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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 doublé 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
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Our study was carried out at the Laboratory of Biomedical, Agrifood and Environmental Health Sciences (LaSBASE) of the University of Lomé, at the Laboratory of Applied Hydrology and Environment (LHAE) of the University of Lomé and at the Togolese Institute of Agronomic Research (ITRA).

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.

Fig 1: *Amaranthus spinosus* L.

Fig 2: *Tridax procumbens* L.

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:

$$\mathbf{H} = \frac{\mathbf{Wt-We}}{\mathbf{Ts}} \times \mathbf{100}$$

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:

$$C = Ri \times \frac{100}{Pe}$$

Ri: residue after incineration in g;
Ts: test sample 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:

$$Nt = 1{,}4 \times V \times N \times \frac{1}{Ts}$$

V: volume in ml of H_2SO_4 titrating;
N: normality of H_2SO_4 titrating (0.5N);
Ts: tests sample in g ; the protein conversion coefficient: 6.25
Protein content = Nt × 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:

$$L = W \times \frac{100}{Ts}$$

W: weight in g of the lipid residue;
Ts: 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 PFP7 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 overall energy value (E), expressed in kilocalories (Kcal) per 100 g of leafy vegetables, was then calculated from the following relationship:

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

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 powder 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

Leafy vegetables	Taux d'humidité (g/100g MB)	Protéines (g/100g MS)	Lipides (g/100g MS)	Glucides (g/100g MS)	Cendres (g/100g MS)	Energie (Kcal/100g MS)
A. spinosus	8,86 ± 0,08	31,54 ± 0,69	5,35 ± 0,03	43,38 ± 0,69	19,75 ± 0,11	347,8 ± 0,25
T. procumbens	11,46 ± 0,07	24,11 ± 0,70	10,27 ± 0,06	43,27 ± 0,89	22,36 ± 0,20	361,9 ± 0,16

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

Leafy vegetables	Content in mg per 100 g DM							
	Ca	Mg	K	Na	P	Fe	Zn	Ni
A. spinosus	3993,31±39,57	1261,80±34,13	4580,86±38,79	680,27±15,51	169,57±2,72	23,59±0,93	7,07±0,10	0,51±0,03
T. procumbens	4835,10±41,53	998,42±17,56	3614,19±63,89	728,49±7,98	364,36±4,63	34,79± 1,28	8,44±0,12	0,71±0,04

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/100g DM) but with a non-significant difference (P = 0.0597). The phosphorus content of *T. procumbens* (364.36 ± 4.63 mg/100g DM exceeds significantly (P = 0.0004) until twice that of *A. spinosus* (169.57 ± 2.72 mg/100g DM). The results also reveal a high iron content. The content of *T. procumbens* (34.79 ± 1.28 mg/100g DM) exceeds with a significant difference that of *A. spinosus* (23.59 ± 0.93 mg/100g DM). Based on the lowest bioavailability of non-heme iron (5%), these leafy vegetables contribute with interesting levels to the RDA. *T. procumbens* has a content exceeding 100% RDA in men and 50% RDA in women. For a low bioavailability (15%) of zinc, there are also interesting contents for *T. procumbens* (60.29% in men and 86.12% in women) and for *A. spinosus* (50.5% in men and 72.14% in women). Also, the nickel contents per 100g DM of *T. procumbens* and *A. spinosus* are significantly different (P = 0.0259) and represent respectively 71 and 51% of the limit dose.

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

		A spinosus		*T. procumbens*	
	RDA in an adult Male/Female	Content per 100 g DM	CRDA (%)	Content per 100 g DM	CRDA (%)
Carbohydrates (g)	130[a]	43,38	33,37	43,27	33,28
Fat (g)	44-97[a]	5,35	5,51-12,16	10,27	10,59-23,34
Proteins (g)	56[a]	31,54	56,32	24,11	43,05
Energy (Kcal)	2500/2000[a]	347,8	13,91/17,39	361,9	14,48/18,09
Na (mg)	1500[b]	680,27	45,35	728,49	48,57
K (mg)	4700[b]	4580,86	97,46	3614,19	76,9
Ca (mg)	900[bd]	3993,31	443,70	4835,10	537,23
Mg (mg)	420[bd]	1261,80	300,43	998,42	237,72
P (mg)	750[bd]	169,57	22,61	364,36	48,58
Fe (mg)	27,4/58,8[c*]	23,59	86,09/40,12	34,79	126,97/59,17
Zn (mg)	14/9,8[c*]	7,07	50,5/72,14	8,44	60,29/86,12
Ni (mg)	1[e]	0,51	51	0,71	71

[a]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) [23]; *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 Koukoui *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 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 *Ocimum 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, 35].

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) [25]. 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 Akubugwo *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) [5].

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-Anin 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.

