GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(Research Article)

Check for updates

Influence of cooking methods and times on purple eggplant (*Solanum melongena* L.) bioactive compounds

Affissata Fathim France Kane *, Edith Adouko Agbo, Souleymane Traore and Kouakou Brou

Nutrition and Food Safety laboratory, Food Science and Technology Department, University Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire.

GSC Biological and Pharmaceutical Sciences, 2024, 29(02), 219–230

Publication history: Received on 07 October 2024; revised on 18 November 2024; accepted on 20 November 2024

Article DOI: https://doi.org/10.30574/gscbps.2024.29.2.0432

Abstract

In several countries of Africa, purple eggplants are added in cooking meals. However, during cooking, high temperature and long time can affect the nutrients and the bioactive compounds. Thus, a study has been conducted to assess the cooking methods and time which better preserve purple eggplant nutrients losses. So, purple eggplant samples were cooked and steamed for 10, 20 and 30 minutes. The analyses were focused on the determination of physicochemical parameters, macro and micronutrients, phytochemical compounds and antioxidant activity. The results showed that protein content, initially 14.11% in fresh eggplants, rosed to 14.73% and 15.60% in eggplants boiled and steamed for 20 mins, respectively. Total carbohydrate content increased from 63.75% in fresh eggplant to 68.17% in eggplant steamed for 20 mins. The fiber content of fresh eggplant (24.75%) rosed to 28.95% and 29.84% in eggplant cooked in water and steamed for 20 mins, respectively. Polyphenol content in fresh eggplant which was about 47.84 mg EAG /100mg increased to 60.57 and 62.85 mg EAG /100 mg in eggplant cooked in water and steamed during 20 mins, respectively. The antioxidant inhibitory concentration of 50% DPPH activity (IC50) was about 0.42 mg/mL for purple eggplants boiled and steamed during 20 mins. These IC50 revealed an antiradical power of 238.09 µmol of reduced DPPH/mg of sample. Morever, purple eggplant steamed during 30 minutes present an antiradical power of 400 µmol of reduced DPPH/mg of sample. Steaming purple eggplant favored nutrient preservation and high antioxidant potentialities.

Keywords: Purple eggplant; Boiling; steaming; Nutrients; Antioxidant potentialities

1. Introduction

Metabolic diseases are disorders that affect metabolism in human cell, particularly energy production. Most of them are genetic, but, some are acquired through diet. To compensate for this, the consumption of fruit and vegetables should be favoured, as they contain nutrients (vitamins, minerals), fiber and phytonutrients that contribute to the body's well-being. Morever, fruits and vegetables are important for a healthy diet, as they promote growth and strengthen the functions of the body's organs, as well as promoting physical, mental and social well-being in all ages. They can help overcome all forms of malnutrition (undernutrition, micronutrient deficiency, overweight and obesity) and reduce the risk of non-communicable diseases [1].

According to the World Health Organization (WHO), the minimum quantity of fruits and vegetables useful per day to ensure a healthy diet is 400 g. But, on average, only around two-thirds of the recommended minimum amounts are consumed [1].

Eggplant fruit is highly nutritious and has been used medicinally because of containing very few calories and beneficial minerals such as potassium, calcium, magnesium, sodium, iron, and phytochemicals that include phenolic components

* Corresponding author: Affissata Fathim France Kane; Email:fathimfrancekane@gmail.com

including polyphenols and flavonoids. It also contains dietary fiber that is good for health [2]. Furthermore, high purple eggplant phenolic content contributes to reduce free radicals by their antioxidant potentialities [3]. However, eggplant need cooking process to support digestibility and improve taste and flavour. But, this promotes nutrient losses [4]. So, it will be useful to limit such losses.

Some studies have been conducted in this field of research. Azizuddin et al. [5] claimed that eggplant is an excellent dietary option because it has a high fiber content and fewer carbs. Massive amounts of calcium, potassium, phosphorus, and magnesium are found in eggplant. These minerals aid in the human body's electrolyte balance. Eggplant can provide a significant proportion of antioxidants, with more phytochemicals, offering many benefits to human health [6]. But, important losses while cooking leaves with water have been revealed by [7 and 8]. Therefore, steaming seemed to be an appropriate cooking method. Indeed, [9] indicated that blanching of sweet potato leaves for 60 s resulted in increased flavonoids retention with level like those in fresh leaves and [10] also revealed that steaming was good for the retention of total phenolic compound. But these studies have been conducted on leafy vegetables. The aim of this research work was to determine the cooking methods and time which optimize the bioactive compounds preservation in a vegetable like purple eggplant.

2. Material and methods

The purple eggplant samples were harvested from experimental field in Guitry town in West Ivory Coast (5° 31′ 08″ North, 5° 14′ 24″ West) during April 2022 (Figure 1). A nursery was made and 4 weeks after sowing, plants were transplanting as follow: 0.7 m between line and 0.5 m between plants on line. Watering was done in morning and in evening for two weeks after transplanting and then, when necessary.

