

# Biochemical Study and Evaluation of the Nutritional Value of *Solanum torvum* (Swartz) Fruits Used as Fruiting Vegetables in Togo

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**Abstract** The fruits of *Solanum torvum* are used as fruiting vegetables and in traditional medicine in Togo, to treat anemia and several infectious diseases. However, no study has been conducted on its nutritional potential in Togo. The present study aims to valorize this species through its biochemical compounds in the interest of food security. The contents of carbohydrates, lipids, proteins, mineral salts and vitamin C of the fruits of *Solanum torvum* have been thus evaluated by the usual methods of AOAC. The contents in biochemical compounds have been of  $71.42 \pm 0.52\%$  for total carbohydrates,  $16.49 \pm 0.47\%$  for proteins,  $7.71 \pm 0.19\%$  for lipids,  $4.65 \pm 0.46\%$  for ash,  $2.44 \pm 0.36\%$  for vitamin C and  $421 \pm 2.01\%$  for metabolizable energy. The spectrophotometric analyses revealed the presence of minerals such as Na, Ca, Mg, K, P, Zn and Fe at interesting levels with  $Na/K < 1$ ,  $Ca/P > 1$  and  $Ca/Mg > 1$  in the analyzed *Solanum torvum* fruits. The results thus indicated that the fruits of *S. torvum* have an appreciable nutritional value similar to that of vegetables and legumes that enter the human diet daily. These fruits would thus contribute to the fight against nutrient deficiencies. The valorization of this pharmaco-nutritional plant in human food is therefore of interest.

**Keywords:** *Solanum torvum*, fruits, biochemical composition, nutritional value, Togo

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## 1. Introduction

Food plants play an important role in the human diet, especially as sources of vitamins, minerals and phytonutrients [1]. A diet rich in vegetables has been associated with a low risk of cardiovascular disease, anemia, gastric ulcer and cancer [2]. Indeed, the fermented seeds of *Parkia biglobosa*, the leaves and pulp of *Adansonia digitata* and the pulp of *Sclerocarya birrea* are used to treat hypertension, anemia and nutritional deficiencies [3]. The same is true for *Moringa oleifera* leaves, which not only have therapeutic potential but also have interesting nutritional characteristics [4,5]. In many African countries, edible plants are used as food and contribute significantly to the nutritional needs of the population [6]. In Togo, several food plants are used in the

pharmacopoeia; this is the case of *Solanum torvum*. The fruits of this plant are used in the diet of the Togolese population. Moreover these fruits have proven antioxidant and antimicrobial properties [7,8]. The phytochemical studies have indicated that the fruits of this species contain alkaloids, flavonoids, saponins, tannins and coumarins [7,8,9]. Studies [10] reported that the fruits of *Solanum torvum* possess significant nutritional value. Moreover, the study on the nutritional value of *Solanum torvum* fruits revealed that they contain vitamin C at interesting levels [11]. In addition the leaves and the fruits of this plant are used in many traditional medical practices in Africa [6-12]. Malnutrition remains one of the major public health problems in Africa. It is estimated that low vegetable consumption in unbalanced diets is responsible for about 31% of ischemic heart disease and 11% of strokes [13]. This is related not only to the quantity and quality of the food we ingest but also to the lack of information and

popularization of local resources. Some edible vegetables are rich in pharmacological properties and are therefore included in the diet of the population. However, if precautions must be taken to ensure the safety of these plants [14,15], it is also essential to research their nutritional value for a contribution to food security. This study is part of this context because although the evaluation of the nutritional potential of these fruits has already been addressed by some studies [7-11], none of these previous studies has been complete. Indeed these previous studies did not analyze biochemical compounds such as total ash, water content and energy value of these fruits. In addition some minerals of interest such as Na and Mg have been not analyzed. Moreover no study in Togo has yet been undertaken in this sense on the fruits of *S. torvum*. This justifies the present study whose objective is to evaluate the nutritional value of these fruits used in Togo in the interest of contributing to their valorization in human food.

