



Nutritional Potential of Pulp Powders of Safou (*Dacryodes edulis* var *Edulis*): Effects of Cooking Treatments

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Authors' contributions

This work was carried out in collaboration among all authors. Author RLK designed the subject and carried out the sampling and the various analyses. Author EEP carried out the preparation of the powders and the various analyses. Author AES collected, analyzed the data and drafted the manuscript. Author SD read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study is to determine the physicochemical characteristics, functional properties, antioxidant and anti-nutrient activities of pulp powders of Safou (*Dacryodes edulis* var *edulis*) according to cooking methods in order to promote their consumption for food security.

Study Design: Biochemical and technological studies.

Place and Duration of Study: Laboratory of Biocatalysis and Bioprocessing, Abidjan, Côte d'Ivoire.

Methodology: Three different Safou powders were prepared (PSS, PSV and PSEB). PSS (Safou pulp was not cooked before drying); PSV (Safou pulp was steamed before drying) and PSEB (Safou pulp was cooked in hot water before drying). The determination of the physicochemical characteristics concerned rates of dry matter, ashes, proteins, lipids, carbohydrates and energy

value. The determination of the functional properties concerned water and oil capacity, water solubility index, bulk density, porosity, wettability, foaming capacity, hydrophilic-lipophilic ratio, swelling, solubility, foam stability and dispersibility. The determination of antioxidant and anti-nutrient activities concerned total polyphenols, tannins, DPPH, iron reducing power, total oxalates and phytates.

Results: Uncooked Safou pulp powders (PSS) are good sources of protein, ash, lipid and polyphenols. Cooking improved carbohydrate and energy values and the functional properties and lowered the anti-nutritional factors of Safou pulp powders.

Conclusion: The different cooking methods applied to the Safou pulp had an influence on the contents of nutrients. The powder of Safou cooked in boiling water (PSEB) showed the best functional properties and lowered the anti-nutrient factors. It could be recommended for the enrichment of local infant flours.

Keywords: Safou (*Dacryodes edulis* var *edulis*); steaming; boiling water cooking; powders.

1. INTRODUCTION

According to FAO [1], Africa is not on track to meet the Sustainable Development Goal (SDG) 2 targets to end hunger and ensure access by all people to safe, nutritious and sufficient food all year round, and to end all forms of malnutrition. The most recent estimates show that 281.6 million people on the continent, over one-fifth of the population, faced hunger in 2020, which is 46.3 million more than in 2019. Globally, 6.7 percent of children (45.4 million) are affected by wasting. The prevalence of wasting in Africa is below the global average. Prevention of wasting requires addressing the underlying causes of malnutrition. Breastfeeding support and nutrition counselling for families, particularly with regard to improving the quality of complementary foods [1]. In fact, in Sub-Saharan Africa, mothers generally feed their children porridges prepared from simple or compound flours from cereals or tubers [2]. However, these foods are unable to cover all the nutritional needs of the child because they are rich in carbohydrates and poor in protein. Also, commercial infant flours are not generally used by low-income households because they are relatively expensive. Nevertheless, solutions are proposed to correct this nutritional deficiency. One solution is to supplement local flours with leguminous seeds or oil seeds such as soybeans, beans and groundnuts [3,4]. Besides these plants already popularized, there are others, less known, which are also studied for their good nutritional values such as Safou (*Dacryodes edulis* var *edulis*).

Safou [*Dacryodes edulis* (G. Don) H. J. Lam (Burseraceae)] is a fruit native to the countries of Central Africa and the Gulf of Guinea. Scientific work on Safou has revealed excellent nutritional qualities of the fruit pulp and interesting agro-

industrial properties of its oil [5,6]. According to a study conducted by researchers at the Tropical Nutrition Laboratory of the Institute for Research and Development (IRD) and the Human Nutrition and Food Research Unit (URNAH) in Brazzaville, breast milk in the Congo is richer in essential fatty acids than in most other countries of the world. These remarkable qualities, which are beneficial for children's growth, are attributable to the diet of Congolese women, which includes Safou [7]. Safou could therefore play a very important role in fight against child malnutrition through its incorporation as a protein-energy source for the enrichment of locally produced infant flours.

In Côte d'Ivoire, Safou is grown in the southeast of the country where it was introduced in the 1970s from Cameroon [5]. In spite of its great nutritional wealth and several decades after its introduction into Ivorian agriculture, Safou is not well known by local populations. In addition, there is very little scientific work on the Safou of Côte d'Ivoire and none of it has focused on the nutritional impact of technological properties applicable to Safou pulp. The aims of this study is to determine the physicochemical characteristics, functional properties, antioxidant and anti-nutrient activities of pulp powders of Safou (*Dacryodes edulis* var *edulis*) according to cooking methods in order to promote their consumption for food security.

