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Impacts of Boiling Times on Physicochemical and Nutritive Composition from Heart of Oil Palm Tree (*Elaeis guineensis* Jacq.) Consumed as Vegetable in Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. Author RMB collected the data and wrote the first draft of the manuscript. Author GSEE performed the manuscript writing. Author BMF designed the study, performed the statistical analysis and wrote the protocol. Author BJF managed the analyses of the study. Author PLK managed the literature searches and supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

Heart of oil palm tree (*Elaeis guineensis* Jacq.), little known, is a vegetable consumed after boiling. This study is an evaluation of the impact of boiling times (15, 30, 45 min) on physicochemical and nutritive composition of this vegetable. Moisture, fiber and carbohydrate contents differ significantly ($p<0.05$) and increased in all three parts (PP, MP, DP) during boiling times. Moisture contents (%) varied from 89.94±0.08 (PP_0) to 92.23±0.15 (PP_{45}), 88.13±0.27 (MP_0) to 89.75±0.97 (MP_{45}) and 91.38±0.5 (DP_0) to 92.08±1.49 (DP_{45}). Fibers contents (%) varied from 26.49±0.13 (PP_0) to 32.26±6,89 (PP_{45}), 34.90±0.01(MP_0) to 37.67±1.12 (MP_{45}) and 21.9±0.02 (DP_0) to 29.41±2.63

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(DP_{45}), Carbohydrates contents (%) varied from 39.85±0.47 (PP_0) to 47.05±3.61 (PP_{45}); 39.91±1.15 (MP_0) to 45.47 (MP_{45}); 46.37±1.97(DP_0) to 59.55±1.26 (DP_{45}). Ash, protein, and fat contents differed significantly ($p<0.05$) and decreased in all three parts (PP, MP, DP) during cooking times. Ash content (%) ranged between 8.28±0.51 (PP_0) to 5.48±1.85 (PP_{45}), 6.91±0.07 (MP_0) to 4.58±1.48 (MP_{45}); 8.00±0.06 (DP_0) to 5.51±0.25 (DP_{45}). Protein contents (%) ranged between 12.56±0.65 (PP_0) to 7.38±1.3 (PP_{45}), 10.70±0.06 (MP_0) to 9.72±0.65 (MP_{45}), 13.12±0.69 (DP_0) to 4.47±0.67 (DP_{45}). Fat contents (%) ranged between 12.81±0.59 (PP_0) to 7.58±0.98 (PP_{45}), 7.57±0.8 (MP_0) to 2.56±0.42 (MP_{45}); 10.61±1.13(DP_0) to 1.06±0.05 (DP_{45}). Boiling times significantly ($p <0.05$) reduced contents of flavonoids, tannins, polyphenols, phytats and oxalats. Significant correlations were observed between moisture and fiber parameters, protein and ash, oxalates and flavonoids, oxalates and phytates.

Keywords: Heart of oil palm tree; Elaeis guineensis; flours; boiling times; physicochemical; nutritive; Côte d'Ivoire.

1. INTRODUCTION

With ever-increasing, population pressure and fast depletion of natural resources, it has become extremely important to diversify today's agriculture in order to meet various human needs [1]. Plant-based foods are the main source of food for humans mainly because of their availability and low cost [2]. People in developing countries derive their protein reserves from pulses and cereals. Finally, the most interesting botanical elements have been included in the food supply [3]. Studies of the nutritional value of wild plant foods are of considerable importance, as they can help identify long-forgotten food resources. Cooking food for a long time, for example, is able to denature some of its nutrients, reducing their levels in foods [4]. Anti-nutritional factors are chemical compounds found in plant tissues that prevent the absorption of nutrients in humans. The main anti-nutritional factors such as nitrates, phytates, tannins, oxalates and cyanogenic glycosides have been implicated in various health problems. Different treatment methods such as cooking, and bleaching can reduce the level of anti-nutritional factors [5].

The heart of the oil palm is an herbaceous vegetable belonging to the genus ELAEIS, from the ARECACEAE family. It can be harvested from different palm species [6].

It is essentially composed of unexpanded leaves immediately above the apical meristem. In some countries, the palm heart is marketed either "in natura" or canned. The raw or unprocessed palm heart market is still nascent, limited to large cities and based on local production of plantations. As a result, in some countries, most of the palm heart is processed and consumed as canned food using standard practices [7].

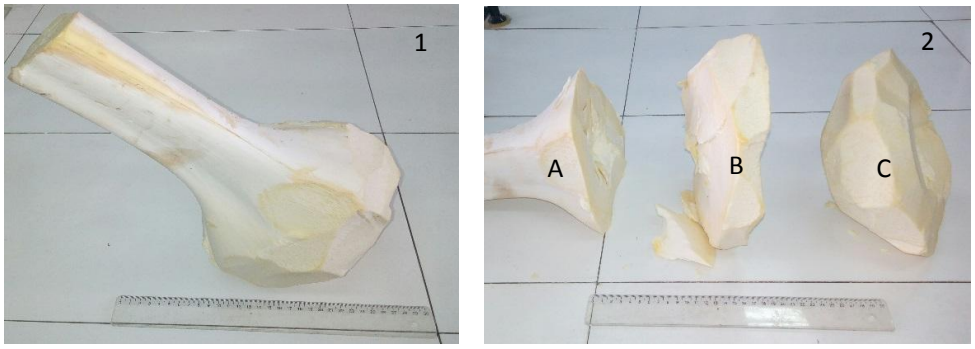
Most of the vegetables are consumed after being cooked or processed. In general, vegetables are prepared at home on the basis of convenience and taste preference rather than retention of nutrient and health-promoting compounds [8]. Moreover, potatoes are always cooked before being eaten. Potato nutrients and bioactive components appear to be influenced by cooking methods. However, there is no consistent information on the effects of thermal treatments on the properties of its constituents.

Cooking has been reported to either be beneficial or detrimental to the nutritional content of food [9]. Cooking helps to improve the microbiological and organoleptic qualities of food, increase digestibility and nutrients bioavailability, destroy toxins, microbes and antinutritional factors in food [10]. Cooking can also cause the loss of some micronutrients in the food [11].

