its quality and functionality (Aguilera et al., 1995) [29]. Another advantage of having a low moisture content lies in the technological uses. Indeed, with a moisture content below 12%, both untreated and treated flourpowders ~~arewere~~ favourable for long-term preservation. Microbiologically, these low moisture levels limit the growth of microorganisms, with the exception of moulds (Aryee et al., 2006) [30].

FS flourpowder has a pH of 5.71. It ~~iswas~~ more acidic than F40 flourpowder with a pH of 6.07 and F50 flourpowder with a pH of 5.95. The pH varies very little and remains below 7. This result ~~iswas~~ comparable with Yetunde et al, (2009) [31] and Alozie et al, (2009) [32]. The pH ~~iswas~~ a sign of the acidity or alkalinity of the flourpowder and greatly affects its performance during its use in the food system. When a flourpowder has a pH<4 this flourpowder ~~iswas~~ said to be very acidic which denotes high fermentation and consequently high degradation of the starch present, so this type of flourpowder would not be suitable for bread making (Tortoe et al., 2017) [33].

The three (3) [flourpowders](#) have a total sugar content that varies from 2.42% to 3.94% and a reducing sugar content that varies from 117.35 mg/100g to 152 mg/100g. These levels [were](#) higher than those observed by **Gutap and Nagar (2008) [34]**. These authors obtained total sugar levels between 0.05 and 0.4% in uncooked and cooked soybean meal and also reducing sugar levels between 0.03 and 0.04%. This difference would be due to the fact that the young shoot of the roast tree belongs to the starch group and [is](#) therefore rich in starch (**Niamke, 2014) [11]** and consequently rich in sugars. It should be noted that [flourpowders](#) rich in sugars [were](#) useful for the manufacture of certain foods such as cakes, biscuits, cakes.

The lipid content of F50 [flourpowder](#) (1.07%) [is](#) higher than that of F40 (0.60%) and FS (0.53%) [flourpowders](#). These levels are close to those obtained by **Oulai, 2014 [27]** (0.84% to 0.48%) when cooking *Artocarpus altilis* pulp. According to **Anses in 2021[35]**, lipids play two (2) major roles: an energy storage role and a structural role (enter into the composition of cells).

The protein percentage of F50 [flourpowder](#) (7.57%) [is](#) higher than that of F40 (6.65%) and FS (6.23%) [flourpowders](#). These contents are close to that of unripe banana [flourpowder](#) (6.57%) (**Anuonye et al., 2012) [36]**. Proteins are essential to the body, they play a structural role (in muscles and even skin) but are also involved in a large number of processes such as the immune response (antibodies), oxygen transport in the body (haemoglobin) or digestion (digestive enzymes) (**Anses, 2021) [35]**.

The fibre content of F50 [flourpowder](#) (3.21%) [is](#) higher than that of F40 (2.96%) and FS (2.72%). These three (3) [flourpowders](#) could be a significant source of dietary fibre which [is](#) eliminated more slowly from the stomach and thus improves intestinal transit. These dietary fibres are absolutely essential for the balance of the digestive tract and the body. It [is](#) a factor in good health. Studies have shown an inverse correlation between dietary fibre consumption and colon cancer. This [is](#) because fibre has the ability to complex with carcinogenic molecules, thus preventing their contact with the colon and facilitating their excretion (**Jansen et al., 1999; Chene, 2003) [37,38]**. Consumption of prepared [flourpowders](#) could therefore increase gastric volume and provide a post-ingestive state to reach a state of satiety more quickly (**Chene, 2003; Al-Dobaib, 2009) [38,39]**. Fibre generally reduces blood glucose, HDL-cholesterol, LDL-cholesterol and thus contributes to the reduction of coronary heart disease (**Jalili et al., 2000) [40]**.

The percentage of total carbohydrates in FS [flourpowder](#) (84.07%) [is](#) higher than in F40 (83.41%) and F50 (82.56%) [flourpowders](#). These total carbohydrate levels [were](#) higher than those of millet (71.35% to 77.13%) (**Ocheme et al., 2010) [41]**. FS, F40, F50 [flourpowders](#) [were](#) rich in carbohydrates, which [were](#) compounds that provide energy for the functioning and maintenance of muscle cells, brain, red blood cells and other organs, etc. (**Martin, 2000; Folin, 2005; Fredot, 2009) [42, 43, 44]**. These [flourpowders](#) could be an important alternative source of calories in rural areas in case of shortage of high energy foods (Attiéké, Yam, banana etc.) commonly consumed by the population. Moreover, the transformation of young shoots into [flourpowder](#) offers a definite advantage because of its better conservation (for the population), as this avoids its rapid degradation.