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Refferences

1. Batal M, Steinhouse L, Delisle H. La transition nutritionnelle et le double fardeau de la malnutrition. Médecine et Santé Tropicales. 2018; 28(4):345-350.
2. OMS. Statistiques sanitaires mondiales. Organisation mondiale de la Santé**,** 2012, 198.
3. Gbekley HE, Karou SD, Gnoula C, Agbodeka K, Anani K, Tchacondo T *et al*. Étude ethnobotanique des plantes utilisées dans le traitement du diabète dans la médecine traditionnelle de la région Maritime du Togo. Pan African Medical Journal. 2015; 20:437.
4. Amouzou KS, Adaké B, Batawila K, Wala K, Akpavi S, Kanda M *et al*. Etudes biochimiques et évaluation des valeurs nutritionnelles de quelques espèces alimentaires mineures du Togo. Acta Botanica Gallica. 2006; 153(2):147-152.
5. Koukoui O, Médégan S, Houngbèmé A, Mansoura B, Gbaguidi F, Sezan A. Propriétés nutritionnelles et phytochimiques de Launaea taraxacifolia et Tridax procumbens, deux alicaments sous utilisés au Bénin. Institut National des Recherches Agricoles du Bénin, Bulletin de la Recherche Agronomique du Bénin (BRAB), 2017, 11-19.
6. AFNOR. Recueil de normes françaises-contrôle de la qualité des produits alimentaires céréales et produits céréaliers. Paris, 3eme edition, 1991, 360.

7. Latimer GW. Official methods of analysis of AOAC International. AOAC international. Gaithersburg, MD, USA, 2012.
8. AOAC. Official methods of analysis of the Association of Official Analytical Chemists. Washington DC, 15th ed. 1990, 1230p.
9. Labat L. La préparation des matrices biologiques pour l'analyse des métaux. Annales de Toxicologie Analytique, EDP Sciences, 2010.
10. Saloufou KI, Boyode P, Simalou O, Eloh K, Idoh K, Melila M *et al*. Chemical composition and antioxidant activities of different parts of *Ficus sur*. Journal of Herbmed Pharmacology. 2018a; 7(3):185-192.
11. Atwater W, Rosa E. A new respiration calorimeter and experiments on the conservation of energy in the human body, II. Physical Review (Series I). 1899; 9(4):214.
12. Trumbo P, Schlicker S, Yates AA, Poos M. Dietary reference intakes for energy, carbohdrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. Journal of the Academy of Nutrition and Dietetics. 2002; 102(11):1621-1650.
13. Frenot M, Vierling E. Biochimie des aliments. Diététique du sujet bien portant-2e édition.
14. OMS/FAO. Vitamin and mineral requirements in human nutrition. World Health Organization and Food and Agriculture Organization of the United Nations: Geneva (Second edition). 2004, 341p.
15. AFSSA. Agence française de sécurité sanitaire des aliments relatif à l'évaluation des teneurs en vitamines et minéraux des denrées enrichies et des compléments alimentaires: synthèse. Maisons-Alfort, 2009, 38p.
16. Trumbo P, Yates AA, Schlicker S, Poos M. Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Journal of the Academy of Nutrition and Dietetics. 2001; 101(3):294.
17. PNUD. Résumé Rapport sur le développement humain en Afrique - 2012 Vers une sécurité alimentaire durable. 2012, 14p.
18. Allen L, DeBenoist B, Dary O, Hurrell R. Directives sur l'enrichissement des aliments en micronutriments. Organisation mondiale de la santé/Organisation des Nations Unies pour l'alimentation et l'agriculture, 2011, 379p.
19. Manios Y, Moschonis G, Androutsos O, Filippou C, Van Lippevelde W, Vik FN *et al*. Family sociodemographic characteristics as correlates of children's breakfast habits and weight status in eight European countries. The ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project. Public health nutrition. 2015; 18(5):774-783.
20. Moore-Schiltz L, Albert JM, Singer ME, Swain J, Nock NL, Dietary intake of calcium and magnesium and the metabolic syndrome in the National Health and Nutrition Examination (NHANES) 2001–2010 data. British Journal of Nutrition. 2015; 114(6):924-935.
21. Fernández-Barrés S, Romaguera D, Valvi D, Martínez D, Vioque J, Navarrete-Muñoz E *et al*. Mediterranean dietary pattern in pregnant women and offspring risk of overweight and abdominal obesity in early childhood: the INMA birth cohort study. Pediatric obesity. 2016; 11(6):491-499.
22. Vodouhe S, Dovoedo A, Anihouvi VB, Tossou RC, Soumanou MM. Influence du mode de cuisson sur la valeur nutritionnelle de *Solanum macrocarpum*, *Amaranthus hybridus* et *Ocimum gratissimum*, trois légumes feuilles traditionnels acclimatés au Bénin. Int. J Biol. Chem. Sci. 2012; 6(5):1926-1937.
23. Itoua OYS, Elenga M, Moutsamboté JM, Mananga V, Mbemba F. Évaluation de la consommation et de la composition nutritionnelle des légumes-feuilles de *Phytolacca dodecandra* L'Herit consommés par les populations originaires des districts d'Owando et de Makoua. Journal of Animal & Plant Sciences. 2015; 27(1):4207-4218.
24. Adu-Dupanah HK. Les feuilles de niébé se mangent aussi. Spore CTA. 1999; 51:963.
25. Ocho-Anin Atchibri AL, Soro LC, Kouame C, Agbo EA, Kouadio KKA. Valeur nutritionnelle des légumes feuilles consommés en Côte d'Ivoire. Int. J Biol. Chem. Sci. 2012; 6(1):128-135.
26. Apfelbaum M, Romon M, Dubus M. Diététique et nutrition. Paris, 6e édition Masson SAS. 2004, 36, 54, 112, 120.
27. Patureau MP, Beaufrère B, Grizard J, Obled C, Arnal M. Protéines et acides aminés *Apports nutritionnels conseillés*. Paris: Tec et Doc. Lavoisier, 2001, 37-62.
28. Kahane R, Temple L, Brat P, De Bon H. Les légumes feuilles des pays tropicaux: diversité, richesse économique et valeur santé dans un contexte très fragile, Colloque Angers 7-9 septembre 2005-03-14 Les légumes : un patrimoine à transmettre et à valoriser Thème III : Utilisation et perception, 2005.
29. Adjatin A. Contribution à l'étude de la diversité des légumes feuilles traditionnels consommés dans le département de l'Atacora au Togo Memoire online. Diplôme d'études approfondies, Université de Lomé (Togo), 2006, 71p.
30. Saloufou KI, Boyode P, Melila M, Simalou O, Eloh K, Kpegba K. Chemical composition and nutritional properties of the edible parts of *Ficus sur* (Moraceae), a dietary and medicinal wild plant of the togolese flora. J Rech. Sci. Univ. 2018b; 20:49-56.
31. Ndong M, Wade S, Dossou N, Guiro AT, Gning RD. Valeur nutritionnelle du Moringa oleifera, étude de la biodisponibilité du fer, effet de l'enrichissement de divers plats traditionnels sénégalais avec la poudre des feuilles. African Journal of Food, Agriculture, Nutrition and Development. 2007; 7(3).
32. AFSSA. Apports nutritionnels conseillés pour la population française. Coordonateur Ambroise Martin, 3e edition, 2001.
33. FAO. Elargir la base des ressources alimentaires grâce aux plantes indigènes. Rome (Italy), 2002.
34. Dupin H, Cuq J-L, Malewiak M-I, Leynaud-Rouaud C, Berthier A-M. Alimentation et nutrition humaines. Paris, ESF Editeur, 1992, 1515p.
35. FAO. La situation mondiale de l'alimentation et de l'agriculture. Protection sociale et agriculture: Briser le cercle vicieux de la pauvreté rurale Rome (Italy), 2015, 143p.
36. Grubben GJH, Denton OA. Ressources Végétales de l'Afrique Tropicale: Légumes. Wageningen - Leyden, Fondation PROTA – Backhuys, 2004, 2.
37. Akubugwo IE, Obasi NA, Chinyere GC, Ugbogu AE. Nutritional and chemical value of Amaranthus hybridus L. leaves from Afikpo, Nigeria. African Journal of Biotechnology. 2007; 6(24).

