Assessment of the nutritional potential of *Amaranthus spinosus* L. (*Amaranthaceae*) and *Tridax procumbens* L. (*Asteraceae*), two leafy vegetables from the Maritime region of Togo

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Abstract

Traditional leafy vegetables contribute to the diet of the population and help improve nutritional status. The objective of this study is to assess the nutritional value of *Amaranthus spinosus* and *Tridax procumbens*, two leafy vegetables from the Togolese flora. The physicochemical analyzes were carried out according to the AFNOR and AOAC methods. The results obtained showed that the leaves of *A. spinosus* have a higher protein content with 31.54 ± 0.69 % of dry matter and contribute 56.32 % to the recommended daily intake while the leaves of *T. procumbens* contain more lipids with 10.27 ± 0.06 % of dry matter. Mineral analysis has shown high levels for these two leafy vegetables with contributions of up to more than 100% of the recommended daily allowance. They contain much more potassium than sodium and therefore, these leafy vegetables are useful in promoting cardiovascular health. *A. spinosus* and *T. procumbens* therefore have a high nutritional value and can contribute to improving the nutritional status of the population and thus to food security.

Keywords: *Amaranthus spinosus*, *Tridax procumbens*, Nutritional value, Togo

Introduction

Developing countries are faced with a double nutritional problem, undernutrition due to general or micronutrient deficiencies and over-nutrition favoring metabolic overload diseases such as obesity, diabetes, dyslipidemia, cardiovascular disease and certain cancers (Batal *et al.*, 2018) [1]. This phenomenon has increased in Africa in the past two decades due to the lack of population nutrition programs (OMS, 2012; Gbekley *et al.*, 2015) [2, 3]. This costly double nutritional burden for the public health system of developing countries such as Togo is avoidable, in particular through the implementation of prevention and health promotion programs and policies. Added to this is awareness about the importance of a healthy, balanced and diversified diet and the practice of physical activity (OMS, 2012; Gbekley *et al.*, 2015) [2, 3]. In Togo, a study on nutritional plants was carried out in order to assess the biochemical and nutritional values of some food species consumed. It made it possible to show that, among these species of current consumption, some have very interesting nutritional values for vulnerable populations as children, women, the elderly or convalescent (Amouzou *et al.*, 2006) [4]. In this perspective, it is essential to find various nutritional formulas based on food plants used in the treatment of over-nutrition pathologies and to produce a food potential to combat undernutrition. Following surveys on plant species regularly consumed by the Togolese population, based on ethnobotanical indices and a biological and phytochemical screening, given the number of documented references, the relevance, the redundancy and the concordance of the testimonies received, two leafy vegetables, *Amaranthus spinosus* and *Tridax procumbens*, among the most active, were selected for an evaluation of their nutritional potential. These two leafy vegetables are identified as being medicinal and food plants because they are cited in the treatment of various pathologies (Koukoui *et al.*, 2017) [5]. This study is therefore a contribution to food security through the evaluation of the nutritional value in macro and micronutrients of the two leafy vegetables in order to highlight their nutritional potential.

Material and Methods

Scientific framework of the study

Our study was carried out at the Laboratory of Biomedical, Agrifood and Environmental Health Sciences (LaSBASE) of the University of Lomé.
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Plant material

The plant material consists of leaves of A. spinosus (Fig 1) harvested in Lomé and T. procumbens (Fig 2) harvested in Afagnangan (in the prefecture of Bas Mono, east of Lomé), in the Maritime region of Togo. These two species have been recorded in the herbarium of the University of Lomé under the numbers “Togo 15455” and “Togo 15454” respectively. They were selected following investigations carried out in the area and on the basis of ethnobotanical indices, the number of documented references, the relevance, the redundancy and the consistency of the testimonies received.