## 2. Material and Methods

### 2.1. Study Frameworks

This study has been carried out at the Department of Biochemistry/Nutrition of the Faculty of Science of the University of Lomé

### 2.2. Vegetal Material

The fruits of *Solanum torvum* (Swartz) constituted the main vegetal material of this study. They have been collected in November 2020 in the prefecture of Agoè-Nyivé Northern side of Lomé (Togo). The species has been identified and preserved at the herbarium of the University of Lomé (Togo) under the number TOGO15697. The fruits have been then dried for one week at the ambient temperature of the laboratory (25 - 28 °C) and then powdered using a laboratory grinder.

### 2.3. Methods

#### 2.3.1. Biochemical Analysis

##### 2.3.1.1. Proteins content

The proteins have been determined by the Kjeldahl method adapted to food. The mineralization of nitrogen by destruction of the organic matter of the sample with concentrated sulfuric acid results in the formation of ammonium sulfate. This has been then decomposed by soda ash with the release of ammonia, which has been distilled, collected in a known quantity of titrated acid and dosed back by a standard solution of base. The nitrogen content obtained was converted to percentage of crude protein by multiplying the result by the factor 6.25.

##### 2.3.1.2. Lipids content

The total lipids content has been determined according to the AFNOR NFV03-713 standard. The operation has consisted in extracting the fat from a 1 g test sample with hexane in a Soxhlet type extractor. The hexane has been then evaporated on a rotary evaporator and the capsule has been dried in an oven at 103 °C and constant weight. The weight difference has given the total lipids content in grams per 100 g of product and expressed by the following formula:

$$L = \frac{\text{Weight in g of lipid residue}}{\text{Test sample mass in g}} \times 100.$$

##### 2.3.1.3. Ash content

The total mineral content (ash) has been determined from a 5 g test sample. The test sample has been placed in a porcelain crucible which has been heated to 550 °C, cooled in a desiccator and tared. The assembly has been gradually heated to 550 °C in a furnace for slow carbonization without ignition. The temperature is maintained at 550 °C for 6 hours to obtain white ash. The ash content has been calculated as follows:

$$Tc(\%) = \frac{Mi - Mf}{Me} \times 100$$

Mi = mass of empty crucible, Mf = mass of calcined crucible + ash, Me = mass of test sample.

##### 2.3.1.4. Determination of the total carbohydrates content

The carbohydrate content has been deduced by differential calculation.

$$\text{Carbohydrate content} = Ms - (P + MG + C)$$

Ms = dry matter; P = total protein mass; MG = fat mass; C = mass of ash.

##### 2.3.1.5. Determination of the energy value

The overall energy value has been obtained from the sum of the metabolizable energies of the carbohydrate, fat and protein components. These energies have been calculated by multiplying the protein, fat and carbohydrate contents by the Atwater coefficients. The overall energy value (E), expressed in kilocalories (Kcal) per 100 g of sample dry matter, has been then calculated.

$$E(\text{Kcal}) = (G \times 4) + (P \times 4) + (L \times 9)$$

G, L and P represent the respective contents of carbohydrates, lipids and proteins per 100 g of dry matter.

##### 2.3.1.6. Determination of minerals

The determination of minerals has been carried out according to the methods of AOAC. After mineralization by wet destruction of organic matter with the combined action of nitric and sulfuric acids, the mineral content has been determined by flame atomic absorption spectrophotometry. Phosphorus determination has been done by colorimetry. The total phosphorus has been first transformed into a yellow phosphomolybdate complex which absorbs at 430 nm [16].

### 2.4. Statistical Analysis

The data collected in this study was entered using Excel 2016 spreadsheet and processed using GraphPad Prism software, version 8.4.3. The differences were considered significant at the 5% ( $p < 0.05$ ). Results were presented as the mean  $\pm$  standard error of the mean (SEM).

## 3. Results and Discussion

Table 1 shows the average mineral contents of the analyzed *Solanum torvum* fruits. These results indicate an average content of  $155.20 \pm 44.37$  mg/100g for sodium,  $1307 \pm$

433.70 mg/100g for potassium,  $78.70 \pm 20.83$  mg/100g for phosphorus,  $38.45 \pm 8.54$  mg/100g for calcium,  $38.45 \pm 8.58$  mg/100g for magnesium,  $21.04 \pm 0.68$  mg/100g for iron,  $14.65 \pm 2.69$  mg/100g for zinc and  $2.44 \pm 0.36$  mg/100g for vitamin C. Minerals are essential elements required for the proper functioning and maintenance of the body. Mineral elements are involved in a wide range of functions in the body related to mineralization, control of water balance, enzyme and hormone systems, muscular, nervous and immune systems. According to studies [17], they are also important constituents of the human diet by serving as enzyme co-factors for many physiological and metabolic processes.