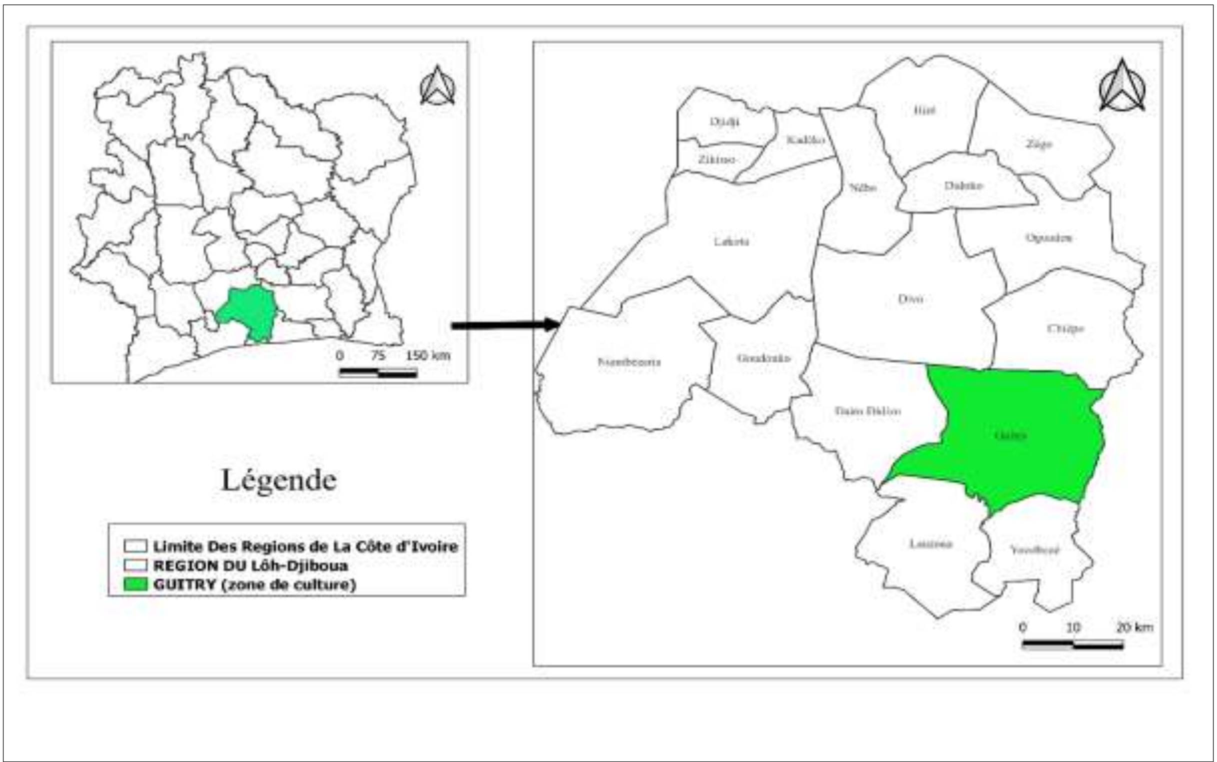


Figure 1 Locality of Guitry

2.1.1. Sampling

On field, eggplants were harvested early in the morning at maturity, 105 days after transplanting. They were transported to laboratory for analysis where they They were cleaned and washed under running water.

2.1.2. Purple eggplant cooking process

After harvesting, the purple eggplant samples were separated in 3 batches of 1 Kg per batch. The first batch was constitued of fresh purple eggplant, the second batch was boiled with water and the third batch was steamed. All cookings were performed at 10, 20, and 30 minutes. Before cooking, purple eggplant samples were washed and cut into thin strips.

2.1.3. Physicochemical characteristics determination of purple eggplant samples

The samples' physicochemical properties, including their pH, titratable acidity, moisture, fat, protein, fiber and ash were determined according AOAC [11]. Water-soluble carbohydrates were determined by phenol sulphuric acid method, according Dubois et al. [12] and total reducing sugars were quantified using the dinitrosalicilic acid method described by Bernfeld [13]. Minerals determination was carried out according Kularatne and Freitas method [14] by using the atomic absorption spectrophotometer equipment.

2.1.4. Phytochemical analyses

Total polyphenol levels were determined using Folin-Ciocalteu colorimetric method [15]. Total flavonoids were determined using the modified method of Hariri et al. [16]. The determination of condensed tannins in the various extracts was carried out according Heimler et al. [17]. The concentrations of condensed tannins are deduced from the calibration ranges established with catechin (0-300 µg/mL), and are expressed in µg of catechin equivalent per mg of extract.

2.1.5. Free radical scavenging activities and anti-radical power determination

Free radical scavenging activity of the extracts was measured with the DPPH method [18]. This test consists in evaluate the capacity of extract to fixed DPPH free radical by the measurement of color diminution at 517 nm. Vitamin C (100 µg/ml) was used as standard. The sample concentration which can inhibit 50% of DPPH (IC_{50}) was determined on graphic and expressed the antiradical activity. It allowed to calculate the antiradical power [19] as follow:

$$ARP = \frac{\text{DPPH solution concentration (µmol of reduced DPPH)}}{IC_{50} \text{ x } 10^{-3} \text{ (µg /ml)}} \dots\dots\dots\dots\dots\dots.(1)$$

- ARP: antiradical power
- DPPH: 2,2-diphenyl-1-picrylhydrazyl
- IC_{50}: Sample concentration which inhibit 50% of DPPH

2.2. Statistical analyses

R.301 software was used. A one-way ANOVA was performed, and means were separated using Tukey test ($p \leq 0.05$). Graph Pad Prism 5.0 (Microsoft U.S.A) were used for antioxydant activity representation. Through Pearson correlation analysis (using the XLSTAT programme), possible links between antioxidant activity and the presence of phenolic compounds were looked at.

3. Results

3.1. Physicochemical composition of purple eggplant

Raw, boiled and steamed purple eggplant physicochemical parameters are presented in Table 1. The pH, titratable acidity, moisture and ash contents were significantly different ($P<0.05$) between raw and cooked eggplant. The pH is acid and vary between 5.2 ± 0.02 (eggplant boiled at 20 min) and 6.03 ± 0.05 (eggplant steamed at 10 min). Eggplant cooked in water for 10 mins had the highest dry matter content and the lowest water content. Whatever the cooking method (boiling or steaming), the water content was higher at 30 min than at the other cooking times (10 min and 20 min). For eggplant cooked in water dry matter was 8.96 ± 0.06 % and for steamed eggplant it was 14.05 ± 0.12 %. Ash content decreased in steamed eggplant, ranging from 7.58 ± 0.1 (T10) to 5.40 ± 0.06 (T30). However, in the boiled eggplant, the rate increased from 7.20 ± 0.06 to 9.08 ± 0.07 %.