Preparation and processing of plant material

The harvested fresh leaves were cut, washed with water and then left to drain for a few minutes on the laboratory bench. The drained leaves were directly dried at laboratory temperature (25 – 27 °C). After drying, the leaves were reduced to a fine powder using a ”Sunbean” brand moulinex and then stored in amber glass bottles away from moisture and light. The leaf powders were used as a sample for all the analyzes carried out.

Determination of macronutrient composition

It consisted of the determination of the humidity, ash, protein, fat and total carbohydrate levels.

Humidity level

The humidity level or water content is determined according to AFNOR standard NFV03-707 of June 1989 (AFNOR, 1991) [6] by drying a test sample of 5 g at 103 °C until the constant mass. The sample was dried in an oven for 4 hours. The difference in weight gave the humidity. The humidity « H » in g per 100 g of the product is calculated by the following formula:

\[ H = \frac{W_t - W_e}{W_t} \times 100 \]

Wt: weight in g of the raw sample and empty beaker; We: weight in g of the sample after baking and empty beaker; Ts: test sample in g.

Ash content

The ash or total mineral content is determined by incineration of a test sample of 5 g at 550 °C according to AFNOR NFV03-760 of December 1981 (AFNOR, 1991) [6] and AOAC International (Latimer, 2012) [7]. Incineration is
carried out in a muffle furnace (Nabertherm P330). Mineralization is continued for 6 hours until total combustion of the organic matter and appearance of a whitish residue. The ash content "C" in g per 100 g of dry product is calculated by the relation:

\[ C = R_i \times \frac{100}{P_e} \]

\( R_i \): residue after incineration in g; 
\( P_e \): residue after ashing in g.

**Total protein level**
The total protein or protein content is determined after determination of total nitrogen by the Kjeldahl method according to AFNOR standard NFV03-050 of September 1970 (AFNOR 1991) \(^6\). The total nitrogen content "Nt" in g per 100 g of dry product is given by the following formula:

\[ Nt = 1,4 \times V \times N \times \frac{1}{T_s} \]

\( V \): volume in ml of H\textsubscript{2}SO\textsubscript{4} titrating; 
\( N \): normality of H\textsubscript{2}SO\textsubscript{4} titrating (0.5N); 
\( T_s \): test sample in g ; the protein conversion coefficient: 6.25 Protein content = \( Nt \times 6.25 \)

**Total lipid level**
The total lipid or fat content was determined according to AFNOR standard NFV03-713 of February 1984 (AFNOR 1991) \(^6\).

The operation consisted in extracting the fat from a test sample of 1 g of the sample with hexane carried out in a Soxhlet type extractor.

The hexane is then evaporated on a rotary evaporator and the capsule dried in an oven at 103 °C to constant weight.

The difference in weight gave the total lipid content "L" in g per 100 g of product and expressed by the following formula:

\[ L = W \times \frac{100}{T_s} \]

\( W \): weight in g of the lipid residue; 
\( T_s \): test sample in g.

Total carbohydrate content: The total carbohydrate content "G" in g per 100 g of dry product was estimated by difference. It was calculated according to the method of AOAC International (Latimer 2012) \(^7\) by subtracting from 100 the sum (humidity + fat + protein + ash) contained in the sample.

\[ G = 100 - (H + C + P + L) \]

\( H \): moisture content (in% of product); 
\( C \): ash content (in% of product); 
\( P \): total protein content (in% of product); 
\( L \): total lipid content (in% of product)

**Determination of mineral composition**
It consisted in the determination of 8 minerals namely 5 macroelements (Ca, Mg, K, Na, P) and 3 trace elements (Fe, Zn, Ni) chosen because of their importance in the diets. After mineralization, sodium and potassium were determined by flame photometry (JENWAY PPFP7 flame photometer Na K Ca Ba Li) and phosphorus by visible UV molecular absorption spectrophotometry (JENWAY 6705 UV/VIS Spectrophotometer). Calcium, magnesium, iron, zinc, nickel were determined by atomic absorption spectrometry (LABEXCHANGE PU 9200X atomic absorption spectrometer). The results are obtained by direct reading (AOAC, 1990; Labat, 2010; Saloufou et al., 2018a) \(^8\)-\(^10\).