2. MATERIALS AND METHODS

2.1 Biological Material

Safou of *edulis* variety (15 kg) were harvested in Azaguié-Blida (South-East of Côte d'Ivoire) with the help of the planters and then sent to the Laboratory of Biocatalysis and Bioprocessing of

the University NANGUI ABROGOUA for the various analyses.

2.2 Preparation of Safou Powders

To obtain the different Safou pulp powders, the fruits were sorted and then washed with distilled water. The pulps were separated from the seeds and divided into three batches L1, L2 and L3. L1 was not cooked. L2 and lot L3 were steamed and cooked in hot water, respectively. The cooking in water consisted in immersing the Safou pulps in a pot containing hot water (water brought to a boil and removed from the fire) for 5 min. The steaming was made in a "couscoussier" fixed to a pot containing

water in boiling during 10 min. The cooking was observed by touch. The different pulps were oven dried at 55°C for 48h, then ground in a Moulinex and sieved with a 250 µm sieve to obtain the powders. PSS, PSV and PSEB were powders obtained from batches 1, 2 and 3 respectively.

2.3 Physicochemical Analyses of Safou Pulp Powders

Physicochemical analyses of the Safou pulp powders concerned the determination of the dry matter rate, the protein, lipid, carbohydrate and ash content [8] as well as the determination of the energy value [9].

2.4 Functional Properties Analyses of Safou Pulp Powders

2.4.1 Water absorption capacity and water solubility index

Measurement of the water capacity (WAC) and water solubility index (WSI) of Safou pulp powders was performed according to the method of [10] with m_0 : sample mass, m_1 : pellet mass before drying and m_2 : pellet mass after drying.

$$\text{WAC}(\%) = \frac{m_2 - m_1}{m_1} \times 100$$

$$\text{WSI}(\%) = \frac{m_0 - m_1}{m_0} \times 100$$

2.4.2 Dispersibility

The method described by [11] was used for the determination of dispersibility (D) of Safou pulp powders with V_0 : total volume of the particles just after manual shaking and V_t : volume of the deposited particles recorded at time t (30 min).

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

2.4.3 Oil absorption capacity

Oil absorption capacity (OAC) of Safou pulp powders was determined according to the method of [12] with M_0 : Mass of powder, M_1 : Mass of pellet

$$\text{OAC}(\%) = \frac{m_1 - m_0}{m_0} \times 100$$

2.4.4 Hydrophilic-lipophilic ratio

Hydrophilic-lipophilic ratio was obtained by making the ratio of the water absorption capacity (WAC) to the oil absorption capacity (OAC) [13].

2.4.5 Wettability, bulk density and porosity

The wettability, bulk density and porosity of Safou pulp powders were determined according [14]. Wettability was the time required for the sample to become completely wet. Bulk density (BD) and porosity (P) were calculated according to the following formulas:

$$\text{BD (g/ml)} = \frac{m_e}{V_t}$$

$$\text{P(\%)} = \frac{V_0 - V_t}{V_0}$$

m_e : mass of the sample; v_t : volume of sample in the test tube at time t ; v_0 : initial volume of the sample in test tube

2.4.6 Foaming capacity and foam stability

The foaming capacity (FC) and foam stability (FS) of Safou pulp powders were determined according to [15] with V_0 : Initial volume; V_1 : Volume before homogenization; V_2 : Volume after homogenization; V_f : Volume of the foam.

$$\text{FS(\%)} = \frac{V_f}{V_0} \times 100$$

$$\text{FC(\%)} = \frac{V_2 - V_1}{V_2} \times 100$$

2.4.7 Swelling and solubility

Swelling (SW) and solubility (S) tests were performed according to the method described by Oulai SF et al. [16] with m_s : mass of the supernatant after drying; m_e : mass of the sample; m_{wp} : mass of wet pellet; m_{dp} : mass of oven dried pellet

$$\text{SW(\%)} = \frac{m_{wp} - m_{dp}}{m_{dp}}$$

$$\text{S(\%)} = \frac{m_s}{m_e} \times 100$$

2.5 Determination of Antioxidant and Anti-nutrient Activities of Safou Pulp Powders

2.5.1 Preparation of extract

Methanolic extracts were prepared as described by Talbi H et al. [17]. Two grams of different Safou pulp powders were mixed with 20 ml of a methanol-water mixture (70/30, v/v). The mixture was under magnetic stirring for 30 min and kept for 24 h at 4°C in dark. The mixture was then centrifuged at 2000 rpm for 20 min and filtered with Whatman No.1 filter paper to obtain extracts.