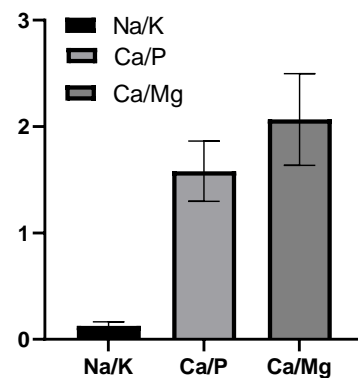
As a result, micronutrient deficiencies are serious health problems. This is the case of iron deficiency which leads to anemia. In fact, iron, magnesium and zinc are essential minerals for the human body cause of their role in the production and oxygenation of blood cells, digestion and blood circulation [18,19]. The Calcium and the phosphorus are major dietary elements, necessary for the formation of the skeleton. The Zinc is considered as a trace element that stimulates the immune system, protects against cell aging and maintains fatty tissue [19]. The Calcium, the magnesium and the potassium are involved in muscle contraction [19]. The Sodium is involved in the transmission of nerve impulses and in the water balance of the body [19]. This shows that minerals are essential and must be provided in the quantities required for the proper functioning of the body. The presence of minerals in appreciable quantities in the fruits of *Solanum torvum* is therefore a nutritional asset. Therefore their dietary use could have beneficial effects on osteoporosis, prevention of aging and strengthening the immune system [3,4,5]. The vitamin C content of *S. torvum* fruits was  $2.44 \pm 0.36$  mg/100g, which confirms the data of other authors [10,20]. This content is close to that of baobab leaves (*A. digitata*), mango (*Mangifera indica* fruit) and lime (*Citrus aurantifolia*) [21]. Therefore the fruits of *Solanum torvum* can provide the body in vitamin C but also in vitamin A [20]. The fruits of *S. torvum* would then contribute to the fight against mineral, vitamin A and C deficiencies. Vitamin C is involved in the defense of the body against viral and bacterial infections, the protection of the blood vessel wall, the assimilation of iron and has an important antioxidant activity [22].

In addition the presence of this species in the Sudano-Sahelian zone where food shortages can often be very pronounced is a great asset for human nutrition [23].

Table 2 shows the average macronutrient content and energy value of the analyzed fruits. These results reveal an average content of  $71.42 \pm 0.52\%$  for total carbohydrates,  $16.49 \pm 0.47\%$  for proteins,  $7.71 \pm 0.19\%$  for lipids and  $421 \pm 2.01$  Kcal for energy. The average total carbohydrate content ( $71.42 \pm 0.52\%$ ) of *Solanum torvum* fruits remains very interesting. Indeed, carbohydrates combined with dietary fiber are generally recommended to prevent atherosclerosis, constipation and diseases in the intestine such as appendicitis and colon cancer. According to the results obtained, the average fat content is relatively low. This low lipid content suggests that *Solanum torvum* fruits can be consumed by people with overweight problems and in anti-hypertensive diets. The average protein content ( $16.49 \pm 0.47\%$ ) of the analyzed fruits is

not negligible. They are therefore a significant source of protein. The energy contribution of *Solanum torvum* fruits is relatively high, concomitantly with the organic matter content, compared to the leaves of *X. sagittifolium* ( $212.70$  Kcal/100 g dry matter) [24]. This result obtained with the fruits of *Solanum torvum* shows that their use in human food can contribute to the fight against protein-energy malnutrition, especially among young children who represent one of the vulnerable groups.

Considering 100 g of dry matter of *S. torvum* fruits, the contribution to the Recommended Daily Allowance (RDA) is relatively low for sodium (10.34%), for potassium (27.80%), for magnesium (9.15%), for calcium (4.28%) and for phosphorus (10.49%). But it is relatively high for iron (76.78%) (Table 4). These contributions are still significant compared to the leaves of *A. digitata* and *X. sagittifolium* [24].