**Determination of the energy value (Energy)**
The overall energy value of leafy vegetables was obtained from the sum of the metabolizable energies of the various carbohydrate, lipid and protein components. These energies were calculated by multiplying the protein, fat and carbohydrate contents by the coefficients of Atwater (Atwater and Rosa, 1899) \(^11\). The total energy value (E), expressed in kilocalories (Kcal) per 100 g of leafy vegetables, was then calculated from the following relationship:

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

G, L and P: respective carbohydrate, lipid and protein contents per 100 g of dry matter.

**Statistical data analysis**
All the tests were carried out in triplicate (n = 3). The data were processed statistically using Graphpad Prism 7.00 software. The means were compared by analysis with the unpaired parametric test t test at the threshold \( P = 0.05 \).

**Results and discussion**

**Macronutrient content of leafy vegetables**
The macronutrient contents of the leafy vegetables have been summarized in Table 1.

Analysis of the results reveals that the water content of the leaves of \( T. \) procumbens is higher than that of \( A. \) spinosus with a significant difference (\( P = 0.0008 \)). The protein content of \( A. \) spinosus was significantly higher (\( P = 0.0087 \)) than that of \( T. \) procumbens. For 100 g dry matter (DM) of leaf powder, this content contributes up to 56.32% to the recommended daily allowance (RDA) of proteins (Table 3).

Conversely, the lipid content was remarkably higher (10.27 ± 0.06% DM) in \( T. \) procumbens with a significant difference (\( P = 0.0001 \)) compared to that of \( A. \) spinosus. This content for 100 g DM contributes up to 23.34% to the RDA. The carbohydrate contents of the two leafy vegetables showed no significant difference (\( P = 0.9070 \)). The total mineral content of \( T. \) procumbens is higher than that of \( A. \) spinosus with a significant difference (\( P = 0.0038 \)). The 100 g of DM of \( T. \) procumbens provides more energy (361.9 ± 0.16 Kcal) with a significant difference (\( P = 0.0002 \)) compared to \( A. \) spinosus and contributes little to the recommended daily allowance (14.48% for men and 18.09% for women).

**Table 1: Macronutrient content and energy value of the leafy vegetables studied**

<table>
<thead>
<tr>
<th>Leafy vegetables</th>
<th>Taux d’humidité (g/100g MB)</th>
<th>Protéines (g/100g MS)</th>
<th>Lipides (g/100g MS)</th>
<th>Glucides (g/100g MS)</th>
<th>Cendres (g/100g MS)</th>
<th>Energie (Kcal/100g MS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A. ) spinosus</td>
<td>8.86 ± 0.08</td>
<td>31.54 ± 0.69</td>
<td>5.35 ± 0.03</td>
<td>43.38 ± 0.69</td>
<td>19.75 ± 0.11</td>
<td>347.8 ± 0.25</td>
</tr>
<tr>
<td>( T. ) procumbens</td>
<td>11.46 ± 0.07</td>
<td>24.11 ± 0.70</td>
<td>10.27 ± 0.06</td>
<td>43.27 ± 0.89</td>
<td>22.36 ± 0.20</td>
<td>361.9 ± 0.16</td>
</tr>
</tbody>
</table>

\( ^{2009} \)
Mineral content of leafy vegetables

The mineral contents were expressed in mg/100 g of DM. Analysis of the results (Table 2) shows that of the 5 macroelements sought, only the contents of Mg and K were dominant in *A. spinosus*. In addition to the Ca, Na and P contents, all the contents of the 3 trace elements were dominant in *T. procumbens*. The calcium content of *T. procumbens* (4835.10 ± 41.53 mg/100 g DM) is significantly high compared to that of *A. spinosus* (3993.31 ± 39.57 mg/100 g DM). In addition, these levels represent the largest contributions of the recommended daily allowance (537.23% and 443.70%) (Table 3). Conversely, the magnesium content of *A. spinosus* is significantly higher (*P* = 0.0105) than that of *T. procumbens* with equally high contributions in the recommended daily intake (300.43% and 237.72%).