2.5.2 Determination of antioxidant activity of Safou pulp powders

Total phenols content (TPC) of Safou pulp powders was determined using the Folin-

Ciocalteu reagent method described by Singleton VL et al. [18]. The total phenol content was expressed as milligram equivalent of gallic acid per gram of extract (mg GAE/g). The free radical scavenging activities of the crude extracts of Safou were evaluated using the DPPH (2, 2-diphenyl- 1-picrylhydrazyl) assay method as described by Sanchez-Moreno C et al. [19]. Ascorbic acid (Vitamin C) was used as control. The radical scavenging percentages were plotted against the logarithmic values of the concentration of test samples and a linear regression curve was established in order to calculate IC50, which is the amount of sample necessary to inhibit 50% of free radical DPPH. The reducing power of iron (III) to iron (II) was measured according to the method described by Oyaizu M [20]. The absorbance was read at 700 nm against a blank. An increase in absorbance corresponds to an increase in the reducing power of the extracts tested. The determination

of tannins in Safou pulp powders was performed according to the method described by Bainbridge Z et al. [21] with some modifications. The absorbance was read at 500 nm against a blank. Results were expressed as milligram equivalent of tannic acid per 100 g dry matter (mg TAE/100 g DM).

2.5.3 Determination of anti-nutrient activity of Safou pulp powders

Phytates were quantified by Latta M et al. [22] based on the decoloration of Wade's reagent by phytates. This discoloration is proportional to the amount of phytates present in the medium. Optical density (OD) was read at 490 nm against a blank. Results were expressed as mg phytic acid equivalent per 100g dry matter (mg PAE/100g DM). Oxalate determination was performed according to the method described by Day RA et al. [23] using potassium permanganate.

2.6 Statistical Analyses

Statistical analyses were performed using Statistica 7.1 software. The analysis of variance (ANOVA) was performed to study the degree of difference between the variables. In case of significant difference between the studied parameters, the classification of means (homogeneous groups) was performed with Duncan's test. The significance level (α) was 0.05.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Composition of Safou Pulp Powders

Physicochemical composition of uncooked (PSS), steamed (PSV) and boiled (PSEB) Safou

pulp powders are presented in Table 1. The dry matter content varies from 91.8 to 94.7% with the highest content for PSEB. The ash content varies from 4.49 to 5.77. PSS has the highest ash content. The protein content varies from 13.77 to 16.25%. PSS has the highest protein content. The lipid and carbohydrate contents vary from 53.37 to 53.87% and 15.91 to 23.07% respectively. PSEB has the low lipid content and high carbohydrate content. The energy value (EV) varies from 613.5 to 627.29 Kcal/100g with the highest values for PSEB. The biochemical composition of safflower pulp powders was evaluated according to the cooking methods (steam and boiling water). The dry matter contents of cooked pulp powders were the highest with a significant difference ($p < 0.05$). The results are in agreement with those of Vodouhe S et al. [24] who stated that cooking followed by drying increased dry matter content. The ash content decreases significantly in cooked safflower pulp powders compared to uncooked pulp powder. These results could be due to the leaching of minerals into water after softening of the pulp cell walls caused by boiling water and steam. However with steaming, mineral losses are reduced as shown in the work of Zoro AF [25] on leafy vegetables in Côte d'Ivoire. The protein content of Safou pulp powders also decreases significantly with cooking. This decrease could be explained by the solubilization of soluble protein fractions in boiling water [26]. This result is similar to those of Lima CS et al. [27] who determined a low protein content in prepared vegetables. The carbohydrate content of cooked Safou pulp powders is the highest. These contents suggest that Safou pulp powders are good sources of calories. Cooking method had no significant effect on the lipid content of Safou pulp powders. Onuegbu [28] obtained similar results in flours of three yam varieties.