In Côte d'Ivoire, the heart of oil palm tree (*Elaeis guineensis* Jacquin) is consumed in rural areas as a vegetable in forest areas. This vegetable is always consumed in cooked form. The cooking process used is boiling because the palm heart is cooked in sauces as vegetable. The aim of this study was to evaluate impacts of boiling times on composition (physicochemical and nutritive) of the heart of oil palm tree (*Elaeis guineensis* Jacquin) in order to preserve their nutritional quality.

2. MATERIALS AND METHODS

The material used is the heart of oil palm tree (*Elaeis guineensis* Jacquin), collected in Soubré (West, Côte d'Ivoire). Put in a cooler to preserve its fresh state, they were transported to the Laboratory of Biochemistry and Food Technology of University of Nangui Abrogoua (Abidjan, Côte d'Ivoire) where the study was conducted.



Photography 1. Heart of oil palm tree (*Elaeis guineensis* Jacquin), 2- Differents parts from heart of oil palm tree (A: Proximal part (PP); B: Median part (MP); C: Distal part (DP))

The heart of oil palm tree (Photography 1) were cut in three equal parts : proximal part (head of heart of oil palm tree), median part (middle) and distal part (tail of heart of oil palm tree) (Photography 1). Each part was divided into two lots. The first lot (raw) was dried in an oven (Memmert, Germany), at 45°C during 3 days, ground with a laboratory crusher (Moulinex, France). The dried slices were ground and pass through sieve (250 µm size). Each sample was stored in a clean dry air-tight sample bottle in a refrigerator (4°C) until required for analyses.

The second lot was cooked according to the method of Randrianatoandro [12] as follow : 500 g of vegetables were immersed in 1.5 L of boiled water in stainless steel container for 15, 30 and 45 min. The cooking solution was discarded and the boiled samples were cooled, drained at ambient temperature and subjected to the same treatment using for raw samples.

2.1 Moisture Content Determination

Moisture content (on dry weigh basis) was determined on fresh sliced samples after oven drying at 105ºC for 24 h according the procedure of AOAC [13].

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

where,

m_e: mass (g) of the sample.
m_1: mass (g) of the whole (capsule + sample) before baking.
m_2: mass (g) of the whole (capsule + sample) after steaming.

2.2 Ash Content

Ash content was determined by measurement of residues left after combustion in a furnace at 550ºC for 8 h [13].

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

Where,

m_0: mass (g) of the empty crucible.
m_e: mass (g) of the sample.
m_1: mass (g) of the whole (crucible + ashes) after incineration

2.3 Fibers Contents

Fiber estimate was obtained from the loss in weight of dried residue following the digestion for fat-free samples with 1.25% each of sulfuric acid and sodium hydroxide solutions [14].

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

Where,

m_1: mass (g) of the dried residue.
m_2 : mass (g) of ashes obtained.
m_e : mass (g) of the sample.

2.4 Protein Contents

Protein content was determined according to standard methods of AOAC [13] and was subsequently calculated by multiplying the nitrogen content by a factor of 6.25.

$$\text{Proteins}\ (\%) = \frac{(V_1 - V_0) \times 14 \times 6{,}25 \times N}{m_e}$$

Where,

V_0: volume (mL) of sulfuric acid solution (0.1 N) poured for the blank test.
V_1: volume (mL) of sulfuric acid solution (0.1 N) poured for the test (sample).
N: normality of the sulfuric acid solution.
m_e: mass (g) of the sample

2.5 Fat Contents

Fat was determined exhaustively extracting sample of flours in a soxhlet apparatus using anhydrous hexan as solvent. Nitrogen was determined by the Kjeldahl method reported by AOAC [13].

$$F\ (\%) = \frac{(M_2 - M_1)}{5\ g} \times 100$$

F: oil content expressed as a percentage (%).
M_2: mass (g) of the extracted oil after taring the extraction flask.
M_1: mass (g) of the seed mill sample subjected to extraction

2.6 Energy Value

Energy were obtained by the summation of multiplied mean values for protein, fat and carbohydrate by their respective Atwater factors, 4, 9 and 4 [15].

Energy value (%) = (4 x %C) + (9 x %F) + (4 x %P)

Where,
C : Carbohydrates Content
F : Fibers Content
P : Proteins Content

2.7 Carbohydrates Determination

Carbohydrate were calculated using the following formulas [16]:

Carbohydrates (dry matter basis) = 100 – (% moisture + % proteins + % lipids + % ash + % fibers).

2.8 Nutritional Properties

2.8.1 Flavonoids determination

The total flavonoids content was evaluated using the method reported by Meda et al. [17]. Briefly, 0.5 mL of the methanolic extract was mixed with 0.5 mL methanol, 0.5 mL of $AlCl_3$ (10%, w/v), 0.5 mL of potassium acetate (1 M) and 2 mL of distilled water. The mixture was allowed to incubate at ambient temperature for 30 min. Thereafter, the absorbance was measured at 415 nm by using a spectrophotometer (PG Instruments, England). The total flavonoids were determined using a calibration curve of quercetin (0.1 mg/mL) as standard.

$$\text{Flavonoids}\ (\text{mg}/100\text{g}) = \frac{\text{DO}_{415} \times 2 \times 10^3}{18{,}12 \times \text{m}_\text{e}}$$

Where,
Calibration line : DO_{415} = 18.12. Mass (mg) quercetin ; R^2 = 0.99
m_e : mass (g) of the sample.

2.8.2 Tannins determination

Tannins of samples were quantified according to Bainbridge et al. [18]. For this, 1 mL of the methanolic extract was mixed with 5 mL of vanillin reagent and the mixture was allowed to incubate at ambient temperature for 30 min. Thereafter, the absorbance was read at 500 nm by using a spectrophotometer (PG Instruments, England). Tannins content of samples was estimated using a calibration curve of tannic acid (2 mg/mL) as standard.

$$\text{Tannins}\ (\text{mg}/100\text{g}) = \frac{\text{DO}_{500} \times 10^3}{3{,}11 \times \text{m}_\text{e}}$$

where,

Calibration line: DO_{500} = 3,11. Mass (mg) tannic acid; R^2 = 0.99
m_e: mass (g) of the sample.