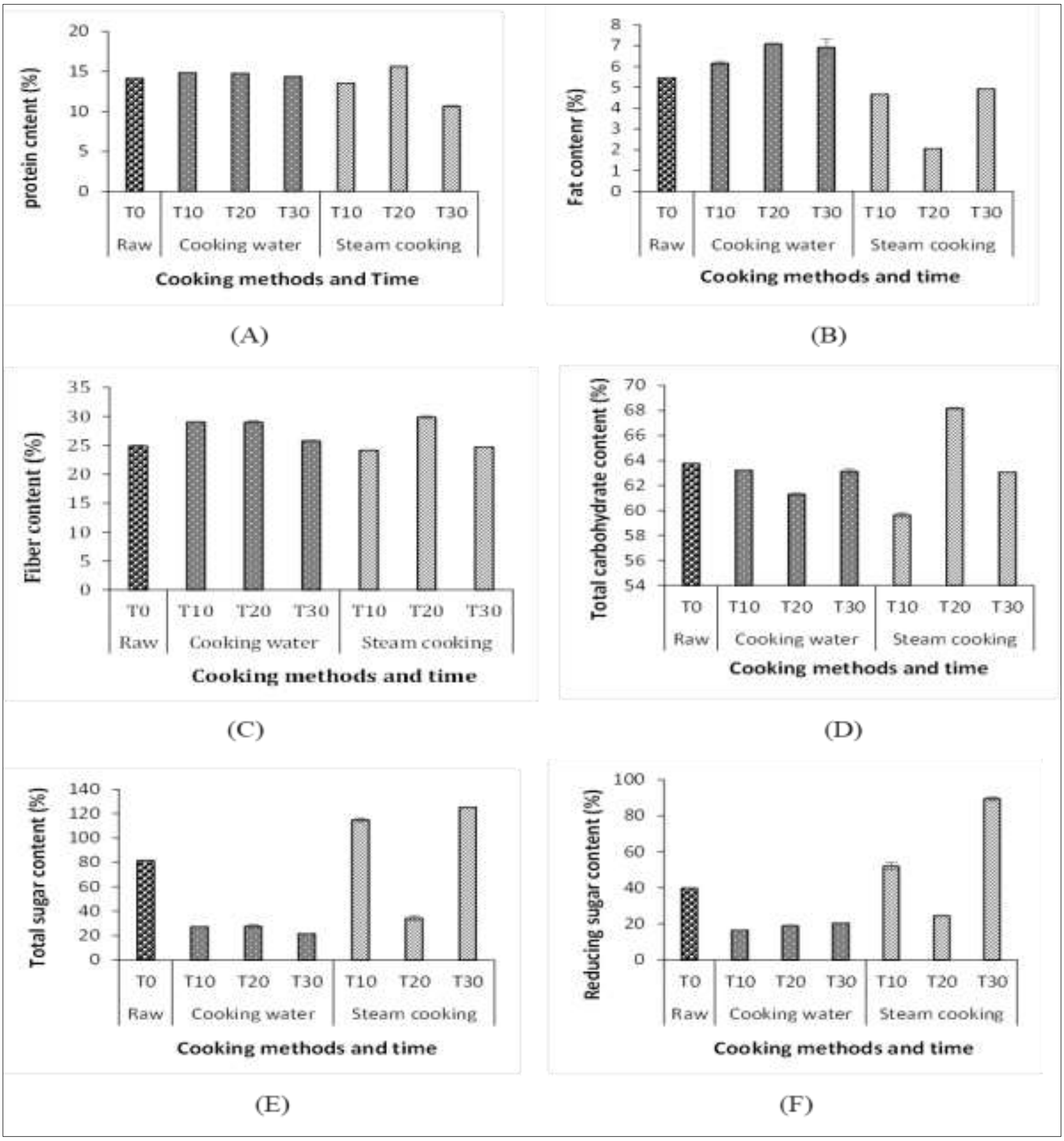
Table 1 Physicochemical parameters of fresh and cooked purple eggplant

Cooking time							
	T10		**T20**		**T30**		
Samples	**AE**	**AV**	**AE**	**AV**	**AE**	**AV**	**AC**
pH	5.56 ± 0.01^{d}	6.03 ± 0.05^{g}	5.2 ± 0.02^{a}	5.80 ± 0.05^{f}	5.3 ± 0.02^{b}	5.4 ± 0.06^{c}	5.62 ± 0.01^{e}
TA (meq-g /l)	0.33 ± 0.01^{abc}	0.2 ± 0.01^{a}	0.3 ± 0.05^{abc}	0.25 ± 0.01^{a}	0.5 ± 0.01^{c}	0.3 ± 0.01^{ab}	0.46 ± 0.06^{bc}
DM (%)	91.45 ± 0.07^{f}	88.91 ± 0.07^{b}	91.03 ± 0.17^{ef}	91.04 ± 0.06^{e}	89.31 ± 0.13^{c}	85.95 ± 0.12^{a}	90.0 ± 0.07^{d}
M (%)	8.55 ± 0.07^{ab}	11.09 ± 0.07^{d}	8.70 ± 0.01^{a}	8.96 ± 0.06^{a}	10.70 ± 0.13^{cd}	14.05 ± 0.12^{e}	9.99 ± 0.07^{bc}
Ash (%)	7.20 ± 0.06^{d}	7.58 ± 0.10^{e}	6.25 ± 0.05^{c}	5.98 ± 0.01^{b}	9.08 ± 0.07^{f}	5.40 ± 0.06^{a}	7.45 ± 0.10^{e}

AE : water cooking eggplant ; **AV** : steam cooking eggplant ; **AC** : Raw eggplant ; **T10** : cooking time 10mins ; **T20 :** cooking time 20mins ; **T30 :** cooking time 30mins ; **TA :** Titratable acidity ; **DM** : Dry Matter ; **M** : Moisture. Mean values with a different letter (a, b) in line are significantly different based on Turkey's test at the 0.05 threshold

3.2. Biochemical parameters of purple eggplant cooking samples

Purple eggplant biochemical parameters are shown in Figure 2. The highest protein content (15.60%) was obtained after 20 mins with steaming process (Figure 2A). Figure 2B showed fat content of boiled and steamed eggplant at different cooking times (10mins, 20mins and 30mins). The highest fat content (7.08%) was observed in eggplant cooked in water for 20 minutes and the lowest in eggplant steamed for 20 minutes. The highest fiber content (29%) was obtained after 10 mins of boiling eggplant and after 20 mins of steaming (29.8%) (Figure 2C). As for total carbohydrates, the highest content (68.17%) was observed in eggplant steamed for 20 mins (Figure 2D). Whatever the cooking time, a drop in total sugar and reducing sugar content was observed after boiling process (Figure 2E and 2F). These values vary respectively between (81.33 g/L to 21.58 g/L) and (39.83 g/L to 16.60 g/L). In contrast, steaming increases the total and reducing sugar content respectively from 81.33 g/L to 124.88 g/L and from 39.83 g/L to 89.43 g/L (Figure 2E and 2F). Globally, significant difference ($P<0.05$) was observed between eggplant samples.