### Table 2: Mineral content of the 2 leafy vegetables

<table>
<thead>
<tr>
<th>Leafy vegetables</th>
<th>Ca (mg)</th>
<th>Mg (mg)</th>
<th>K (mg)</th>
<th>Na (mg)</th>
<th>P (mg)</th>
<th>Fe (mg)</th>
<th>Zn (mg)</th>
<th>Ni (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. spinosus</em></td>
<td>3993.31±59.57</td>
<td>1261.80±34.13</td>
<td>4580.86±38.79</td>
<td>680.27±15.51</td>
<td>169.57±2.72</td>
<td>23.59±0.93</td>
<td>7.07±0.10</td>
<td>0.51±0.03</td>
</tr>
<tr>
<td><em>T. procumbens</em></td>
<td>4835.10±41.53</td>
<td>998.42±17.56</td>
<td>3614.19±63.89</td>
<td>728.49±7.98</td>
<td>364.36±4.63</td>
<td>34.79±1.28</td>
<td>8.44±0.12</td>
<td>0.71±0.04</td>
</tr>
</tbody>
</table>

The results in Table 3 also reveal a good contribution to the recommended daily allowance (RDA) of potassium up to approximately 100% for *A. spinosus*. The sodium content of *T. procumbens* (728.49 ± 7.98 mg/100 g DM) is higher than that of *A. spinosus* (680.27 ± 15.51 mg/100 g DM) but with a non-significant difference (*P* = 0.0597). The phosphorus content of *T. procumbens* (364.36 ± 4.63 mg/100 g DM) exceeds significantly (*P* = 0.0004) until twice that of *A. spinosus* (169.57 ± 2.72 mg/100 g DM). The results also reveal a high iron content. The content of *T. procumbens* (34.79 ± 1.28 mg/100 g DM) exceeds with a significant difference that of *A. spinosus* (23.59 ± 0.93 mg/100 g DM).

Table 3: Recommended Daily nutritional Allowance (RDA) in an adult and Contribution to the Recommended Daily Allowance (CRDA) of the leafy vegetables studied.

<table>
<thead>
<tr>
<th>Leafy vegetables</th>
<th>RDA in an adult Male/Female</th>
<th>Content per 100 g DM</th>
<th>CRDA (%)</th>
<th>Content per 100 g DM</th>
<th>CRDA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. spinosus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>130a</td>
<td>43.38</td>
<td>33.37</td>
<td>43.27</td>
<td>33.28</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>44.97b</td>
<td>5.35</td>
<td>5.51-12.16</td>
<td>10.27</td>
<td>10.59-23.34</td>
</tr>
<tr>
<td>Proteins (g)</td>
<td>56c</td>
<td>31.54</td>
<td>56.32</td>
<td>24.11</td>
<td>43.05</td>
</tr>
<tr>
<td>Energy (Kcal)</td>
<td>2500/2000</td>
<td>347.8</td>
<td>13.91/17.39</td>
<td>361.9</td>
<td>14.48/18.09</td>
</tr>
<tr>
<td>Na (mg)</td>
<td>150d</td>
<td>680.27</td>
<td>45.35</td>
<td>728.49</td>
<td>48.57</td>
</tr>
<tr>
<td>K (mg)</td>
<td>470e</td>
<td>4580.86</td>
<td>97.46</td>
<td>3614.19</td>
<td>76.9</td>
</tr>
<tr>
<td>Ca (mg)</td>
<td>900f</td>
<td>3993.31</td>
<td>443.70</td>
<td>4835.10</td>
<td>573.27</td>
</tr>
<tr>
<td>Mg (mg)</td>
<td>420g</td>
<td>1261.80</td>
<td>300.43</td>
<td>998.42</td>
<td>237.72</td>
</tr>
<tr>
<td>P (mg)</td>
<td>750h</td>
<td>169.57</td>
<td>22.61</td>
<td>364.36</td>
<td>48.58</td>
</tr>
<tr>
<td>Fe (mg)</td>
<td>27.4j/58.8k</td>
<td>23.59</td>
<td>86.09/40.12</td>
<td>34.79</td>
<td>126.97/59.17</td>
</tr>
<tr>
<td>Zn (mg)</td>
<td>14.9,l/k</td>
<td>7.07</td>
<td>50.5/72.14</td>
<td>8.44</td>
<td>60.29/86.12</td>
</tr>
<tr>
<td>Ni (mg)</td>
<td>1c</td>
<td>0.51</td>
<td>51</td>
<td>0.71</td>
<td>71</td>
</tr>
</tbody>
</table>