2.8.3 Polyphenols determination

Polyphenols content was determined using the method reported by Singleton et al. [19]. A quantity (1 g) of dried powdered sample was soaked in 10 mL of methanol 70% (w/v) and centrifuged at 1000 rpm for 10 min. An aliquot (1 mL) of supernatant was oxidised with 1 mL of Folin-Ciocalteu's reagent and neutralised by 1 mL of 20% (w/v) sodium carbonate. The reaction mixture was incubated for 30 min at ambient temperature and absorbance was measured at 745 nm by using a spectrophotometer (PG Instruments, England). The polyphenols content was obtained using a calibration curve of gallic acid (1 mg/mL) as standard.

$$\text{Polyphenol (mg/100g)} = \frac{DO_{725} \times 5 \times 10^3}{5{,}04 \times m_e}$$

Where,
Calibration line: DO_{725} = 5.04. Mass (mg) gallic acid; R^2 = 0.992
m_e: mass (g) of the sample.

2.9 Antinutritional Properties

2.9.1 Oxalats determination

The titration method as described by Day et Underwood [20] was performed. One (1) g of dried powdered sample was weighed into 100 mL conical flask. A quantity of 75 mL of sulphuric acid (3 M) was added and stirred for 1 h with a magnetic stirrer. The mixture was filtered and 25 mL of the filtrate was titrated while hot against $KMnO_4$ solution (0.05 M) to the end point.

$$\text{Oxalats (mg/100g)} = \frac{2{,}2 \times V_{eq} \times 100}{m_e}$$

Where,
Veq: volume (mL) of $KMnO_4$ equivalence.
m_e: mass (g) of the sample.

2.9.2 Phytats determination

The method described by Wheeler et Ferrel [21] was used for determination of phytates content. A quantity (0.5 g) of dried powdered sample was mixed with 25 mL of trichloroacetic acid (3%, w/v) and centrifuged at 3500 rpm for 15 min. The supernatant obtained was treated with $FeCl_3$ solution and the iron content of the precipitate was determined using spectrophotometric method at 470 nm. A 4 :6 Fe/P atomic ratio was used to calculate the phytic acid content.

$$\text{Phytats (mg/100g)} = \frac{DO_{490} \times 4}{0{,}033 \times m_e}$$

Where,
Calibration line: DO_{490} = 0.033. Mass (µg) sodium phytat; R^2 = 0.99.
m_e: mass (g) of the sample.

2.10 Statistical Analysis

All the analyses were performed in triplicate and data were analysed using EXCELL and STATISTICA 7.1 (StatSoft). Differences between means were evaluated by Duncan's test. Statistical significant difference was stated at $p<0.05$. Pearson correlation coefficients (r) for relationships between various parts of heart of oil palm tree raw and cooked properties were calculated. The variations observed in the physicochemical compositions and nutritional properties were examined by principal component analysis (PCA) with the Minitab Statistical Software version 7.1.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties

3.1.1 Moisture contents

Physico-chemical composition from heart of oil palm tree (different parts) cooked are presented in Table 1. Moisture contents of differents parts (PP, MP, DP) from heart of oil palm tree increased significantly ($P<0.05$) during cooking times. Thus, the highest moisture contents at 45 min of cooking were observed with PP (92.23 ± 0.15%) and DP (92.08 ± 1.49%). The high moisture content of the samples suggests that they would have a short shelf life. High moisture content increased the activity of water soluble enzymes and coenzymes required for metabolic activities could enhance microbial action leading to food spoilage. Onyeike et al. [22] and Ifemeje [23] report that vegetables contain 70-90% moisture. This increase is due to the softening of the cell wall resulting in water absorption by the cells of these leaves during boiling [24].

3.1.2 Ash contents

In contrast to moisture, the ash content of the various parts of the oil palm heart cooked in water decreased with cooking time (Table 1). Thus, the lowest levels were observed at the 45th minute with PP (5.48 ± 1.85%), MP (4.58 ± 1.48%) and DP (5.51 ± 0.25%). The decrease of ash contents during cookinng times are in agreement with those of Onu et Okongwu [25] and Onyeike et Oguike [26]. These losses could be due to the leaching of minerals in boiling water. The high ash content of differents parts (PP, MP, DP) could suggest that this vegetable is a good source of minerals [27]. The mineral elements serve as inorganic cofactors in metabolic processes. In the absence of these cofactors, the metabolism may be impaired [28].

3.1.3 Fibers contents

According to Table 1, the fibers contents varied from 26.49 to 32.26 % for PP, from

34.90 to 37.67% for MP and from 21.90 to 29.41% for DP. These values were also found to increase significantly ($P<0.05$) with increasing of boiling time. The increase in the fiber content of the various parts (PP, MP, DP) during the cooking times corresponds to the results of Slavin [29] and Mc Dougall et al. [30], which showed that cooking causes an increase in the soluble fiber content and a decrease in the insoluble fiber content. Indeed, cooking changes the physical and chemical properties of plant cell walls, affecting their performance as dietary fiber [31]. Oulai et al. [32] also showed an increase in fiber content during cooking of some leafy vegetables consumed in Côte d'Ivoire. The increase in fiber content could be justified by the increase in temperature during cooking [32]. Baking would result in the breaking of weak bonds between polysaccharides and the cleavage of glycosidic bonds leading to the solubilisation of dietary fiber [33]. Consumption of cooked oil palm heart could cover the daily fiber requirement estimated between 25 and 30 g [34] and would help reduce the risk of hypertension, constipation, diabetes, colon cancer and breast cancer [35], the fibers decreasing the absorption of cholesterol and glucose in the blood [36].

3.1.4 Proteins contents

According to Table 1, an observation made in all the parts studied showed a decrease in their content during cooking. Thus, the lowest contents were observed with DP (4.47 ± 0.67%) at 45 minutes of cooking. This decrease in protein content could be explained by the denaturation of peptide bonds and certainly disulfide bridges, by heat [37] but also by the solubilisation and diffusion of proteins in cooking water [38]. These results are similar to those of Zoro et al. [39] who reported that heat treatment (cooking) resulted in huge protein losses in leafy vegetables of up to 40.14%.