A: Protein; B: Fat; C: Fiber; D: Total carbohydrate; E: Total sugar; E: Total sugar F: Reducing sugar

Figure 2 Changes of biochemical parameters of purple eggplant cooking samples

3.3. Mineral composition of purple eggplant cooking samples

Mineral contents of raw and cooked eggplant are shown in Table 2. There was a significant statistical difference (P<0.05) between raw and cooked eggplant samples for the same cooking method. For eggplant cooked in water, the highest sodium levels were observed at 30 minutes (4.54 ± 0.05 mg/100 g DM) and 10 minutes (4.29 ± 0.05 mg/100 g DM). Phosphorus levels fell throughout eggplant boiling. Values fell from 4.03 ± 0.11 mg/100 g DM at T10 minutes to 2.96 ± 0.15 mg/100 g DM at T30 minutes. The highest concentration of potassium was recorded after 20 minutes with a value of 4.26 ± 0.05 mg/100 g DM. For calcium, the highest concentration was obtained with eggplant cooked in water after 30 minutes (8.58 ± 0.05 mg/100 g DM). In terms of manganese and zinc content, the highest levels were recorded after 20 minutes with 10.12 ± 0.02 mg/100 g DM and 3.46 ± 0.24 mg/100 g DM, respectively. Concerning steamed eggplant, the analysis revealed higher levels of all the minerals analyzed after 20 mins of cooking. However, higher concentrations of zinc and calcium were observed after 30 mins for zinc (4.47± 0.1 mg/100 g DM) and after 10 mins for calcium (9.05 ± 0.04 mg/100 g DM). The sodium, phosphorus, potassium and manganese contents of the steamed eggplant samples after 20 mins were 3.41 ± 0.14 mg/100 g DM, 5.35 ± 0.01 mg/100 g DM, 4.56 ± 0.01 mg/100 g DM and 87.77 ± 1.48 mg/100 g DM, respectively.

Table 2 Mineral composition of raw and cooked purple eggplant

Mineral mg /100g	Water cooking			Steam cooking			AC
	T10	T20	T30	T10	T20	T30	
Sodium	4.29 ± 0.05ᵃ	2.86 ± 0.05ᵇ	4.54 ± 0.05a	2.46 ± 0.10ᵃ	3.41 ± 0.14ᵇ	3.3 ± 0.01ᵇ	2.61 ± 0.5ᵃ
Phosphorus	4.03 ± 0.11ᵃ	3.67 ± 0.01ᵇ	2.96 ± 0.15ᶜ	2.45 ± 0.15ᵃ	5.35 ± 0.1ᵇ	3.21 ± 0.01ᵇ	3.04 ± 0.01ᵇ
Potassium	0.57 ± 0.01ᵃ	4.26 ± 0.05ᵇ	2.64 ± 0.05ᶜ	2.85 ± 0.10ᵈ	4.56 ± 0.01ᶠ	0 ±0ᵃ	6.68 ± 0.05ᶜ
Calcium	5.84 ± 0.01ᵃ	6.73 ± 0.05ᵇ	8.58 ± 0.09ᶜ	9.05 ± 0.04ᵉ	5.89 ± 0.07ᵃ	5.79 ± 0.01ᵃ	7.05 ± 0.05ᶜ
Manganese	0 ± 0ᵃ	10.12 ± 0.02ᵇ	0 ± 0ᶜ	0 ± 0ᵃ	8.67 ± 0.01ᵈ	0 ± 0ᵃ	10.73 ± 0.05ᵈ
Zinc	0 ± 0ᵃ	3.46 ± 0.24ᵈ	1.52 ± 0.04ᵇ	1.65 ± 0.11ᵇ	2.7 ± 0.1ᶜ	4.47± 0.1ᵉ	2.14 ± 0.01ᵉ

AC: Raw Eggplant, **T10**: Time of 10 mins, **T20**: Time of 20 mins, **T30**: Time of 30 mins. Mean values with a different letter (a, b, c, d, e) in a line and for the same cooking method are significantly different (Tukey test at 0.05 threshold)

3.4. Phytochemical composition and antioxidant activity of cooked and steamed purple eggplant

The analyses revealed that the highest polyphenol content was obtained in samples cooked in water for 20 minutes with a value of 62.85 ± 0.45 mg GAE/g DM, while those of steamed eggplant always at 20 minutes had a concentration of 60.57 ± 0.30 mg GAE/g DM. These two values were still higher than that of raw eggplant, which was 47.84 ± 0.30 mg GAE/g DM. In terms of flavonoids, the highest content was recorded in samples of eggplant cooked in water for 10 minutes, with a value of 5.27 ± 0.15 mg QE/g DM. This value differed significantly to that for raw eggplant, which was 5.70 ± 0.03 QE/g DM. Concerning condensed tannins, the highest content (7.28 ± 0 mg CE/g DM) was obtained with eggplant samples steamed for 20 minutes and this value was higher than that of raw eggplant, which was 5.93 ± 0 mg CE/g DM (Table 3). Overall, the statistical analyses showed a significant difference ($P < 0.05$) between the raw and cooked eggplant samples for the same cooking method.

DPPH free radical scavenging activities of vitamin C, boiled and steamed purple eggplant increased with concentrations (Figure 3). The inhibitory concentration (IC_{50}) values that inhibite 50% of DPPH radical was determined graphically. For vitamin C (reference) and raw purple eggplant, the IC_{50} was about 0.23 mg/ml and 0.20 mg/ml respectively. This suggests a strong inhibitory capacity with respective antiradical power of 434.78 and 500.00 µmol of reduced DPPH / mg. The other samples that underwent heat treatment such as steaming for 30 mins (AVT30) and 10 mins (AVT10) also showed low IC_{50} of 0.25 mg/ml and 0.38 mg/ml, respectively, indicating antiradical power of 400.00 and 263.15 µmol of reduced DPPH / mg. For purple eggplant boiled and steamed during 20 minutes (AVT20 and AET20) IC_{50} was about 0.42 mg/ml, indicating an antiradical power of 238.09 µmol of reduced DPPH / mg (Table 4).