*Recommended nutritional intake for a body weight of 70 kg (Trumbo et al., 2002) [12]; b Frenot and Vierling, 2002 [13]; c Recommended nutritional intake for a bioavailability of iron of 5% RDA and zinc of 15% RDA (OMS/FAO, 2004) [14]; d AFSSA, 2009 [15]; e Trumbo et al., 2001 [16].

The populations of southern Togo, particularly in the Maritime region, still suffer from a nutritional deficit (PNUD, 2012) [17] as in most developing countries (Allen et al., 2011) [18]. In addition, several studies have shown that daily intakes of nutrients such as calcium and magnesium are often lower than the recommended nutritional intakes (Manios et al., 2015; Moore-Schiltz et al., 2015; Fernández-Barrés et al., 2016) [19-21]. It is therefore recommended, to compensate for this insufficiency, to favor the consumption of foods rich in these nutrients rather than opting for medication supplementation since diet is the first source of medication (Gbekley et al., 2015; Saloufou et al., 2018a) [3, 10]. The results of the study show that the water contents of the leaf powders of *A. spinosus* and *T. procumbens* are quite close to those obtained on the powders of raw and dried leaves of *Solanum macrocarpum*, *Amaranthus hybridus* and *Ocimum gratissimum* in Benin (Vodouhe et al., 2012) [22]. These results also reveal that leafy vegetables are packed with major nutrients. The protein contents of *T. procumbens* and *A. spinosus* are as interesting as those obtained for certain leafy vegetables reputed to be rich in proteins such as *Phytolacca dodecandra* (34.56 ± 1.23% DM) (Itoua et al., 2015) [23], *Vigna unguiculata* L. (28-34% DM) (Adu-Dupanah, 1999) [24], *Lagenaria siceraria* (24.5% DM) (Itoua et al., 2015) [25], *Amaranthus hybridus* (37.21%), *Corchorus olitorius* (32.18%), *Celosia argentea* (34.25%), *Solanum nigrum* (37.5%), *Cleome gynandra* (37.17%) (Ocho-Anin et al., 2012) [25]. The leaves of *T. procumbens* containing significant amounts of protein have also been confirmed by the work of Koukou et al. (2017) in Benin. The results (Table 3) confirmed the high protein content of leafy vegetables, through their recommended daily intake. Proteins are the only source of nitrogen, the main role of which is to constitute the proteins and enzymes participating in the body with metabolic functions (Apfelbaum et al., 2004) [26]. The efficiency of food proteins is the same in men as in women and nitrogen balances are balanced in almost all subjects when the amount of protein exceeds 0.8 g/kg/day and when the energy

![Image: Journal of Pharmacognosy and Phytochemistry](http://www.phytojournal.com)
requirements are covered (Patureau et al., 2001[27]). It therefore requires 56 g/day of protein for a subject of 70 Kg on average. For 100 g of dry matter, the leaves of A. spinosus and T. procumbens covered respectively 56.32% and 43.05% of the daily protein requirements in an individual weighing 70 Kg or less. These leafy vegetables can therefore be recommended as a source of vegetable protein.