The generally low levels of crude protein in leafy vegetables would require dietary supplementation of animal protein or complementary protein from cereals and legumes, particularly in diets targeted to the target population of kwashiorkor (growing children and pregnant women) [27].

3.1.5 Lipids contents

In general, the lipid content in the various parts of the heart of oil palm tree cooked has also shown a decrease with cooking time. The lowest values were observed at 45 min cooking time (7.58 ± 0.98%, 2.56 ± 0.42% and 1.06 ± 0.50%) respectively for PP, MP and DP. The low lipid content of different parts of the oil palm heart (*Elaeis guineensis* Jacq.) is similar to the findings of many authors who have shown that vegetables are not lipid sources [40]. In addition, the decrease in lipid levels observed during the cooking of the heart of oil palm tree corroborates the work of Vadivel and Pugalenthi [41] who found the reduction of lipids content in the flour of cooked Mucuna spp. These losses would also be due to lipid leaching phenomena during cooking. However, consumption of the vegetables due to the low content of lipid is a good dietary habit with risk reduction of obesity and recommendable to individuals who would want to reduce weight.

3.1.6 Carbohydrate contents

The carbohydrate content of the different parts of the heart of oil palm tree increases with cooking. Thus, the highest levels as a function of the cooking time in the different parts were observed at 45 min of cooking (PP : 47,05%, MP : 45,47% and DP : 59, 55%). Indeed, this apparent increase is due to the decrease in protein, fat, ash and fiber, because the carbohydrate is a function of these nutrients. As for lipids, the various parts of the heart of oil palm tree studied are not importante source of carbohydrate compared to starch products with a carbohydrate base of more than 70% [42]. Carbohydrate provides a readily available energy source for oxidation metabolism and carbohydrate containing foods are vehicles for many important micronutrient.

3.1.7 Energy values

Energies values of differents parts of heart of oil palm tree cooked, decreased from 324,98 Kcal/100 g to 285,94 Kcal/100 g (PP); 270,63 Kcal /100 g to 243,8 Kcal/100 g (MP) and 333,45 Kcal /100 g to 265,62 Kcal/100 g DP) significantly ($p<0.05$) by cooking when compared to the raw samples (Table 1). The decrease of the energy values with cooking was agree with the general observation that vegetables have low energy values due to their low crude fat and relatively high level of moisture [43]. This justify that cooked leafy vegetables are usually eaten as a relish together with a starchy staple food, usually in the form of porridge [44].

3.2 Nutritional Properties

Cooking resulted in reduction of all the phytochemicals analysed in this study, which is in agreement with Farris et al. [45] and Balogun et al. [46] reports, which state that most anti-nutritional factors in food can be reduced by proper application of heat.

3.2.1 Flavonoids contents

The effect of cooking on the flavonoid and tannin content of the three parts of the heart of the palm tree is shown in Fig. 1. The results obtained showed a decrease in these contents compared to the initial state during the cooking time. At 15 min of cooking, MP obtained the highest content of flavonoids (9.81 mg / 100g DM) and the lowest content was observed with DP (4.37 mg / 100g DM). This was confirmed by the study of Mc William [47] which reported that flavonoids are destroyed by heat processing methods like drying, roasting and cooking. The biological functions of flavonoids apart from its antioxidant properties include protection against allergies, inflamemation, free radicals, platelet aggregation, microbes, ulcers, viruses and tumors [48]; [49]. Flavonoids reduce cancer by interfering with estrogen synthetase, an enzyme that binds estrogen to receptors in several organs [49].

3.2.2 Tannins contents

Tannins contents of differents parts (PP, MP, DP) of heart of oil palm tree was decrease significantly ($p<0.05$) during cooking times (Fig. 2). At 15 min of cooking time, the highest tannin content was obtained with DP (91.78 mg / 100g MS) and the lowest content with PP (43.69 mg / 100g MS). This decrease was also observed by Jude et al. [50] on cooked yam (*Dioscorea)* varieties. The decrease of tannin content during cooking times may be due to the thermal degradation and denaturation of the tannin as well as the formation of insoluble complexes [51]. This decline was also observed by the phenols and tannins are water soluble compounds [52] and as such can be eliminated by soaking followed by cooking [53].

3.2.3 Polyphenols contents

The effect of cooking on the polyphenol content of the various parts of the heart of oil palm tree is represented in Fig. 3. The results obtained showed a gradual increase in the polyphenol contents during the cooking time whatever the part studied. PP had the highest content of polyphenols (909.79 mg / 100g DM) while the lowest content at 45 min of water cooking was observed with DP (628.30 mg / 100g DM). Those results obtained indicate that cooking with water has a positive impact on the total polyphenol content of the different parts of the heart of oil palm tree. The percentages of increase varied from one part to another and can be explained on the one hand by the nature and the content of the different phenolic compounds appropriate to each part and on the other hand by the great facility with which the polyphenols are extracted from the cooked samples, following a strong embrittlement of the cell walls of plant tissues by heat [54]. It may be due to cooking which softens or disrupts the plant cell walls and destructs the complex phenolics [55]. Reportedly, total phenolics are usually stored in pectin or cellulose networks and can be released during thermal processing. Individual phenolics may, sometimes, increase because heat can break supramolecular structures and release the phenolic sugar glycosidic bounds, which react with the Folin- Ciocalteau's reagent [56].

3.2.4 Antinutritional contents

Figs. 4 and 5 shows the variation in the antinutritional factors content of the various parts of the heart of oil palm tree studied during cooking.

A decrease in the phytat content was observed at 15 minutes of cooking. This decrease has been progressive with DP content than in the other parts. The highest rate of phytat loss was observed with MP (56.93%) at the 45th minute of cooking.