Table 3 Phenolic compounds of eggplant samples

Samples	Phenolic compounds		
	TP (mg/g GAEDM)	TF (mg/g QE)	CT (mg CE/g DM)
AC	47.84 ± 0.0ᵈ	5.70 ± 0.03ᵈ	5.93 ± 0ᵈ
AET10	39.76 ± 0.17ᵃ	5.27 ± 0.15ᶜ	4.51 ± 0.2ᶜ
AET20	62.85 ± 0.45ᵍ	4.68 ± 0.10ᵇ	4.31 ± 0.54ᵇᶜ
AET30	46.02 ± 0.80ᶜ	3.68 ± 0.22ᵃ	3.59 ± 0.31ᵇ
AVT10	56.03 ±0.91ᵉ	3.64 ± 0.07ᵃ	3.68 ± 0.15ᵇ
AVT20	60.57 ± 0.30ᶠ	4.69 ± 0.05ᵇ	7.28 ± 0ᵉ
AVT30	41.93 ± 0.15ᵇ	3.76 ± 0.04ᵃ	1.79 ± 0.15ᵃ

AC: raw aubergine, **AET10**: aubergine cooked in water for 10 minutes, **AET20**: aubergine cooked in water for 20 minutes, **AET30**: aubergine cooked in water for 30 minutes, **AVT10**: aubergine cooked in steam for 10 minutes, **AVT20**: aubergine cooked in steam for 20 minutes, **AVT30**: aubergine cooked in steam for 30 minutes. **TP**: polyphenols, **FLAV**: flavonoids, **CT**: condensed tannins. Values are expressed as mean ± standard deviation for three independent measurements. Mean values with a different letter in a column are significantly different (Tukey test at 0.05 threshold).

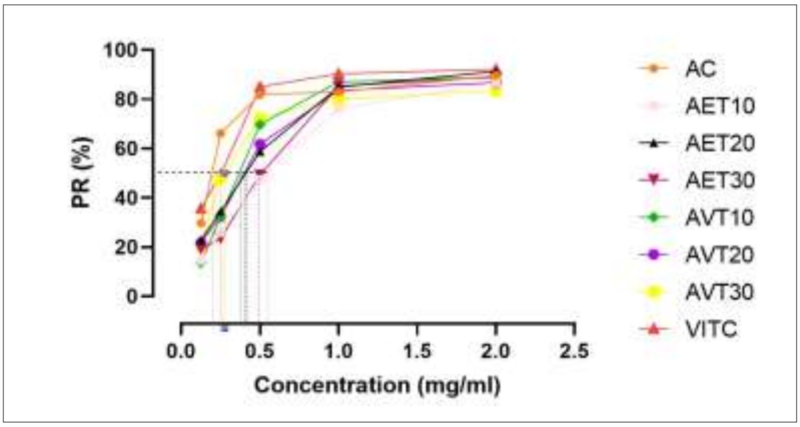


Figure 3 Antioxidant activities of eggplant samples

Table 4 IC_{50} values and antiradical power of cooked and raw purple eggplant

Samples	IC_{50} (mg/ml)	ARP (µmol of reduced DPPH / mg)
AC	0.20 ± 0.01	500 ± 0.01
AET10	0.55 ± 0.01	181.81± 0.01
AET20	0.42 ± 0	238.09 ± 0.01
AET30	0.50 ± 0	200 ± 0
AVT10	0.38 ± 0.02	263.15 ± 0.02
AVT20	0.42 ± 0.01	238.09 ± 0.01
AVT30	0.25 ± 0.01	400 ± 0.01
VITC	0.23 ± 0	434.78 ± 0

AC: Raw aubergine. **AET10**: boiled for 10 min. **AET20**: boiled for 20 min. **AET30**: boiled for 30 min. **AVT10**: steamed for 10 min. **AVT20**: steamed for 30 min. **IC_{50}**: Inhibitory concentration for 50 % DPPH. **ARP**: antiradical power.

3.5. Correlation between phytochemical composition and antioxydant activities

In order to establish link between phenolic compounds and antioxydant activities, a Pearson correlation test has been conducted. It revealed a positive correlation ($r=0.553$ at $p<0.05$) between polyphenol and antioxydant activities (Table 5).

Table 5 Pearson correlation matrix between phenolic compounds and antioxidant activities

Variables	Polyphenols Total	Total flavonoids	Total flavonoids
DPPH	0.553*	0.249	0.331

* The correlation is significant at the 0.05 threshold.

4. Discussion

The aim of the study was to determine the cooking methods and time which optimize the bioactive compounds preservation in purple eggplant. The moisture levels of purple eggplants increased with steaming until 30 mins. These results can be explained by the fact that steaming increases the water content of vegetables up to saturation. The results obtained are in agreement with those of Kadri [20] who showed that the water content of potatoes (*Solanum tuberosum* L.) increased by 0.04% during steaming. According to Muller and Kunzuk [21], the heat treatment that a plant can undergo causes partial solubilization of pectins, easier separation of cells but also good conditions for hydration of the cell walls. The pH was slightly acidic and varies from raw eggplants to eggplants cooked at different cooking times. Indeed, cooking temperature can modify the structure of the compounds present in the eggplant, thus promoting the release of acids and the modification of the pH. Moreover, the variation of pH could be explained by the modification of the rheological state (structures, textures, viscosities) of the starch that occurs during the cooking process [22]. The properties of starches can be modulated with the pH of the medium, the water binding capacity of the mixtures increasing with the pH [23].

Ashes revealed the presence of minerals in eggplants. Their rates decrease in eggplants during cooking in water and steaming. This decrease could be explained by the leaching of minerals in cooking water or by the partial degradation of mineral compounds under the effect of heat. Indeed, Traoré et al. [24] stated that heat treatments affected certain nutrients contents in meat. The majority proteins in meat (myosin and actin) are the main targets of oxidation. In addition, the oxidative modifications of these proteins contributed to their polymerization and aggregation which seemed to be amplified by the increase in cooking temperature [25]. These results are lower than those of Briki et al. [26] who found ash contents between 7.35 and 10.70%.