The low lipid contents of T. procumbens and A. spinosus confirm the low lipid content of leafy vegetables (Kahane et al., 2005, Adjatin, 2006) [28, 29]. These contents are however higher than those obtained with the leaves of Ficus on (1.95% DM) by Saloufou et al. (2018b) [30] and with Lagenaria siceraria (1.93% DM) by Itoua et al. (2015) [23]. The lipid content of A. spinosus is also lower than that obtained on the species of the same genus A. hybridus (Vodouhe et al., 2012) [22]. The presence of lipids in moderate proportion in the 2 leafy vegetables is a major nutritional advantage, since a large proportion of contemporary diet regimes (weight loss, reduction of risks of cardiovascular disease, etc.) recommend reduced intakes in lipids.

The carbohydrate levels of A. spinosus and T. procumbens are low compared to those of Ficus sur, 70.78% (Saloufou et al., 2018b) [30] and compared to those of Lagenaria siceraria, 63.22% (Itoua et al., 2015) [23]. Carbohydrates represent a high percentage of biomass and mainly have an energy role. The diet that seems most suitable for limiting cardiovascular risk should contain two thirds to three quarters of the total daily energy intake of carbohydrates (Patureau et al., 2001, Saloufou et al., 2018b) [27, 30].

Thanks to the good distribution of lipids, proteins and carbohydrates, these leafy vegetables provide per 100 g DM, 347.8 Kcal (A. spinosus) and 361.9 Kcal (T. procumbens) as energy necessary for the human body. These values are close to the energy value of the leaves of Lagenaria siceraria (364.25 Kcal) (Itoua et al., 2015) [23] and Ficus sur (331.43 Kcal) (Saloufou et al., 2018b) [30]. These contents per 100 g DM contribute to the daily calorie intake (male: 14.48%, female: 18.09%) for T. procumbens and (male: 13.91%, female: 17.39%) for A. spinosus.

Leaf vegetables are known to be low in energy. Their cooking in the form of sauces is often accompanied by increased seasonings in vegetable oils (Kahane et al., 2005; Adjatin, 2006) [28, 29] which increases the energy value of these leafy vegetables.

The ash contents of A. spinosus and T. procumbens were interesting compared to those of Ocinum gratissimum (12.18% DM), Amaranthus hybridus (18.93% DM) (Vodouhe et al., 2012) [22] and Moringa oleifera (11.39% DM) (Ndong et al., 2007) [31]. These contents testify to the richness in minerals of the leafy vegetables.

The nutritional value of leafy vegetables is generally related to their mineral content (AFSSA, 2001; FAO, 2002) [32, 33]. In fact, around twenty minerals are essential for humans. They are essential for the activity of hormones and especially that of enzymes in the body (Dupin et al., 1992) [34]. They are characterized by a great diversity, weight and functional. The daily quantities in the body are very variable with almost 1 Kg for calcium and phosphorus, a few grams for the most abundant trace elements like iron, zinc and fluorine and less than 1 mg for chromium and cobalt (AFSSA, 2001) [32].

Considering the daily nutritional intake recommended for an adult by the current diet, we can say that the two leafy vegetables have very interesting mineral contents and can contribute to the fight against deficiencies in these nutrients. However, the different mineral contents vary from other vegetables in the work of other authors. For example, T. procumbens and A. spinosus have interesting calcium contents which are still lower than those of Amaranthus hybridus (5663 mg/100 g DM) (Ocho-Anin et al., 2012) [25]. The most abundant mineral in the human body, 99% of calcium contributes to the formation and solidity of bones and teeth. The low proportion of extra-osseous calcium (1%) is just as important since it intervenes in multiple essential functions. At all ages, it is therefore essential to ensure permanent and sufficient coverage of calcium needs (AFSSA, 2001; FAO, 2015; PNUD, 2012) [25, 32, 33].