As with phytat contents, oxalat contents decreased during cooking. The content obtained were varied between 117.02 and 114.62 mg / 100 g at PP, 350.55 and 222.27 mg / 100 g for CPM and 308.98 and 159.56 mg / 100 g for DP from the 15th min of cooking. The rate of oxalat loss varied between 2.05 and 48% at 15 minutes of cooking. The largest loss was recorded with DP (48%) and the lowest with MP (2.05%).

Table 1. Physico-chemical composition from heart of oil palm tree (different parts) raw and cooked

Different parts	Composition (%DM)						
	Moisture (%FM)	Ash	Fibres	Proteins	Fat	Carbohydrates	Energy (Kcal/100g)
				PP			
PP_0	89.94 ± 0.08^{c}	8.28 ± 0.51^{a}	26.49 ± 0.13^{e}	12.56 ± 0.65^{g}	12.81± 0.59^{e}	39.85± 0.47^{b}	324.98 ± 0.57^{i}
PP_{15}	90.84 ± 0.30^{c}	6.53 ± 1.88^{a}	29.81 ± 0.37^{f}	12.33 ± 1.34^{c}	8.93 ± 0.00^{c}	42.40± 1.64^{b}	299.29 ± 1.99^{f}
PP_{30}	91.11 ± 0.82^{b}	6.31 ± 1.84^{a}	30.98 ± 1.12^{f}	10.56 ± 0.65^{g}	8.02 ± 0.37^{c}	44.13± 2.25^{c}	290.94 ± 2.76^{h}
PP_{45}	92.23 ± 0.15^{f}	5.48 ± 1.85^{a}	32.26 ± 6.89^{b}	7.38 ± 1.30^{g}	7.58 ± 0.98^{c}	47.05± 3.51^{a}	285.94 ± 2.93^{j}
				MP			
MP_0	88.13 ± 0.27^{a}	6.91 ± 0.07^{a}	34.90 ± 0.1^{h}	10.70 ± 0.66^{e}	7.57 ±0.80^{c}	39.91 ±1.15^{b}	270.63 ± 1.87^{b}
MP_{15}	88.56 ± 0.30^{a}	6.14 ± 1.12^{a}	35.65 ± 4.08^{h}	10.22 ± 0.00^{e}	4.86 ±0.28^{c}	42.83 ±2.75^{d}	255.67 ± 3.01^{a}
MP_{30}	89.20 ± 0.75^{a}	5.04 ± 0.64^{a}	36.13 ± 4.53^{e}	10.02 ± 1.32^{f}	4.19 ±0.59^{b}	44.62 ±1.89^{f}	256.27 ± 1.27^{c}
MP_{45}	89.75 ± 0.97^{a}	4.58 ± 1.48^{a}	37.67 ± 1.12^{a}	9.72 ± 0.65^{d}	2.56 ±0.42^{c}	45.47 ±1.41^{h}	243.8 ± 1.49^{h}
				DP			
DP_0	91.38 ± 0.50^{c}	8.00 ±0.06^{a}	21.90 ± 0.02^{a}	13.12 ± 0.69^{h}	10.61± 1.13^{d}	46.37 ± 1.97^{e}	333.45 ± 3.26^{j}
DP_{15}	92.01 ± 0.45^{c}	7.50 ±1.64^{a}	24.39 ± 2.65^{e}	11.60 ± 0.66^{i}	7.93 ± 1.51^{c}	48.58 ± 1.62^{f}	312.09 ± 1.26^{g}
DP_{30}	92.68 ± 1.29^{b}	6.52 ±0.95^{a}	28.17 ± 2.31^{e}	8.65 ± 0.00^{a}	9.59 ± 1.78^{c}	47.09 ± 2.51^{f}	309.27 ± 3.09^{d}
DP_{45}	92.08 ± 1.49^{e}	5.51 ±0.25^{a}	29.41 ± 2.63^{c}	4.47 ± 0.67^{b}	1.06 ± 0.50^{a}	59.55 ± 1.26^{g}	265.62 ± 1.14^{e}

Values on a column with the same letter are not significantly different (p<0.05). Data are represented as means ± SD (n=3) PP: heart of oil Palm tree (Proximal Part). MP: heart of oil palm tree (Median Part). DP: heart of oil palm tree (Distal Part)

Table 2. Pearson correlation coefficients between various physicochemical and nutritional parameters of the different parts of raw and boiled heart of oil palm tree (*Elaeis guinnensis* Jacquin) consumed in Côte d'Ivoire

Variable	Moisture	Fibers	Ash	Proteins	Lipides	Carbohydrates	Energy	Polyphenols	Flavonoids	Tannins	Phytats	Oxalats
Moist	1.00											
Fibers	-0.63	1.00										
Ash	0.09	-0.79	1.00									
Proteins	-0.33	-0.32	0.65	1.00								
Lipides	0.17	-0.63	**0.83**	0.68	1.00							
Carbohydrates	0.63	-0.22	-0.32	-0.75	-0.56	1.00						
Energy	0.51	-0.92	**0.86**	0.51	**0.88**	-0.12	1.00					
Polyphenols	0.49	0.28	-0.72	-0.68	-0.44	0.18	-0.86	1.00				
Flavonoids	-0.57	-0.15	0.58	0.47	0.30	-0.40	0.18	-0.86	1.00			
Tannins	-0.42	-0.16	0.03	-0.19	0.23	0.09	0.24	0.21	-0.31	1.00		
Phytats	-0.43	0.10	0.07	0.08	-0.22	-0.00	-0.21	-0.34	0.47	0.08	1.00	
Oxalats	-0 44	-0.13	0.47	0.41	0.22	-0.32	0.14	-0.67	**0.85**	-0.07	0.73	1.00

NB : In thick, significant correlation values (p <0.05).