The protein content increased in eggplants steamed for 20 mins. This is due to the cooking process during which the water vapour once inside the eggplants could solubilize the proteins. However, these results are lower than those of Vodouhé et al. [27] who obtained a high protein content (30.66% DM) for *S. macrocarpum* also cooked by steaming. Indeed, cooking has a beneficial effect on the nutritional value of proteins by facilitating their accessibility to digestive enzymes thanks to the inactivation of protease inhibitors. The consumption of foods rich in proteins contributes to the structure of muscle tissue. They also intervene in the maintenance and regeneration of cells in adults. For Hayat et al. [28], proteins play a vital role in building and repairing the body. The lowest lipid content was observed during steaming for 20 mins while the highest content was observed during boiling for 20 mins. This could be due to the fact that all parts of the fruit (skin, flesh and seeds) were used for the analysis. Furthermore, this variation in lipid content is due to the decomposition of the fat in the eggplant during cooking, which proves that cooking may or may not maintain the biochemical characteristics of eggplants [29]. The total carbohydrate content decreases during boiling but increases during steaming for 20 min. This could be due to solubilization and transformation of total carbohydrates during cooking. In fact, carbohydrates, called water-soluble molecules, could solubilize in cooking water [30].

The highest dietary fiber content was observed in steam cooking after 20 mins and in boiling eggplant for 10 mins. These results were higher than those of Vodouhé et al. [27] for steamed *Solanum macrocarpum* leafy vegetables (8.39% DM). Indeed, cooking leads to an increase in soluble fiber content and a decrease in insoluble fiber content by modifying the plant cell walls. In addition, the fiber content of eggplant promotes healthy digestion, which helps the body get rid of waste and harmful toxins, thereby reducing the risk of colon and stomach cancer [31]. These fibers are important to the body because they intervene in the digestive tract and prevent the absorption of excess cholesterol. In addition, the high fiber content and low soluble carbohydrate content of eggplant make it a good choice to help manage type 2 diabetes [32]. Total sugar and reducing sugar contents decrease after boiling regardless of the cooking time. This could be explained by the fact that some sugars are heat labile due to cooking. These values are higher than those obtained by Enzonga-Yoca et al. [33] which were 0.36 ± 0.17% for *Citrullus lanatus* and 0.83 ± 0.36% for *Cucumeropsis manii*.

Increased vegetable consumption can improve mineral regulation and reduce the risk of cardiovascular diseases and certains cancers as they play an important role in the body metabolism [34]. According to De Fermicourt [35], the presence of minerals in vegetables is of capital importance for populations because they are essential for the activity of hormones and especially for that of enzymes in the body. The highest sodium content was obtained in eggplants cooked in water after 30 mins, but the lowest content was in eggplants steamed during 10 mins. This high content could be explained by a high capacity of sodium to be soluble in water (high water-soluble capacity). Sodium plays an important role in nerve impulses [36]. The osmotic power of potassium maintains cell volume. Both intracellular and extracellular cations of sodium and potassium are important. They regulate plasma volume, nerve transmission and muscle contractions [37]. In addition, minerals are soluble in water and during cooking, they diffuse into the extracellular environment [38]. Phosphorus content was higher in eggplants steamed during 20 min. On the other hand, in boiled eggplants the rates had decreased over time. Cooking in water promotes more loss of phosphorus and potassium than steaming. This could be due to the leaching of minerals in the cooking water. It is therefore important not to pour out the cooking water and to consume the sauces in order to optimize the quantities of minerals ingested given their importance for the body. Concerning calcium, an increase in the content in eggplants cooked in water over time opposite to a decrease in eggplants steamed was observed. This could be explained by the concentration effect due to the loss of water during cooking. In addition, calcium can be released from cellular structures under the effect of prolonged heat. Indeed, calcium contributes to the prevention of certain diseases such as osteoporosis in adults and rickets in children. Moreover, when phosphorus and calcium are combined, it helps teeth, muscles and bones to function properly [39]. Manganese content was high in eggplants steamed during 20 mins while zinc content was high in eggplants steamed during 30 mins. This difference could be explained by the cooking time and the mineral. Thus, the residual content of certain minerals in foods may be dependent on the time and method of cooking.

Regarding total polyphenols, steaming and boiling eggplants for 20 mins showed the highest levels. These results are higher than those obtained by Kadri [20] for vegetables cooked in water (carrot: 8.70 mg GAE/100g and green cabbage 3.6 mg GAE/100g) and for steamed vegetables (Carro t: steam 1.67 mg GAE/100g and green cabbage: 16.06 mg GAE/100g). This increase could be explained by the great ease with which polyphenols are extracted from cooked samples, following by a strong weakening of the cell walls of plant tissues by heat [40]. They may also be due to the fact that cooking, particularly steaming and blanching, promotes an increase in the level of polyphenols by bursting the cells [41]. On the other hand, heat treatment, such as cooking, resulted in an increase in total phenolic content. According to Ramírez-Anaya et al. [42], cooking resulted in an increase in total phenolic content and antioxidant capacity compared to raw eggplant. For flavonoid content, boiling for 10 mins and steaming eggplant for 20 mins showed the highest flavonoid contents. The increase in flavonoid content is related to the loss of tissue, cell, membrane and organe integrity after heat treatments [43]. According to Eversley, [44] flavonoids are effective free radical scavengers. They are essential to inhibit lipid peroxidation, chelate redox-active transition metals and prevent the catalytic degradation of hydrogen peroxide. The highest content of condensed tannins was observed in purple eggplants steamed for 20 mins. This could be due to the formation of a complex of condensed tannins with nutrients that could not be eliminated by leaching due to the absence of water. This same observation was made by kenfack et al. [45] who claimed that the variation in phenolic compounds, specifically saponins, was due to a decomposition of saponins linked to nutrients that were leached from the cooking water.

Eggplant is one of the most consumed agricultural products in the world [46]. This could be due to the high proportions of phenolic compounds which induced significant antioxidant potentialities able to provide several benefits for human health [6]. Thus, the relatively high antioxidant activity found in this study is mainly due to total phenolics as indicatedby a strong and positive correlation. According to Khoulati et al. [47] the phenolic compounds present in eggplant would be responsible for its antioxidant activity. Furthermore, the different cooking methods applied to eggplant in this study did not affect the phenolic content and the corresponding antioxidant potentialities too much. Indeed, eggplants cooked with steam at all times and boiled for 20 mins presented low IC_{50} and significant antiradical powers. This would be due to the presence of total polyphenols in the eggplant samples. In fact, N'guessan et al. [48] established a correlation between the levels of total phenols and the antiradical activity. According to Chen and Ho [49], the functional groups of phenolic compounds have the ability to easily donate electrons or protons to neutralize free radicals, thus explaining the high antioxidant activity linked to a high concentration of total phenols. These results are consistent with the conclusions of Adeolu et al. [50], indicating that high levels of phenolic groups are associated with substantial antioxidant activity.