The magnesium content of A. spinosus and T. procumbens although contributing respectively 300.43% and 237.72% to the recommended daily allowance, are low compared to those obtained with Amaranthus hybridus (1947 mg/100 g MS), with Cleome gynandra (1436 mg/100 g DM) (Ocho-Anin et al., 2012) [23]. Magnesium is one of the most abundant body minerals, half of which is found in bone tissue. It plays a role in a large number of cellular functions, in particular those involving oxidative phosphorylations, glycolysis, DNA transcription and protein synthesis. It is also involved in ionic currents and membrane stabilization (AFSSA, 2001) [32]. Compared to phosphorus, the contents of the two vegetables are higher than those obtained by Grubben and Denton (2004) [40], with Corchorus olitorius (122 mg/100 g DM), with Celosia argentea (43 mg/100 g DM), with Amaranthus hybridus (66 mg/100 g DM), with Cleome gynandra (111 mg/100 g DM), with Solanum nigrum (75 mg/100 g DM) and by Akubugo et al. (2007) [37], with Amaranthus hybridus (34.91 mg/100 g DM). On the other hand, these contents are low compared to those obtained by Ocho-Anin et al. (2012) [25], with Amaranthus hybridus (2050 mg/100 g DM), with Corchorus olitorius (2262 mg/100 g DM), with Celosia argentea (1772 mg/100 g DM), with Solanum nigrum (2229 mg/100 g DM) and with Cleome gynandra (2410 mg/100 g MS). Phosphorus is an essential component of biological cells and membranes. It combines with calcium in the form of calcium phosphate, a hard substance which gives the body its rigidity (Latham, 2001) [41].

The potassium contents of the two plants are lower than those obtained with Amaranthus hybridus by Ocho-Anin et al. (2012) [25]. The content of A. spinosus is however similar to that obtained with Celosia argentea, 4477 and 4076 mg/100 g DM respectively on two other sites by the same author. The content of T. procumbens was higher than that obtained (1639.7 mg/100 g DM) with leaves and stems of the same species in Benin (Koukoui et al., 2017) [5]. These variations in the mineral composition could be due to the soil, the diversity of the species, the methods used or even cultural practices (Agbo et al., 2009) [38].

Potassium plays several roles in the body, namely the maintenance of intracellular osmotic pressure, the proper functioning of the heart, muscles, brain and nerves, and the regulation of blood pressure (Whelton et al., 1997) [42]. The high potassium contents of the two leafy vegetables are a renewed interest in the use of the latter since a diet rich in potassium lowers blood pressure and therefore reduces the risk of cardiovascular accidents (Whelton et al., 1997) [42]. This justifies the use of the two leafy vegetables for the treatment of hypertension (Gbekley et al., 2017; Koukoui et al., 2017) [5, 43]. A. spinosus and T. procumbens showed very high potassium levels compared to sodium and thus, these leafy vegetables are very interesting for the promotion of cardiovascular health.
The sodium contents of the two leafy vegetables are comparable to those obtained on spontaneous female leaves (798.51 mg/100 g DM) and spontaneous male leaves (754.51 mg/100 g DM) of *Ceratonia siliqua* L. (El Hajaji et al., 2013) [44]. However, they are lower than those obtained (928.4 mg/100g DM) on the same species of *T. procumbens* in Benin (Koukoui et al., 2017) [3].

*T. procumbens* (34.79 mg/100 g DM) has a high iron content with a significant difference (*P* = 0.0099) compared to *A. spinosus* (23.59 mg/100g DM). By comparing these iron contents to those of the leaves of *Amaranthus hybridus* (13.58 mg/100 g DM) in Nigeria (Akubugwo et al., 2007) [37], of *Ipomoea batatas* (16.00 mg/100 g DM) in Nigeria (Antia et al., 2006) [39], *Ficus sur* (34.10 mg/100 g DM) in Togo (Saloufou et al., 2018a) [10] and other leafy vegetables in Côte d'Ivoire and Benin (Ocho-Annin Atchibri et al., 2012, Vodouhe et al., 2012) [22, 25], the 2 leafy vegetables in this study have a good iron content and could be used in diets requiring iron. Based on a low iron availability (5%) these leafy vegetables provide significant amount of the recommended daily requirement. The iron contents of these two leafy vegetables are however very low compared to those obtained for spontaneous female leaves (242.95 mg/100 g DM) and leaf s spontaneous males (189.24 mg/100 g DM) of *Ceratonia siliqua* L. (El Hajaji et al., 2013) [44].