The energy values of FS, F40, F50 [flourpowders](#) vary from 366 to 369.69Kcal/100g. This energy value [is](#) due to the high total carbohydrate content. This value [is](#) close to that of *Dioscorea alata* yam raw and cooked for 90 min (357.65 and 370.01 Kcal/100g respectively) (**Ezeocha and Ojmelukwe, 2012) [45]**. FS, F40, F50 [flourpowders](#) could be

used partly as energy [flourpowder](#) in porridges for infants and children whose energy requirements vary from 547 to 1092 Kcal/day (Butte, 1996) [46].

**Table I : Physico-chemical properties of FS, F40, F50 [flourpowders](#)**

Parameters	FS	F40	F50	General Average	P-value
Moisture (%)	7.17±0.15 <sup>c</sup>	7.1±0.17 <sup>b</sup>	6.47±0.15 <sup>a</sup>		0.003
pH	5.71±0.01 <sup>a</sup>	6.07±0.01 <sup>c</sup>	5.95±0.01 <sup>b</sup>		0.03
Reducing sugars (mg/100g)	117.35±6.2 <sup>a</sup>	121.19±1.4 <sup>a</sup>	152.63±21.57 <sup>a</sup>	130.39	0.06
Total sugars (%)	2.42±0.22 <sup>a</sup>	3.36±0.44 <sup>b</sup>	3.94±0.32 <sup>c</sup>		0.004
Lipids (%)	0.53±0.11 <sup>a</sup>	0.60±0.2 <sup>b</sup>	1.07±0.11 <sup>c</sup>		0.009
Proteins (%)	6.23±0.04 <sup>a</sup>	6.65±0.35 <sup>b</sup>	7.57±0.02 <sup>c</sup>		0.03
Ash (%)	2±0.2 <sup>a</sup>	2.24±0.06 <sup>a</sup>	2.34±0.15 <sup>a</sup>	2.19	0.08
Fibers (%)	2.72±0.05 <sup>a</sup>	2.96±0.1 <sup>b</sup>	3.21±0.01 <sup>c</sup>		0.0004
Total carbohydrate (%)	84.07±0.2 <sup>c</sup>	83.41±0.6 <sup>b</sup>	82.56±0.4 <sup>a</sup>		0.01
Energy content(Kcal/100g)	366±0.35 <sup>a</sup>	365.65±1.14 <sup>a</sup>	369.69±0.1 <sup>a</sup>	367.11	0.06

Per line, values followed by different superscript letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference [iswas](#) significant

### 3.2. Functional properties of FS, F40, F50 [flourpowders](#) (Table II)

The dispersibility (after 30 min) of F50 [flourpowder](#) (63.63%) [iswas](#) higher than that of F40 (61.83%) and FS (60.55%) [flourpowders](#). The dispersibility of a [flourpowder](#), which [iswas](#) an indicator of its reconstitution power in water, [iswas](#) a useful functional parameter in the formulation of various food products (Mora-Escobedo et al., 1991) [47]. The dispersibility percentage of the three [flourpowders](#) [iswas](#) similar to that of local Nigerian rice (56-66%) (Eke-Ojiofor et al., 2011) [48]. The higher the dispersibility percentage, the greater the ability of the [flourpowder](#) to reconstitute in water to give a fine, coherent paste

The tapped (bulk) density of F50 [flourpowder](#) (0.75 g/ml) [iswas](#) higher than that of F40 (0.73g/ml) and FS (0.70g/ml) [flourpowders](#).) All these values are close to that of wheat [flourpowder](#) (0.80 g/cm<sup>3</sup>) (Ijarotimi, 2012) [49]. Density [iswas](#) a very important parameter in that it determines the packaging and transport conditions of the food product (Shittu et al., 2005) [50]. Nutritionally, a low packed density promotes the digestibility of food products, especially in children because of their immature digestive systems (Nelson-Quartey et al., 2007) [51]