5. Conclusion

This study revealed that cooking in general had a positive or negative influence on the various nutritional components of purple eggplants. However, steaming for 20 mins exhibited in greater optimization in nutrients preservation, while steaming for 30 mins showed greater antioxidant potentialities. Purple eggplants were good sources of protein, carbohydrates, fibers and phenolic compounds. Eating them could help fight against certain metabolic diseases. Losses could also be limited by incorporating foods with high antioxidant potential, such as spices during cooking process.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest relevant to this article.

References

[1] Afshin A, Mary A, Mark L, Mcnaughton S. Healthy and sustainable diet. Diets, 2019, 1 : 1-44.

[2] Quamruzzaman A, Khatun A, Islam F. Nutritional Content and Health Benefits of Bangladeshi Eggplant Ccultivars. European Journal of Agriculture and Food Sciences, (2020). 2, (4): 1-7.

[3] Caguiat XGI, Hautea DM. Genetic diversity analysis of eggplant (*Solanum melongena* L.) and related wild species in the Philippines using morphological and SSR markers. Sabrao J Breed Genet, (2014), 46(2): 183-201.

[4] Agbo E, Brou D, Gnakri D, Fondio L, Nemlin G, Kouamé C. Evolution of nutrients during some leafy vegetables growth, XXVIIIth IHC – IS on Emerging Health Topics in Fruits and Vegetables, 2012 1(55): 411-418.

[5] Azizuddin S, Muhammad Iqbal M, Qadeer A. A review on therapeutic potential and nutritional composition of eggplant. European Academic Research (2022), 10 (2): 545-557.

[6] Nergiz U, Selman F, Amy A, Frary, SD. Health benefits and bioactive compounds of eggplant, Food Chem. 2018: 602–610

[7] Zoro, A.F., Zoué, L.T., Bédikou, M.E., Kra, S.A., and Niamké, S.L. (2014). Effect of cooking on nutritive and antioxidant characteristics of leafy vegetables consumed in Western Ivory Coast. Archives of Applied Sciences Research*, 6*(4), 114-123.

[8] Agbo, A. E., Gbogouri, A. G., N'Zi, J. C., Kouassi, K., Fondio, L., and Kouamé, C. (2019). Evaluation of micronutrient and oxalate losses during boiling and steaming of Malabar spinach leaves (*Basella alba*) et de célosie (*Celosia argentea*). Agronomie Africaine*,*31(2), 100-110.

[9] Johnson, M., and Pace, R. (2010). Sweet potato leaves: properties and synergistic interactions that promote health and prevent diseasenure. Nutrition Reviews*, 68*(10),604-615. https://doi.org/10.1111/j.1753-4887.2010.00320.x

[10] Tang, Y., Cai, W. and Xu, B. (2015). Profile of phenolics, carotenoids and antioxidative capacities of thermal processed white, yellow, orange, and purple sweet potatoes grown in Guilin, China. *Food science andHuman Wellness,*4, 123-132.https://doi.org/10.1016/j.fshw.2015.07.003

[11] AOAC. Association of Official Analytical Chemists. Official methods of analysis (1990). 15thed, 684.

[12] Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. Colorimetric method for determination of sugars and related substances. Anal. Chem, (1956), 28 :350-356.

[13] Bernfeld P. Amylase and Proteases. In Methods in Enzymology, NewYork, USAColswick SP, Kaplan NO Academic Press (1955).

[14] Kularatne KIA, de Freitas CR. Epiphytie lichens as biomonitors of airborne heavy metal pollution. Environ Exp Bot, (2013) 88, 24-32.

[15] Singleton VL, Orthofer R, Lamuela-Raventós RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In Methods in enzymology. Academic press. (1999), 299: 152–178.

[16] Hariri EB, Sallé G, Andary C. Involvement of flavonoids in the resistance of two poplar cultivars to mistletoe (*Viscum album* L.). Protoplasma, (1991), 162(1): 20–26.

[17] Heimler D, Vignolini P, Dini MG, Vincieri FF, Romani A. Antiradical activity and polyphenol composition of local Brassicaceae edible varieties. Food Chemistry (2006), 99(3): 464-469.

[18] Parejo, I.; Codina, C.; Petrakis, C.; Kefalas, P., (2000). Evaluation of scavenging activity assessed by Co (II)/EDTA-induced luminol chemilunescence and DDPH (2,2-diphenyl-1-pycryl-hydrazyl) free radical assay. J Pharmacol Toxicol Methods, 44, 507-512. https://doi.org/10.1016/S1056-8719 (01)00110-1. PubMed.

[19] Kroyer, G. T., (2004). Red clover extract as antioxidant active and functional food ingredient. Innov Food Sci Emerg Technol. 5, 101–105. https://doi.org/10.1016/S1466-8564 (03)00040-7.

[20] Kadri F. Effect of two cooking methods and storage time at room temperature on the total polyphenol content of four vegetable species. Master's thesis, Institut de la Nutrition, Food and Food Technology, University of Constantine, Algeria (2015), 6: 41-4541.

[21] Muller S. Kunzek H. Material properties of processed fruit and vegetables- I. Effect of extraction and thermal treatment on apple parenchyma. Food Research and Technology, (1998), 206(4): 264-272.

[22] Strauta L, Muižniece-Brasava S. The characteristics of extruded faba beans (*Vicia faba* L.). Rural sustainability research (2016) 36(331) :42-48.

[23] Katayama K, Komae K, Kohyama K, Kato T, Tamiya S, Komaki K. New sweet potato line having low gelatinisation temperature and alteres starch structure. Starch-Starke, (2002), 54(2) :51-57.

[24] Traore S, Aubry L, Gatellier P, Przybylski W, Jaworska D, Kajak-Siemaszko K, Santé-Lhoutellier V. Effect of heat treatment on protein oxidation in pig meat. Meat Science, (2014).