Moisture: Moisture; Ash: Ash; Fibers: Fibers; Proteins: Proteins; Lipids: Lipids; Carbohydrates: Carbohydrates; Energy: Energy value; Polyphenols: Polyphenols; Flavonoids: Flavonoids; Tannins: Tannins; Phytats: Phytats; Oxalats: Oxalats

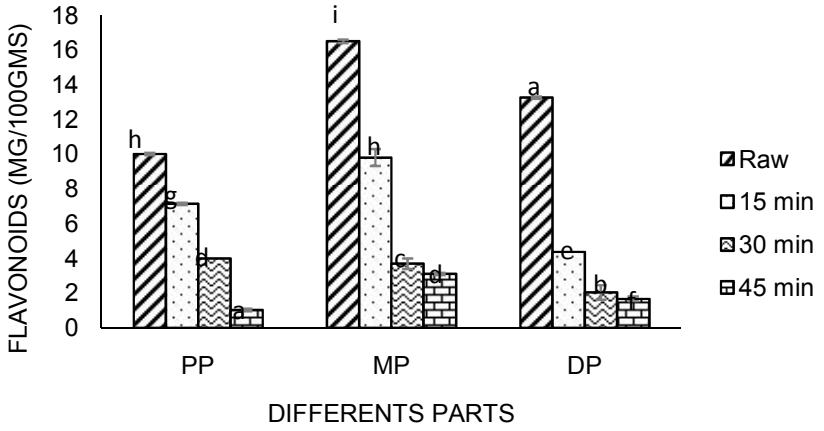


Fig. 1. Flavonoids content of heart of oil palm tree (different parts) raw and cooked

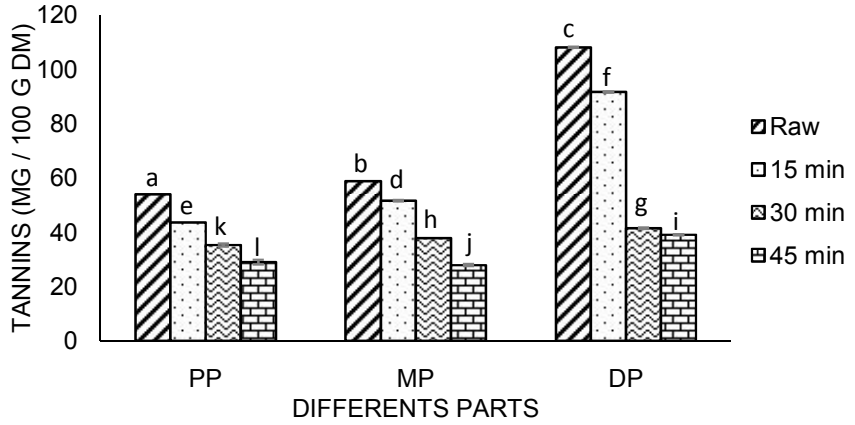


Fig. 2. Tannins content from heart of oil palm tree (different parts) raw and cooked

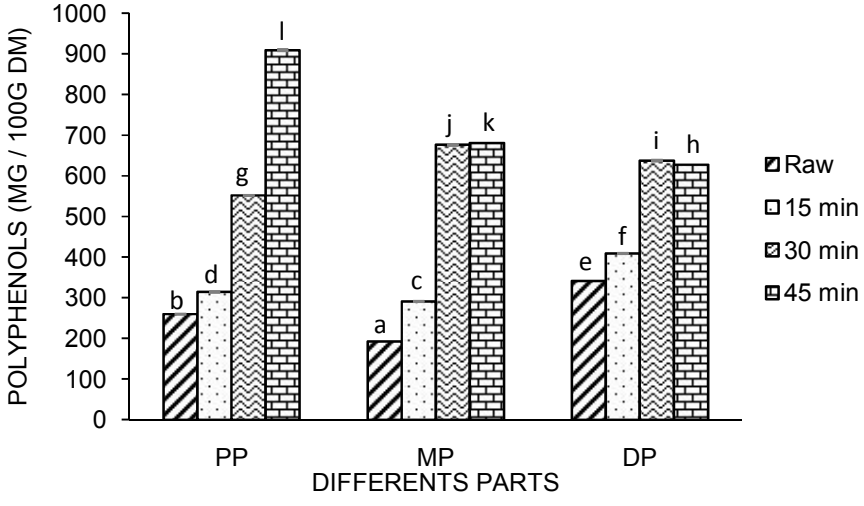


Fig. 3. Polyphenols content from heart of oil palm tree (different parts) raw and cooked

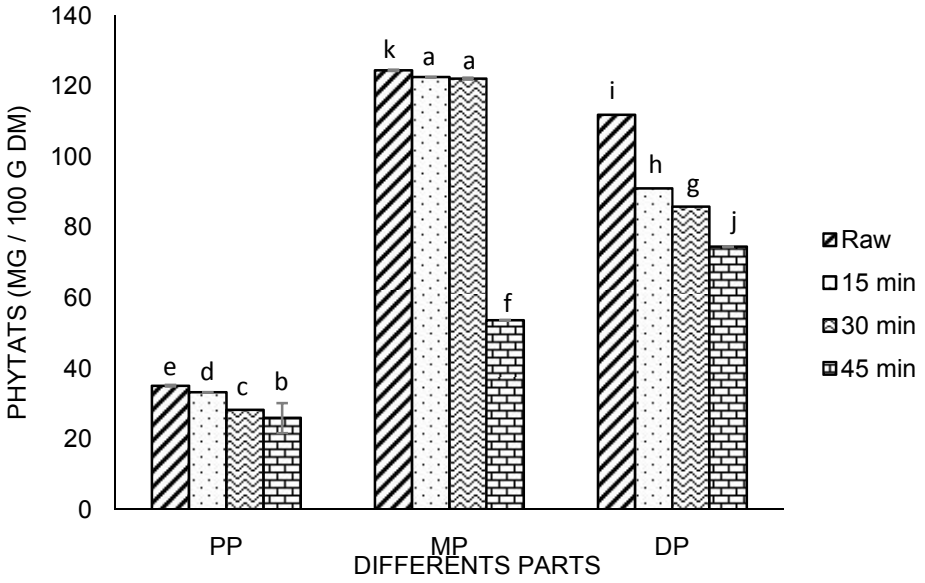


Fig. 4. Phytats contents from heart of oil palm tree (differents parts) raw and cooked