The water absorption capacity of F50 [flourpowder](#) (146.58%) [iswas](#) higher than that of F40 (143.70%) and FS (138.95%) [flourpowders](#). These values are lower than those of uncooked and cooked rice (225% and 250% respectively) (Abulude, 2004) [52]. Furthermore, the use of [flourpowders](#) as food ingredients depends, to a large extent, on their interaction with water. The water absorption capacity of [flourpowders](#) plays an important role in the food preparation process as it predicts the ability of the [flourpowder](#) to absorb water under conditions where water [iswas](#) in short supply. A high capacity allows more water to be added to the dough, thus improving its workability. Furthermore, water absorption capacity [iswas](#) an essential property of doughs and bakery products as it allows for thickening and increasing the viscosity of foods (Falade and Okafor, 2015) [53]. The high water absorption capacity of seedling [flourpowder](#) could reflect the presence of high amounts of hydrophilic substances capable of improving the viscosity of various food products (Grah et al., 2014) [54]. This could also

reflect a greater interaction between proteins and water in the formed system. Furthermore, the type of protein such as polar proteins would also increase this ability (Grah *et al.*, 2014; Tortoe *et al.*, 2017) [54,33].

Oil *iswas* more absorbed by F50 *flourpowder* with a percentage of oil absorption of 128% higher than F40 (119.67%) and FS (118.67%) *flourpowders*. These oil absorption capacities are lower than that of yam *flourpowder* (190%) (Ukpabi, 2010) [55]. Oil absorption capacity *iswas* an important characteristic in fatty food formulations as it *iswas* believed to act as a flavour retention device and mouthfeel enhancer (Yadahally, 2011) [56]. This oil absorption capacity of *flourpowder iswas* due to the existing interactions between the side chain of non-polar amino acids and the hydrocarbon chains of lipids (Shindhu *et al.*, 2016) [57]. Since these *flourpowders* have a high oil absorption capacity, they could be a good lipophilic component and therefore suitable for the preparation of sausages, soups and cakes (Aremu *et al.*, 2006) [58].

The foaming capacity of F50 *flourpowder* (25.66%) *iswas* higher than that of F40 (23.43%) and FS (18.17%) *flourpowders*. The foaming capacity improves the texture, uniformity and appearance of the food (Akubor, 2007) [59]. According to Yasumatsu *et al.* 1972 [60], foam formation depends on pH, viscosity, protein and processing methods. The foaming capacity of these three *flourpowders iswas* higher than that of cassava *flourpowder* (13.70%) (Ubbor and Akobundu, 2009) [61].

**Table II : Functional properties of FS, F40, F50 *flourpowders***

Parameters	FS	F40	F50	General Average	P-value
Dispersibility of <i>flourpowders</i> after 30 min (%)	60.55±3.04 <sup>a</sup>	61.83±0.11 <sup>a</sup>	63.63±0.006 <sup>a</sup>	62	0.06
Tapped density (g/ml)	0.70 <sup>a</sup>	0.73 <sup>b</sup>	0.75 <sup>c</sup>		0.02
water absorption capacity (%)	138.95±0.09 <sup>a</sup>	143.70±4.8 <sup>a</sup>	146.58±0.37 <sup>a</sup>	143.08	0.2
Oil absorption capacity (%)	118.67±4.72 <sup>a</sup>	119.67±3.05 <sup>b</sup>	128±2.64 <sup>c</sup>		0.03
The foaming capacity (%)	18.17±0.01 <sup>a</sup>	23.43±0.76 <sup>b</sup>	25.66±1.52 <sup>c</sup>		0.03

Per line, values followed by different superscript letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference *iswas* significant

### 3.3. Particle size of FS, F40, F50 *flourpowders* (Table III)

The results of the particle size classification made it possible to separate seven characteristic fractions of the three *flourpowders* expressed as a percentage in Table III. All three (3) *flourpowders arewere* composed of grains smaller than 1mm. In addition, 98.8% of the grains of the FS and F40 *flourpowders* and 98.9% of the grains of the F50 *flourpowder arewere*