**Figure 1.** Na/K, Ca/P and Ca/Mg ratios of the analyzed *Solanum torvum* fruits. Values have been expressed as mean  $\pm$  SEM (n = 3)

The average Mg, Ca and P content of *Solanum torvum* fruits was  $38.45 \pm 53\%$ ,  $38.45 \pm 8.54\%$  and  $8.70 \pm 20.8\%$  mg/100 g dry matter, respectively (Table 5). These contents were lower than what was observed with the leaves of *Moringa oleifera* and *A. digitata* with respectively  $97.27 \pm 3.25$ ,  $423.19 \pm 25.90$  and  $301.70 \pm 45.11$  mg/100 g of dry matter for the leaves of *Moringa oleifera* and  $77.69 \pm 28.99\%$ ,  $231.21 \pm 29.40\%$  and  $145.4 \pm 20.80\%$  mg/100 g of dry matter for the leaves of *A. digitata* [27,28]. On the other hand, the Na and K contents of *Solanum torvum* fruits were close to what was observed with *Moringa oleifera* and *A. digitata* leaves [27,28]. The average iron content of *Solanum torvum* fruits ( $21.04 \pm 0.68\%$  mg/100 g) was higher than that of *A. digitata* leaves ( $6.31 \pm 1.75\%$ ) and close to that of *Moringa oleifera* leaves ( $21.72 \pm 0.61\%$ ). The mineral contents of *Solanum torvum* fruits were therefore not negligible and even comparable to those of some vegetables and legumes that are main sources of supply such as baobab and moringa leaves [27,28]. Moreover the average Na/K ratio was 0.12 (Figure 1) and therefore beneficial for the promotion of cardiovascular health [29] as it is lower than 1. This low sodium concentration and the presence of a significant amount of potassium justify the interest of using vegetables in an anti-hypertensive diet [30]. In addition, the Ca/P ratio, which was 1.58 (Figure 1), concomitantly with the high average calcium content of the analyzed fruits, indicates that these fruit vegetables are less rich in phosphorus compared to calcium. This high calcium content of *Solanum torvum* fruits shows that they

can be used in diets aimed at skeletal formation [31] and balancing the body's pH by neutralizing excess acids. Phosphorus is also essential in the processes of energy storage in the body in the form of ATP. The fruits of *Solanum torvum* analyzed can therefore help in the formation of the skeleton in children through the phosphorus and calcium they contain [31]. Moreover the presence of relatively large average quantities of

magnesium in these fruits is also interesting for the body. Indeed magnesium is involved in the mechanism of chemical reactions at the level of intestinal absorption and is an essential cofactor of the enzymes of carbohydrate metabolism [32]. The presence of these different minerals in the analyzed fruits of *Solanum torvum* makes them a very beneficial food for human health, cause of their role in several physiological activities [7,10,20].

**Table 1. Mineral and vitamin C contents of analyzed *Solanum torvum* fruits**

	Contents of analyzed elements (mg/100g of DM)							Vit C
	Na	K	P	Ca	Mg	Fe	Zn	
Minimum	55.61	533.30	36.10	53.34	22.83	19.86	7.66	2.08
Median	147.70	1075.00	46.00	62.76	40.09	21.04	23.34	2.35
Maximum	270.00	2543.00	63.00	120.00	52.43	22.22	25.01	2.69
Mean $\pm$ SEM	155.2 $\pm$ 44.37	1307 $\pm$ 43.7	7 8,70 $\pm$ 20.83	38.45 $\pm$ 8.54	38.45 $\pm$ 8.58	21.04 $\pm$ 0.68	14.65 $\pm$ 2.69	2.44 $\pm$ 0.36

DM: Dry Matter; Values were expressed as mean  $\pm$  SEM (n = 3); Vit C: Vitamin C.