Table 1. Physicochemical composition of Safou pulp powders

Parameters	Safou pulp powders		
	PSS	PSV	PSEB
Dry Matter (%)	91.80±0.16 ^a	93.58±0.05 ^b	94.70±0.05 ^c
Ash (%)	5.77±0.19 ^a	4.73±0.32 ^b	4.49±0.14 ^c
Protein (%)	16.25±0.10 ^a	14.15±0.10 ^b	13.77±0.01 ^c
Lipid (%)	53.87±0.45 ^a	53.67±0.39 ^a	53.37±1.35 ^a
Carbohydrates (%)	15.91±0.31 ^a	21.03±0.40 ^b	23.07±1.24 ^c
Energy value (kcal/100g)	613.47±3,23 ^a	623.75±2,78 ^b	627.69±7,11 ^c

Values represent means of triplicate reading, follow by different lowercase letter Means within the same row with different alphabets are significantly different ($p \leq 0.05$); PSS: uncooked Safou pulp powder, PSV: steamed Safou pulp powders; PSEB: boiled Safou pulp powders

Table 2. Functional properties of safou pulp powders

Parameters	PSS	PSV	PSEB
Water absorption capacity (WAC %)	290.71±1.30 ^a	309.06±5.54 ^b	393.47±2.68 ^c
Water solubility index (WSI %)	30.20±0.15 ^a	47.27±0.31 ^b	58.27±0.40 ^c
Bulk density (g/ml)	0.51±0.02 ^a	0.58±0.10 ^b	0.60±0.03 ^b
Wettability (s)	40.00±0.05 ^a	30.00±0.02 ^b	27.00±0.01 ^b
Porosity (%)	26.76±0.51 ^a	27.39±0.70 ^a	28.57±1.01 ^a
Foaming capacity (FC %)	2.48±0.63 ^a	2.27±0.66 ^a	1.91±0.28 ^b
Oil absorption capacity (OAC %)	OO 69.00±0.87 ^a UPO 70.40±0.63 ^a RPO 76.67±1.80 ^a	83.33±1.51 ^b 96.40±0.34 ^b 98.93±1.12 ^b	91.67±1.32 ^c 107.07±2.30 ^c 112.87±0.95 ^c
Hydrophilic-Lipophilic ratio	OO 4.21±0.01 ^a UPO 4.13±0.01 ^a RPO 3.79±0.01 ^a	3.70±0.01 ^b 3.22±1.10 ^b 3.13±0.02 ^b	4.30±0.02 ^a 3.66±0.01 ^b 3.48±0.05 ^c
Swelling (%)	50°C 4.01±0.16 ^a 70°C 4.49±0.15 ^a 90°C 5.07±0.04 ^a	4.15±0.01 ^b 4.62±0.01 ^b 6.21±1.34 ^b	4.23±0.17 ^c 4.89±0.45 ^c 6.80±1.85 ^c
Solubility (°%)	50°C 13.00±0.50 ^a 70°C 13.26±0.08 ^a 90°C 13.77±0.83 ^a	14.92±0.76 ^b 16.33±0.28 ^b 16.66±0.76 ^b	16.92±0.28 ^c 23.16±0.57 ^c 23.66±0.29 ^c
Foam stability (FS %)	10 mn 99.76±0.02 ^a 30 mn 97.31±0.20 ^a 60mn 97.31±0.02 ^a 10mn 32.67±0.02 ^a	97.17±0.18 ^b 95.97±0.29 ^b 95.97±0.15 ^b 35.67±0.02 ^b	97.07±0.45 ^c 95.87±0.17 ^c 95.87±0.16 ^c 39.40±0.45 ^c
Dispersibility (%)	30mn 38.67±0.25 ^a 60mn 38.67±0.38 ^a 90mn 38.67±0.11 ^a	40.62±0.00 ^b 40.62±0.10 ^b 40.62±0.43 ^b	45.56±1.26 ^c 45.56±0.73 ^c 45.56±1.09 ^c

Values represent means of triplicate reading, follow by different lowercase letter Means within the same row with different alphabets are significantly different ($p \leq 0.05$); OO: Olive oil, UPO: Unrefined Palm oil; RPO: Refined Palm Oil; PSS: uncooked Safou pulp powder, PSV: steamed Safou pulp powders; PSEB: boiled Safou pulp powders

3.2 Functional Properties of Safou Pulp Powders

Table 2 shows characteristics of the functional properties of uncooked (PSS), steamed (PSV) and boiled (PSEB) Safou pulp powders. The water and oil capacity, water solubility index, bulk density, porosity, wettability, foaming capacity, hydrophilic-lipophilic ratio, swelling, solubility, foam stability and dispersibility were in the ranged of 290.71-393.47%; 69-112.87%; 30.2-58.27%; 0.51-0.60 g/ml; 26.76-28.57%; 27-40s; 1.91-2.48%; 3.13-4.30; 4.01-6.80%; 13-23.66%; 95.87-99.76% and 32.67-45.56% respectively.