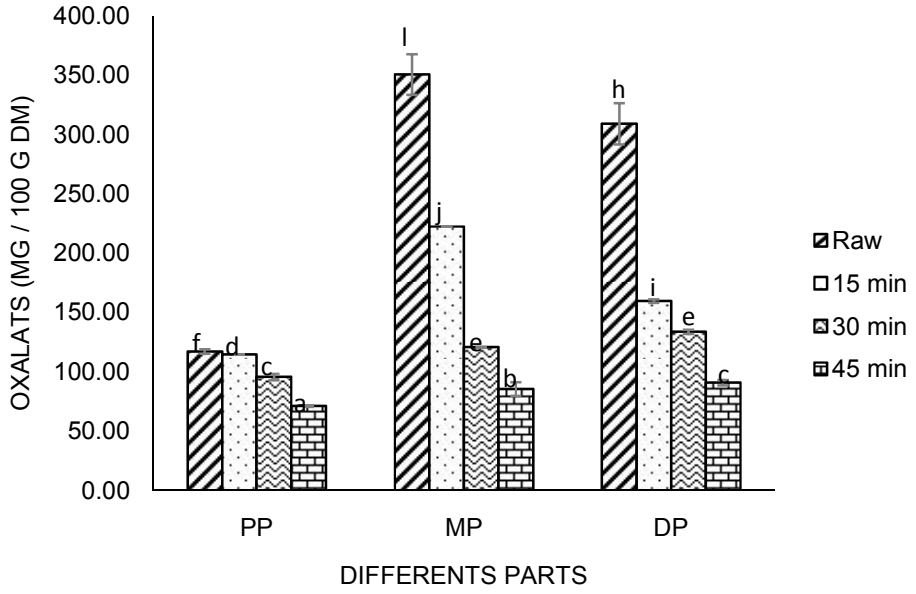


Fig. 5. Oxalates contents from heart of oil palm tree (differents parts) raw and cooked

Recent researchers report that the phenolic compound is the main human dietary antioxidant and has decreased incidence of chronic diseases [57]. The reduction increase with cooking times. This trend may be due to higher ability of hydrolysing the anti-nutritional factors as cooking period increased. The determination of the anti-nutritional substances was of interest because of their toxicity, negative effects on mineral bioavailability and their pharmacological effect. These metabolites occur in varying concentrations in the heart of oil palm tree. The decrease in the levels of these antinutrients during heat treatment might be due to thermal degradation and denaturation of the antinutrients as well as the formation of insoluble complexes [51].

3.2.5 Principal components analysis

The principal components analysis (PCA) and (Fig. 7) revealed that 15 and 30 min (MP_{15} and MP_{30}) cooking of the median part (PM) better preserves nutrients such as fiber and phytate contents. The cooking time (45 min) has no effect on the polyphenol and carbohydrates contents of the three parts (PP, MP, DP). The cooking time (15 minutes) of the proximal parts (PP) seems to better preserve the Lipids, Ash, Proteins, Flavonoids and Oxalats contents.

Pearson correlation (Table 2) and PCA analysis (Fig. 6) revealed a positive correlation of Lipids with Ash (r=0.83, p<0.05), Energy with Ash (r=0.86, p<0.05) and Energy with Lipids (r =0.88, p<0.05) and a negative with Energy and Fibers (r=-0.92, p<0.05), Flavonoids and Polyphenols (r =-0.86, p<0.05). This suggests that high Ash, Lipids exhibit high Energy and low Fibers, Flavonoids and Polyphenols contents.