**Table 2. Biochemical composition and energy value of the analyzed *Solanum torvum* fruits**

	Elements analyzed					
	Total carbohydrates (g/100g of DM)	Proteins (g/100g of DM)	Fat (g/100g of DM)	Ash (g/100g of DM)	Watter content (% of FM)	Energy (Kcal/100g of DM)
Minimum	70.67	15.67	7.37	3.85	79.20	418.00
Median	71.15	16.49	7.71	4.65	79.25	420.20
Maximum	72.43	17.31	8.05	5.45	79.40	424.90
Mean $\pm$ SEM	71.42 $\pm$ 0.52	16.49 $\pm$ 0.47	7.71 $\pm$ 0.19	4.65 $\pm$ 0.46	79.28 $\pm$ 0.06	421 $\pm$ 2.01

Values have been expressed as mean  $\pm$  SEM (n = 3); DM: Dry Matter; FM: Fresh Matter.

**Table 3. Biochemical analyses of *S. torvum* fruits in comparison with previous work**

Elements analyzed	Our data (Mean $\pm$ SEM)	Previous work [10,30]
Total carbohydrates (g/100 g of DM)	71.42 $\pm$ 0.52	7.04 – 10.70
Proteins (g/100 g of DM)	16.49 $\pm$ 0.47	2.32 – 2.40
Fat (g/100 g of DM)	7.71 $\pm$ 0.19	0.28
Ash (g/100 g of DM)	4.65 $\pm$ 0.46	Not Available
Watter content (% of FM)	80.05 $\pm$ 0.06	Not Available
Energie (Kcal/100 g of DM)	421 $\pm$ 2.01	Not Available
Na	155.2 $\pm$ 44.37	Not Available
K	1307 $\pm$ 433.7	1.97
P	8.70 $\pm$ 20.83	70.00
Ca	38.45 $\pm$ 8.54	221.6 - 51.20
Mg	38.45 $\pm$ 8.58	Not Available
Fe	21.04 $\pm$ 0.68	60.10 – 76.90
Zn	14.65 $\pm$ 2.69	21.50
Vitamine C	2.44 $\pm$ 0.36	1.84 – 2.68

**Table 4. Contribution of organic and mineral substances of 100 g of dry matter of *S. torvum* fruits to the Recommended Daily Allowance (RDA)**

Elements analyzed	RDA for an adult (Male/Female)	Amount in 100 g of DM of <i>S. torvum</i> fruits	Contribution of 100 g of DM of <i>S. torvum</i> fruits to RDA (%)
Fat (g)	44-97 <sup>a</sup>	7.71	7.94-17.52
Proteins (g)	56	16.49	29.46
Energy (Kcal)	2500/2000 <sup>a</sup>	421	16.84-21.05
Na (mg)	1500 <sup>a</sup>	155.20	10.34
K (mg)	4700 <sup>b</sup>	1307	27.80
Ca (mg)	900 <sup>bc</sup>	38.45	4.28
Mg (mg)	420 <sup>a</sup>	38.45	9.15
P (mg)	750 <sup>bc</sup>	78.70	10.49
Fe (mg)	27.40/58.80	21.04	35.36-76.78

<sup>a</sup>Reference nutrient intakes for minerals, energy, carbohydrates, fiber, fat, proteins, and amino acids; <sup>b</sup>Recommended nutrient intakes for a body weight of 70 kg [25], <sup>c</sup>AFSSA [26].

**Table 5. Comparison of mineral contents in fruits of *Solanum torvum* with those of leaves of *Moringa oleifera* and leaves of *Adansonia digitata***

	Elements analyzed						
	Na	K	P	Ca	Mg	Fe	Zn
<i>S. torvum</i> (this study)	155.2 ± 44.37	1307 ± 433.7	78.70 ± 20.10	38.45 ± 8.54	38.45 ± 8.58	21.04 ± 0.68	14.65 ± 2.69
<i>A. digitata</i> [27]	156.65 ± 6.74	1584 ± 65.46	145.4 ± 16.5	231.21 ± 29.40	77.69 ± 28.99	6.31 ± 1.75	16.04 ± 0.78
<i>M. Oleifera</i> [28]	70.87 ± 0.48	254.44 ± 7.74	153.2 ± 23.8	423.19 ± 25.90	97.27 ± 3.25	21.72 ± 0.61	1.13 ± 0.14

Values have been expressed as mean ± SEM (n = 3).