A high water absorption capacity (WAC) allows the flour or powder to absorb water without dissolving protein, which results in thickening and increasing the viscosity of the food. The WAC obtained in safflower pulp powders are high. The high water retention capacity is thought to be due to the hydrophilic groups of the proteins [29]. Water absorption capacity is important in consistency and bulking of products, as well as in

baking applications. High WAC of some composite flours suggests that the combination of different flours can be used in formulation of many foods such as processed cheese, bakery products, sausage, and dough.

Water solubility index (WSI) reflects the extent of starch degradation [30]. Thus, these could be good ingredients for the preparation of soups, creams, pasta and bakery products. Steam-cooked (PSV) and boiling water-cooked (PSEB) Safou pulp powders have a higher WAC and WSI than uncooked Safou pulp powders (PSS). Thus, cooking significantly increased the WAC and WSI.

Safou pulp powders have a high oil absorption capacity (OAC) which means that they have pleasant textures and promote food enjoyment, thus increasing food appetite. They could also be good lipophilic constituents and thus suitable for the preparation of sausages, soups and cakes. Cooking increases OAC of Safou pulp powders. Indeed, the removal of other constituents during

cooking leaves the protein lipophilic functions free, hence the maximum values obtained in this study. These results corroborate those of [31] who showed that OAC of yam increased during cooking.

The high hydrophilic-lipophilic ratio (HLR) determined in this study prove a higher affinity of Safou pulp powders for water compared to oil; this suggests that Safou pulp powders should be preferentially intended for the formulation of products requiring a high water absorption capacity.

Low bulk density (BD) is desirable as it helps to reduce dough thickness which is an important factor in convalescent and child feeding [32]. Safou pulp powders could potentially be used in the formulation as a supplement for children's food. However, steamed (PSV) and water-cooked (PSEB) Safou pulp powders have a higher bulk density than uncooked Safou pulp powders (PSS).

Statistical analysis shows that cooking significantly increases the porosity (P) of Safou pulp powders. High porosity facilitates food digestibility especially in children because of their immature digestive system [32]. The high porosities of cooked safflower pulp powders suggest that they could be useful in infant food formulation.

A flour or powder is wettable when its wetting time is less than 20s [33]. Statistical analysis shows that baking significantly reduced the wettability time of Safou pulp powders. However, none of these powders is wettable.

The foaming capacity (FC) of Safou pulp powders decreased significantly with cooking and the foam stability (FS) decreased with time at room temperature until stabilization. This result may be due to the cooking of the Safou pulp which denatured its proteins favoring the formation of protein aggregates hence the decrease in FC and FS. These results corroborate those of [31] who showed that FC and FS of yam decreased during cooking.

High swelling power and low solubility are required for the formation of highly viscous and elastic gels or pastes [34]. Therefore, Safou pulp powders cannot form highly viscous and elastic gels or pastes due to their high solubility and low swelling power. However, the solubility levels of the obtained powders suggest that they are

digestible and could be useful in the formulation of infant food.

The Dispersibility (D) of a powder or flour is an indicator of reconstitution power in water, a useful functional parameter in formulations of various food products. A high dispersibility percentage is an indicator of good water absorption capacity [35] and induces the high capacity of the flour to reconstitute in water giving a fine and coherent paste. Safou pulp powders have high dispersibility. Thus, they could be used in the formulation of instant flours. Statistical analysis revealed that the different technological treatments applied to Safou pulp powders (cooking) significantly increased the dispersibility of these powders.

3.3 Antioxidant Activity of Safou Pulp Powders

Antioxidant activity of uncooked (PSS), steamed (PSV) and boiled (PSEB) Safou pulp powders are presented in Table 3. Total polyphenol content ranged from 5.63 to 14.20 mg GAE/g. The highest value was observed in the extract from PSV. Polyphenols play an important role in human health by preventing degenerative pathologies such as cancers, cardiovascular diseases or osteoporosis [36]. These contents obtained make it possible to classify Safou among the fruits rich in polyphenols like the grape and the apple. Tannin levels ranged from 0.25 to 0.71 mg TAE /g DM. Like total polyphenols, the highest level was observed in the extract from PSV. According [37], tannins would nevertheless be one of the factors behind the astringent taste normally noticed in Safou consumption. The tannin contents obtained in this study are largely lower than the limit values indicated in the human food (760 to 900 mg GAE/100g DM). Cooking the pulps resulted in a decrease in the total polyphenol and tannin content of the different powders. Cooking or exposure to high temperatures causes a decrease in the total phenolic content of most fruits and vegetables [38]. This may be due to the inactivation of enzymes responsible for the oxidation of polyphenols (polyphenol oxidase).