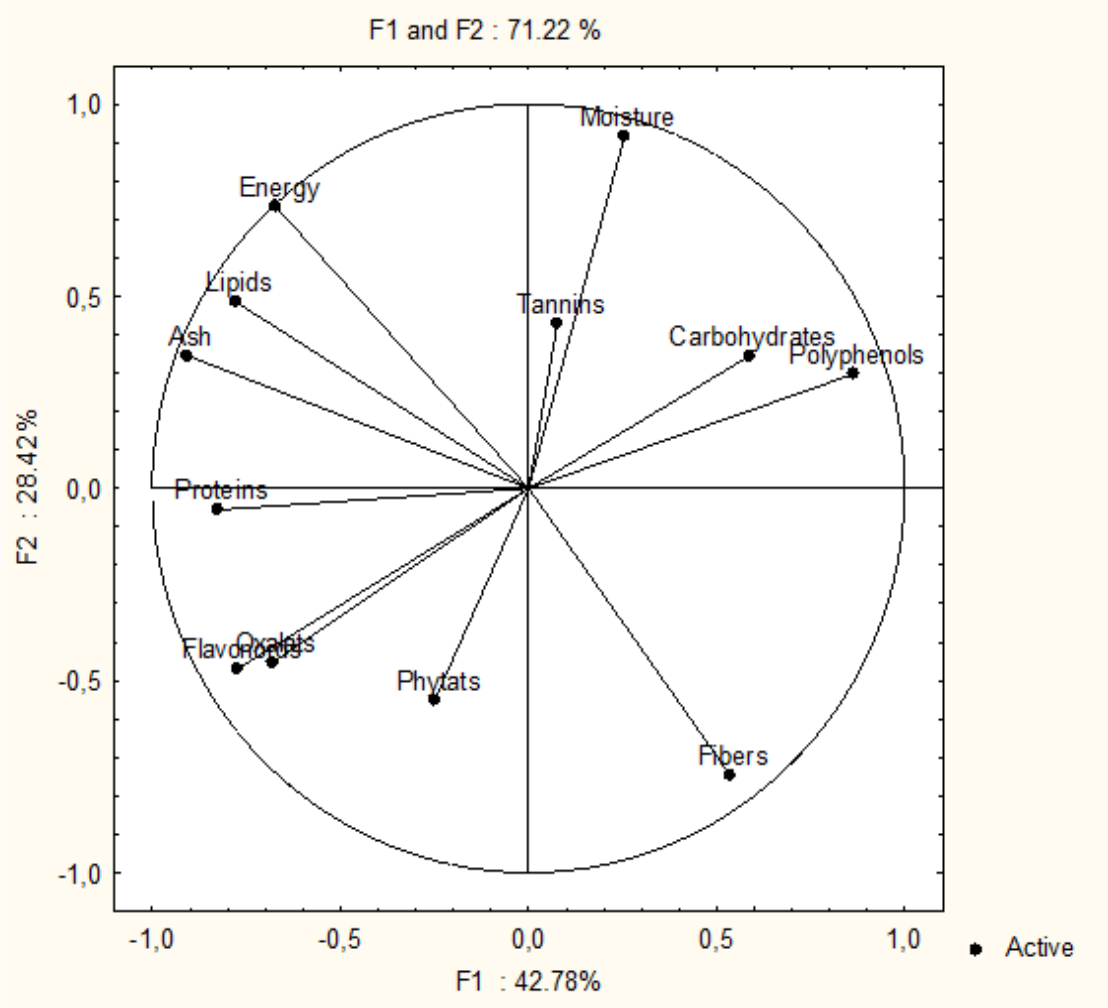


Fig. 6. Circle of correlation of physicochemical and nutritional parameters of differents parts of raw and boiled heart of oil palm tree (*Elaeis guineensis* Jacquin) consumed in Côte d'Ivoire on axes 1 and 2. Moisture: Moisture; Ash: Ash; Fibers: Fibers; Proteins: Proteins; Lipids: Lipids; Carbohydrates: Carbohydrates; Energy: Energy; Polyphenols: Polyphenols; Flavonoids: Flavonoids; Tannins: Tannins; Phytats: Phytats; Oxalats: Oxalats

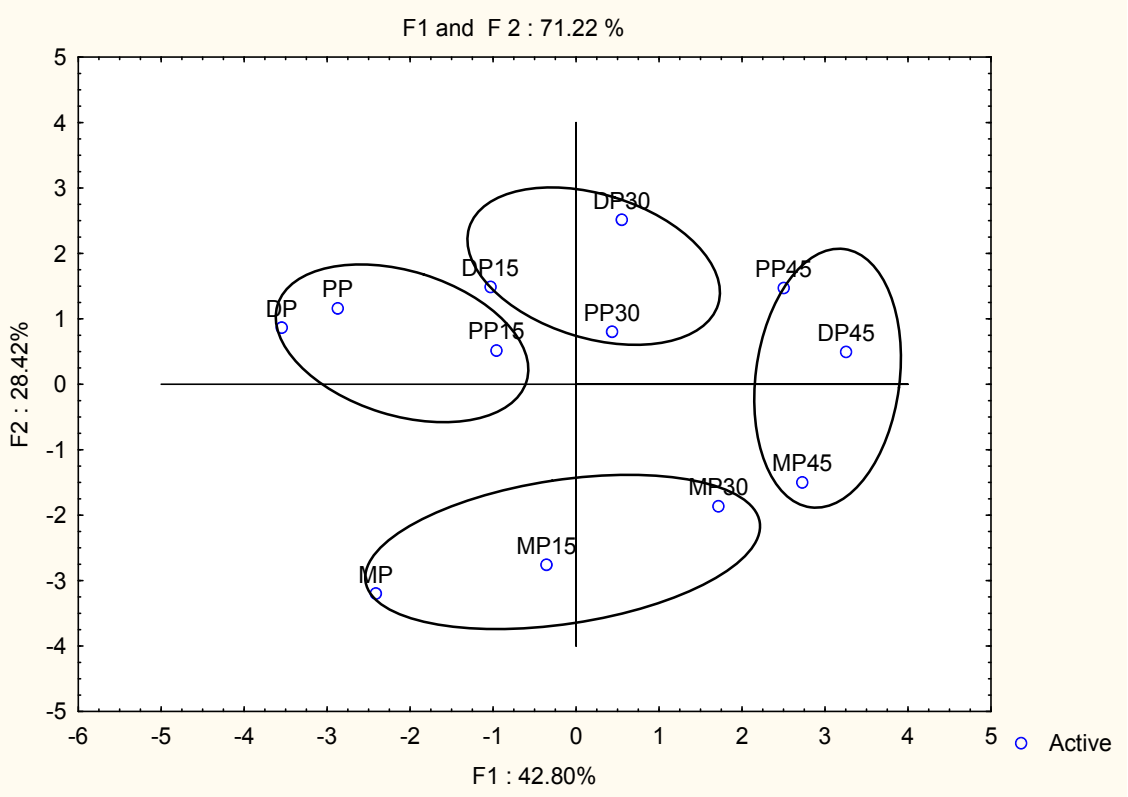


Fig. 7. Sample plot of principal components 1 and 2 of flours from raw and boiled heart of oil palm tree (*Elaeis guineensis* Jacquin) consumed in Côte d'Ivoire. PP: Proximal Part of raw heart of oil palm tree; PP_{15}: Proximal Part of heart of oil palm tree boiled in water during 15 min; PP_{30}: Proximal Part of heart of oil palm tree boiled in water during 30 min; PP_{45}: Proximal Part of heart of oil palm tree boiled in water during 45 min; MP : Mediane Part of raw heart of oil palm tree; MP_{15}: Mediane Part of heart of oil palm tree boiled in water during 15 min; MP_{30}: Mediane Part of heart of oil palm tree boiled in water during 30 min; MP_{45}: Mediane Part of heart of oil palm tree boiled in water during 45 min; DP: Distal Part of raw heart of oil palm tree; DP_{15}: Distal Part of heart of oil palm tree boiled in water during 15 min; DP_{30}: Distal Part of heart of oil palm tree boiled in water during 30 min; DP_{45}: Distal Part of heart of oil palm tree boiled in water during 45 min

4. CONCLUSION

The different parts of the palm heart studied are rich in nutrients. The distal part (DP) contains most nutrients compared to the other two parts. The cooking time 45 min has no effect on the total polyphenol and carbohydrate content of the three parts. The cooking time 15 minutes for the proximal parts seems to better preserve nutrients such as lipids, ashes, proteins, flavonoids and oxalates content is also safe for the body. For a diet rich in energy, it would be interesting to consume the proximal parts cooked at 30 and the distal parts cooked at 15 and 30 min. The best cooking time would be 15 minutes, due to low nutrient loss rates.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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