**Table 6. Comparison of macronutrient content and energy value of *Solanum torvum* fruits with those of leaves of *Moringa oleifera* and leaves of *Adansonia digitata***

	Elements analyzed					
	Total carbohydrates (g/100g of DM)	Protein (g/100g of DM)	Fat (g/100g of DM)	Ash (g/100g of DM)	Water content (% of FM)	Energy (Kcal/100g of DM)
<i>S. torvum</i> (this study)	71.42 ± 0.52	16.49 ± 0.47	7.71 ± 0.19	4.65 ± 0.46	79.28 ± 0.06	421 ± 2.01
<i>M. oleifera</i> [26]	14.1	57.79	0.60	2.42	73	390.11
<i>A. digitata</i> [24]	16.1	2.8800	0.4204	5.6147	74	305.862

DM: Dry matter; FM: Fresh matter; Values have been expressed as mean ± SEM (n = 3) for *S. torvum*.

The water content of *S. torvum* fruits (79.28 ± 0.06%) was higher than that of *M. oleifera* and *A. digitata* leaves and similar to that of fruits and vegetables (80-90%) but higher than that observed with cereals (10-20%) and fish, meat and animal flesh (60-70%) [33]. This result shows that *S. torvum* fruits can be classified as water-rich foods.

The total ash content was 4.65 ± 0.46% in *S. torvum* fruits. This content is higher than that reported previously [28] in young leaves of *M. oleifera* (2.42 ± 0.30%). This indicates that the fruits of *S. torvum* are rich in minerals.

The average total carbohydrate content of *S. torvum* fruits was 71.42 ± 2.94 g/100g dry matter. This is higher than 16.1% for *A. digitata* leaves and 14.1% for young *M. oleifera* leaves [27,28]. This total carbohydrate content justifies the contribution of *Solanum torvum* fruits to the carbohydrate RDA. This shows that these fruits have a good nutritional value in relation to carbohydrates.

The fat content obtained with *S. torvum* fruits was 7.71 ± 0.19%. This content is higher than that of *A. digitata* (0.42%) and *M. oleifera* (0.60%) leaves [27,28]. In fact, the fruits of *S. torvum* contribute between 7.94% and 17.52% of the RDA in lipids (Table 4) for an adult of 70 kg. This lipid content is higher than that of most leafy vegetables such as baobab, *M. oleifera* and cassava leaves [27,28].

The average protide content (Table 5) was 16.49 ± 0.47%. It was close to that of *A. digitata* leaves, but low compared to that obtained with young *M. oleifera* leaves (57.79 ± 0.24). On the other hand, 100 g of *S. torvum* fruits would contribute between 16.49% and 29.46% of the RDA in protein (Table 4). This confirms that these fruits are a significant source of vegetable protein.

The energy value of *S. torvum* fruits was higher than what was observed in *A. digitata* and *Moringa oleifera* leaves. This result shows that their use in human food can contribute to the fight against protein-energy malnutrition.

In view of the overall organic matter (Table 6) and mineral (Table 5) contents, it can be said that the fruits of *S. torvum* have a significant nutritional value, similar to that of vegetables and legumes that are part of the daily human diet. These fruits would contribute effectively to

the fight against mineral and vitamin C deficiencies as well as to the fight against protein-energy malnutrition [34]. In addition, their content in phytochemical and biochemical compounds testifies to their biological activities approved by previous works [7,35].

## 4. Conclusion

*Solanum torvum* is an indigenous resource, well known for its pharmacological properties. This study showed that the fruits of this species have an important nutritional value with a significant contribution to the Recommended Daily Allowance. Therefore, their dietary using as fruiting vegetables could combat mineral deficiency and protein-energy malnutrition. In order to provide more data on the nutritional quality of this plant, it is desirable to continue this study by determining the vitamin, amino acid and fatty acid profiles of *Solanum torvum* fruits. This will further highlight the importance of this plant in the interest of promoting the nutritional status of the population.

## Author Contributions

Conceived and designed the experiments: MM, LAA and FS. Species identification and fruit collection: MM, KDE, BRD, LAA, FS and KA. Performed the experiments: MM, BRD, KDE and KB. Analyzed the data: MM, EK and KGL. Contributed reagents/materials/analysis tools: KDE and KA. Wrote the paper: MM, KDE, BRD, EK and KGL.

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## Conflicts of Interest

The authors declare no conflict of interest.

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