The median inhibitory concentration (IC50) values of the Safou pulp powders range from 0.12 to 0.17 mg/mL. They are all higher than that of vitamin C (IC50= 0.06 mg/mL). The reducing power of Iron is expressed by its absorbance at 700 nm (OD700). The OD700 values range from 0.37 to 0.61 with the highest absorbance for the

Table 3. Phenolic compound content and antioxidant activity of Safou pulp powders

Parameters	PSS	PSV	PSEB	Vit C
Total polyphenols (mg GAE/g)	13.4±1.06 ^a	14.20±0.55 ^a	5.63±0.79 ^b	
Tanins (mg TAE/g MS)	0.68±0.05 ^a	0.71±0.05 ^a	0.25±0.03 ^b	
IC ₅₀ du DPPH (mg/mL)	0.12±0.02 ^a	0.16±0.01 ^b	0.17±0.01 ^b	0.06^c
Iron reduction (DO ₇₀₀)	0.61±0.03 ^a	0.45±0.01 ^b	0.37±0.01 ^b	0.84^c

Values represent means of triplicate reading, follow by different lowercase letter Means within the same row with different alphabets are significantly different ($p \leq 0.05$); PSS: uncooked Safou pulp powder, PSV: steamed Safou pulp powders; PSEB: boiled Safou pulp powders

Table 4. Composition of total oxalates and phytates in Safou pulp powders

Parameters	PSS	PSV	PSEB
Total oxalate (mg/100g DM)	0.14±0.02 ^a	0.10±0.01 ^b	0.05±0.02 ^c
Phytates (mg/100g DM)	0.03±0.00 ^a	0.02±0.00 ^b	0.01±0.00 ^c

Values represent means of triplicate reading, follow by different lowercase letter Means within the same row with different alphabets are significantly different ($p \leq 0.05$); PSS: uncooked Safou pulp powder, PSV: steamed Safou pulp powders; PSEB: boiled Safou pulp powders

PSS extract. The results obtained indicate the presence of antioxidant activity in Safou pulp powders influenced by the cooking mode. Indeed, the PSS has the highest DPPH inhibition power and the highest iron reducing power. The variation in iron reducing power and DPPH inhibiting power could be explained by the variation in phenolic compounds contents that are also influenced by the cooking mode.

3.4 Anti-nutrient Activity of Safou Pulp Powders

Anti-nutrient activity of uncooked (PSS), steamed (PSV) and boiled (PSEB) Safou pulp powders are presented in Table 4. The anti-nutrient factors represented by oxalates and phytates ranged from 0.05 to 0.14 g/100g DM and 0.01 to 0.21 g/100g DM respectively. Total oxalates levels were higher than phytates levels in all powders. Phytate forms complexes with copper, zinc, manganese, iron and calcium, making the minerals unavailable to the body. Oxalates form small crystals in the body with sharp edges that irritate the tissues. Therefore, high levels of oxalic acid and oxalates in the diet can lead to irritation of the gastrointestinal tract [39] particularly the stomach and kidneys. PSEB has the lowest levels of oxalates and phytates. Cell bursting loss facilitates the release of phytates, oxalates and other substances into the cooking water which would contribute to the decrease in their contents in Safou pulp powders. These results are similar to those of [16] who also showed that cooking with water decreased the level of anti-nutrient factors in breadfruit flour.

4. CONCLUSION

This study determined the biochemical compositions, functional properties, antioxidant activity and anti-nutritional factors of Safou pulp powders that underwent different technological treatments such as cooking (steaming and boiling). Uncooked Safou pulp powder (PSS) obtained the best lipid and ash content and the highest energy value. Cooking improved the functional properties and lowered the anti-nutritional factors of safflower pulp powders. Thus, uncooked Safou pulp powder (PSS) with these interesting contributions of macro and micronutrients could be suggested as a good source of phenolic compounds to be exploited in food industry. However, Safou pulp powder cooked in boiling water (PSEB), with its better functional and antinutritional properties in addition to its richness in protein and minerals could be recommended for the enrichment of infant flours. It would then be judicious to evaluate its capacity to enrich local flours poor in proteins.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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