smaller than 500  $\mu\text{m}$ . These results are almost identical to those of **Djidohokpkin (2012) [62]** for fonio-soya composite flourpowders. Our flourpowder could be recommended after formulation as infant flourpowder because according to the standard established on the granulometry of infant flourpowders by the Advisory Committee of the PAAN project (Projet d'Appui aux Activités de Nutrition) which stipulates that infant flourpowder should not contain particles larger than 500 micrometers (**Tchibindat and Trèche, 1995) [63]**. Also, 62.7%; 52.9%; 47.8% of the grains of FS, F40, F50 flourpowders have sizes in the range [250  $\mu\text{m}$ , 125 $\mu\text{m}$ ]. For **Djidohokpkin (2012) [62]**, the highest retention rate for fonio-soya composite flourpowders *iswas* obtained at the 180 $\mu\text{m}$  sieve level while for the three flourpowders FS, F40, F50, the highest retention rate *iswas* obtained at the 125 $\mu\text{m}$  sieve level; this means that the roast flourpowders *arewere* finer than the fonio-soya composite flourpowders. The granulometry of flourpowders *iswas* of major importance for their analysis and use. Indeed, it allows to detect the presence of foreign particles and to pronounce on milling problems. It plays a fundamental role in hydration, which *iswas* the operation of bread-making and the preparation of the dough. It also makes it possible to predict its behaviour during hydration. In baking, the amount of water absorbed during dough fermentation, as well as the rate of water absorption increases with the fineness of the flourpowder particles (**Feillet, 2000) [64]**.

**Table III : Particle size of FS, F40, F50 flourpowders**

FlourPowders Particle size	FS	F40	F50
< 2mm	100%	100%	100%
<] 2mm ,1mm]	100%	100%	100%
] 1mm, 500 $\mu\text{m}$ ]	1,2%	1,2%	1,1%
] 500 $\mu\text{m}$ , 250 $\mu\text{m}$ ]	18,9%	15,3%	18,6%
] 250 $\mu\text{m}$ , 125 $\mu\text{m}$ ]	62,7%	52,9%	47,8%
] 125 $\mu\text{m}$ , 63 $\mu\text{m}$ ]	9,7%	15,2%	15,8%
<63 $\mu\text{m}$	7,5%	15,4%	16,7%

### 3.4. Antioxidants (Table IV)

The presence of antioxidants can reflect a response to stress (scarcity of rainfall, unfavourable soil quality, which are associated with an increase in tannin levels) (**Mebirouk-Boudechiche et al., 2014) [65]**. Thus, depending on the efforts made by the plant to adapt to environmental conditions, the amount of antioxidant decreases or increases. Flavonoids can neutralise free radicals and reduce cancer risk by stopping cell growth in tumours (**Wang et al., 2014) [66]**.

Current literature suggests that long-term consumption of a polyphenol-rich diet protects against certain cancers, cardiovascular disease, type 2 diabetes, osteoporosis, pancreatitis, gastrointestinal problems, lung damage and neurodegenerative diseases (Fuujiki et al., 2015; Xiao et al., 2015; Martin- Pelaez et al., 2013; Fraga et al., 2010 ) [67,68,69,70].

**Table IV : Antioxidants of FS, F40, F50 flourpowders**

Parameters		FS	F40	F50	P-value
Antioxidants	Polyphenols (mg/100g)	243,45±0.68 <sup>a</sup>	267,25±0.67 <sup>b</sup>	280,44±0.93 <sup>c</sup>	0.02
	Flavonoids (mg/100g)	68,46±0.48 <sup>a</sup>	75,15±0.086 <sup>b</sup>	83,03±0.16 <sup>c</sup>	4.49*10 <sup>-9</sup>
	Tannins (mg/100g)	45,47±0.69 <sup>a</sup>	54,13±0.26 <sup>b</sup>	59±0.73 <sup>c</sup>	4.56*10 <sup>-7</sup>

Per line, values followed by different superscript letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b<c; P value < 0.05 (5%) so the difference iswas significant

### 3.5. Minerals (Table V)

The results of this study showed the presence of minerals in young shoots flourpowders. Some of them were affected by the drying temperature. Indeed, the mineral contents increased with temperature. This increase in the mineral content of the young shoots flourpowders would be due to the effect of the heat. This can be explained by the fact that certain anti-nutritional factors interfere with the availability of minerals by complexing them in their structure, as suggested by Alonso et al, (2001) [71] and Anigo et al, (2009) [72]. The degradation of these anti-nutritional factors by heat releases these minerals into the matrix (Ewald et al., 1999) [73]. The sodium content of roasted sapling flourpowders increases with temperature (0.04 to 0.11 ppm). This result iswas lower than that reported for breadfruit (*Artocarpus altilis*) from Ghana (690ppm DM) (Polycarp et al., 2012) [74]. Sodium plays an important physiological role in humans at several levels as it participates in the control of the volume of the extracellular medium (which refers to the fluid balance) of the body, maintenance of the electrochemical gradient of cells, transmission of nerve impulses, muscle contraction, intestinal absorption of some nutrients (Alexandra Retion, 2022) [75]. With its low sodium content, the flourpowder of young roasted shoots could be used as food without fear of health risks for people with high blood pressure.