[25] Mettre la référence

[26] Briki, A, Zidani Z, Laksaci, H. Drying study and physicochemical and hygienic characterization of a food product from the Adrar Site. Ahmed Draia University of Adrar, Adrar, (2021), 75.

[27] Vodouhe S, Dovoedo A, Anihouvi VB, Rigobert C, Tossou RC. Soumanou M. M. Influence of cooking method on the nutritional value of *Solanum macrocarpum*, *Amaranthus hybridus* et *Ocimum gratissimum*, three traditional leafy vegetables acclimatised in Be. International Journal of Biologycal and Chemical Sciences, (2012), 6 (5): 1926-1937.

[28] Hayat I, Ahmed A, Ahmebd A, Khalil S, Gulfraz M. Exploring the potentialof red kidney beans (*Phaseolus vulgaris* L.) to develop protein-based product for food applications. Journal of Animal and Plant Sciences, (2014), 24(3): 860-866.

[29] Ni, Wang P, Zhan P, Tian H, Li T. Effects of different frying temperatures on the aroma profiles of fried mountain pepper (*Litsea cubeba* (Lour.) Pers.) oils and characterization of their key odorants. Food Chemistry, (2021), 357: 129786.

[30] Ejoh A, Tanya A, Djuikwo N, Mbofung M. Nutritional components of some non-conventional vegetables consumrd in Cameroon. Pakistan journal of nutrition, (2007), 6 (6): 712- 717.

[31] Fraikue FB. Unveiling the potential utility of eggplant: a review, Conference Proceedings of INCEDI, (2016), 883-895.

[32] Nwanna EE, Ibukun EO, Oboh G. Inhibitory effects of methanolic extracts of two aubergine species from south-west England and two aubergine species from south-west Nigeria on starch hydrolysis enzymes associated with type 2 diabetes. African Journal of Pharmacy and Pharmacology, (2013), 7 :1575-1584.

[33] Enzonga-Yoca, Nitou, Allou Kippré, Niamayoua, Mvoulatsieni, Silou T. Chemical characterisation and evaluation of the conservation temperature of Cucurbitaceae seed milk in Ivory Coast: *Cucumeropsis manii* et *Citrullus lanatus*. *Journal of animal et plant science*, (2011), 10 (1) :1232-1238.

[34] Ismail A, Marjan ZM, Foong CW. Total antioxidant activity and phenolic content in selected vegetables. Food Chemistry (2004), 87: 581-586.

[35] De Fermicourt I. Food and health: Eating fruit and vegetables is good for your health. Cahier agro. Environ (2006), 17- 19.

[36] Dekkaki IC. Assessment of the nutritional status of children attending public schools in the city of Rabat: the role of socio-economic factors, Thesis, University Mohammed Vde rabat, Morocco, (2014), 173 p.

[37] Casenave PCH. (2004). Interest of oral administration of potassium for the treatment of hyperkalaemia in cattle. Thesis, Toulouse National Veterinary School, France, 100 p.

[38] Nafir-Zenati S, Gallon G, Favier J-C. Effect of cooking on the mineral content of spinach. ORSTOM fonds documentaire, (1993), 36(915) :7.

[39] Umar KJ, Hassan LG, Dangoggo SM, Ladan MJ. Nutritional composition of water spinach (*Ipomoea aquatica Forsk*.) leaves. Journal of Applied Sciences (2007) 7 (6) : 803-809.

[40] Barkat M, Kadri F. Impact of two cooking methods on the soluble polyphenol content of six vegetables, Industrial engineering journal, (2011) 6: 41-45.

[41] Oboh G, Rocha JBT. Polyphenols in red pepper [*Capsicum annuum var. aviculare* (Tepin)] and their protective effect on some pro-oxidants induced lipid peroxidation in brain and liver. European Food Research and Technology (2007), 225 : 239–247.

[42] Ramirez-Anaya PD, Castañeda-Saucedo C, Olalla-Herrera M, Villalon-Mir M, Changes in the antioxidant properties of extra virgin olive oil after cooking typical Mediterranean vegetables. Antioxydants, (2009), 8 (8): 246.

[43] Olivera DF, Vina SZ, Marani CM, Ferreyra RM, Mugridge A, Chaves AR, Mascheroni RH. Effect of blanching on the quality of Brussels sprouts (*Brassica oleracea L. gemmifera* DC) after frozen storage. Journal of Food Engineering, (2008), 84 :148-155.

[44] Eversley TC. The antioxidant potential of the diet as estimated by the ORAC score: a comparison of the intakes of elderly people with dementia of the Alzheimer type with those of controls with no cognitive problems. Magister thesis in Science, Université de Montréal, Faculty of Medicine, (2012), 164 p.

[45] Kenfack SR, Mouamfon M, Tene ST, Ngueguim JR, Matenchi PY. Effects of three culinary treatments on the physico-chemical, functional and antioxidant properties of wild yam (*Dioscorea praehensilis Benth*) grown in the East Cameroon region / Int. J. Biol. Chem. Sci. (2021), 15 (6): 2665-2684.

[46] Taher SYC. World vegetable center eggplant collection: origin, composition, seed dissemination and utilization in breeding, Front. Plant Sci. (2017), 8(1484) :1–12,

[47] Khoulati A, Sabir O, Ismail C, Khalid C, Samira M, Anas Z, Sanae B. Crocus sativus L. (saffron): A cocktail of bioactive molecules as a biostimulant by influencing plant growth, the polyphenol and ascorbic acid content of eggplant fruit. (2023), 13: 62671-62678.

[48] N'guessan JD, Zirihi GN, Kra AKM, Kouakou K, Djaman AJ, Guede-Guina FF. Radical scavenging activity, flavonoid and phenolic contents of selected Ivoirian plants. International Journal of Natural and Applied Sciences, (2007) 4: 425-429.

[49] Chen CW, Ho CT. Antioxidant properties of polyphenols extracted from green tea and black tea. Journal of Lipids, (1995), 2: 35-46.

[50] Adeolu AA, Jimoh FO, Afolayan AJ, Masika PJ. Antioxidant Properties of the Methanol Extracts of the Leaves and Stems of Celtis Africana. Records of Natural Products, (2009), 3 (1) : 23-31.