Iron has several vital functions in the body. It serves as a transporter of oxygen to the tissues of the lungs through the hemoglobin of the red blood cells and as a means of transport for the electrons in the cells. It is an integral part of important enzyme systems in various tissues (OMS/FAO, 2004) [15]. These vegetables may be suitable for vulnerable people with significantly increased iron needs, including infants and women during pregnancy. Zinc deficiency leads to a deficiency of the immune system, growth retardation, skin lesions, diarrhea, alopecia etc. Together with iron, they constitute essential trace elements with a risk of deficiency demonstrated in humans. The zinc contents of the two leafy vegetables are higher than those obtained on the leaves of *Amaranthus hybridus* (3.80 mg/100 g DM) (Akubugwo et al., 2007) [37] and comparable to those obtained on spontaneous male leaves (9, 16 mg/100 g DM) of *Ceratonia siliqua* L. but weak compared to spontaneous female leaves (26.07 mg/100 g DM) (El Hajaji et al., 2013) [44].

*T. procumbens* and *A. spinosus* have nickel contents (0.71 mg/100 g DM and 0.5 mg/100 g DM) which comply with international recommendations. Nickel is an essential trace element in the diet but at low risk of deficiency. It has a role in the metabolism of iron and carbohydrates. Its excess is toxic and presents a risk of bioaccumulation in the kidney. In view of this toxicity, the North American Institute of Medicine recommends a limit dose of nickel of 1 mg/day for an adult (Trumbo et al., 2001) [16]. The World Health Organization has set this value at 22 µg/Kg of BW/day (for example, 1.32 mg/day for a person weighing 60 Kg) (OMS, 2005) [45].

Referring to the recommendations of Trumbo (2001) [16], the contents of 100 g DM of *T. procumbens* and *A. spinosus* are relatively low in nickel compared to the dose limits. It is even known that a higher simultaneous intake of iron, copper or zinc reduces the assimilation of nickel (Martin, 2001) [46].

Studies on food plants and leafy vegetables in particular have been carried out by various authors, and the results obtained, just like in this study, present a diversity of nutritional components making these plant species an unsuspected breeding ground for elements minerals analyzed (Tchiégang and Kitikil, 2004; Mensah et al., 2008; El Hajaji et al., 2013) [44, 47, 48].

**Conclusion**

This study on the nutritional properties of *A. spinosus* and *T. procumbens*, shows that these 2 leafy vegetables are an excellent source of nutrients: proteins, fats, carbohydrates and minerals such as calcium, magnesium, sodium, potassium, phosphorus, iron, zinc and nickel. Scientific confirmation that these leafy vegetables contain essential nutrients is a major advantage in their consumption. A current consumption of these spontaneous species would therefore be well indicated to compensate for mineral deficiencies and be used for possible food supplements, especially in rural areas. These results confirm the importance of the use of these leafy vegetables in the diet of populations in the maritime region of Togo. The obvious consumption of these leafy greens is believed to be due to the beneficial effect of these nutrients they provide.

**Conflicts of interest**

The authors declare no conflict of interest in relation to this article.

**Authors’ contributions**

ES, GEH, AA, TT, OE, KSD and KK: Initiation and elaboration of the protocol; ES and GEH: Data collection; KK: Identification of plants; ES, MM and GEH: Data processing; ES, GEH, MM, AA, TT: Writing of the manuscript.

**Acknowledgments**

The authors thank all phytotherapists, herbalists and households in the Maritime region of Togo for their frank collaboration which made this study possible.

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