Potassium iswas a mineral that increases cardiovascular well-being and iswas recommended for the prevention of certain complications of myocardial infarction (Kannel, 1997; Chow, 2009) [76,77]. Its content varies from 0.07 to 0.18 ppm. This content iswas much lower than that of *Artocarpus altilis* flourpowder (7045 to 8706 ppm) (Oulai, 2014) [27]. Regarding phosphorus, the results showed that the content which was 0.02 ppm for FS flourpowder did not increase for F40 (0.02 ppm) and F50 (0.02 ppm) flourpowders. These

levels are were lower than that of uncooked *Colocasia esculenta* (208 ppm DM) (Lewu et al., 2010) [78]. The calcium content of the three flour powders also did not vary with temperature (0.11 to 0.12 ppm). These levels are were lower than those of cooked *Hibiscus sabdariffa* seeds (740 ppm) (Yagoub et al., 2008) [79]. A diet rich in calcium and phosphorus is a factor in the prevention of osteoporosis and also a factor in reducing the risk of high blood pressure, colon and prostate cancer (Bonithon-Kopp et al, 2000) [80]. Iron plays an important role in the human body. The haemoglobin present in the red blood cells absorbs the 70% of iron consumed. This allows oxygen to function properly. This oxygen is was then transmitted to the cells. Iron is was also found in the myoglobin of the muscles, which enables air to be stored. The remaining 30% of iron plays a role in activating the body's metabolisms. It contributes greatly to the production of energy and the activation of the immune system (Eric Favre, 2022) [81]. Iron deficiency anaemia affects one third of the world's population. However, excessive iron intake causes colorectal cancer (Senesse et al., 2004) [82]. The iron contents of our flour powders (0.04 to 0.06 ppm) are were lower than that of sweet potato flour powder (10.97 ppm) revealed by Ofori et al., 2016 [83]. The iron values of the three flour powders are were below the limit of 15 ppm set by WHO as the limit of iron in food (WHO 1982) [84].

**Table V : Minerals of FS, F40, F50 flour powders**

Parameters	FS	F40	F50	General average	P-value
<b>Sodium (ppm)</b>	0.04±0.001 <sup>a</sup>	0.07±0.004 <sup>b</sup>	0.11±0.004 <sup>c</sup>		0,000
<b>Phosphorus (ppm)</b>	0.02±0.005 <sup>a</sup>	0.02±0.006 <sup>a</sup>	0.02±0.003 <sup>a</sup>	0.02	0,892
<b>Potassium (ppm)</b>	0.07±0.009 <sup>a</sup>	0.12±0.004 <sup>b</sup>	0.18±0.001 <sup>c</sup>		0,000
<b>Calcium (ppm)</b>	0.11±0.007 <sup>a</sup>	0.11±0.006 <sup>a</sup>	0.12±0.003 <sup>a</sup>	0.11	0,082
<b>Iron (ppm)</b>	<b>0.04±0.006<sup>a</sup></b>	<b>0.06±0.006<sup>b</sup></b>	<b>0.07±0.003<sup>b</sup></b>		<b>0,002</b>

Per line, values followed by different superscript letters are statistically different at 5%. P-value: value of the statistical probability test. With a < b < c; P value < 0.05 (5%) so the difference is significant

## CONCLUSION AND PERSPECTIVES

With the exception of moisture, which is was high for FS flour powder, and pH, which is was higher for F40 flour powder, all other parameters increase in the flour powder with increasing temperature. This is was because sun-drying exposes the flax to moisture in the air; the higher the temperature, the more concentrated the various parameters are were in the flour powder. The young shoot of roan is was a tuber, which makes it a potential staple food that could be used in the diet to combat hunger and to provide food security. The results of this study prove that the three (3) flour powders are were a good source of carbohydrate and could therefore be useful for energy purposes. The low moisture content of the three (3) flour powders (< 8%) would allow the flour powders to be stored for a long time. All flour powders contain fibre and minerals that are were beneficial to the health of the population. The functional properties of the flour powders, i.e. dispersibility, packed density, water absorption capacity, oil absorption capacity and foaming capacity, suggest that the flour powders from young shoots would be suitable for use in food formulations (infant porridges, pastries, cakes, etc.) for which these different properties are were required

In perspective, it would be important to carry out the following research

-Study the different properties of [flour powder](#)s made from roasted sapling [flour powder](#) with other [flour powder](#)s.

-To propose a feed formulation

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