38. Agbo E, Kouamé C, Mahyao A, N'Zi J, Fondio L. Nutritional importance of Indigenous Leafy Vegetables in Côte d'Ivoire. Acta Hort. 806, ISHS. 2009; 1:361-366.
39. Antia BS, Akpan EJ, Okon PA, Umoren IU. Nutritive and anti-nutritive evaluation of sweet potatoes. Pakistan Journal of Nutrition. 2006; 5(2):166-168.
40. Grubben GJH, Denton OA. Ressources Végétales de l'Afrique Tropicale: Légumes. Wageningen - Leyden, Fondation PROTA – Backhuys, 2004, 2.
41. Latham MC. La nutrition dans les pays en développement, FAO, 2001.
42. Whelton PK, He J, Cutler JA, Brancati FL, Appel LJ, Follmann D *et al*. Effects of oral potassium on blood pressure: meta-analysis of randomized controlled clinical trials. Jama. 1997; 277(20):1624-1632.
43. Gbekley HE, Karou DS, Katawa G, Tchacondo T, Batawila K, Ameyapoh Y. Medicinal plants used in the management of arterial hypertension in the Maritime Region of Togo, an ethnobotanical survey. African Journal of Traditional, Complementary and Alternative Medicines, 2017.
44. El Hajaji H, Farah A, Ennabili A, Bousta D, Greche H, El Bali B *et al*. Etude comparative de la composition minérale des constituants de trois catégories de *Ceratonia siliqua* L. (Comparative study of the mineral composition of the constituents of three varieties of *Ceratonia siliqua* L.). J. Mater. Environ. Sci. 2013; 4(2):165-170.
45. OMS. Nickel in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva: World Health Organization, 2005.
46. Martin A. Apports nutritionnels conseillés pour la population française, Ed. Lavoisier Tec & Doc, 2001.
47. Tchiégang C, Kitikil A. Données ethnonutritionnelles et caractéristiques physico-chimiques des légumes-feuilles consommés dans la savane de l'Adamaoua (Cameroun). Tropicultura. 2004; 22(1):11-18.
48. Mensah JK, Okoli RI, Ohaju-Obodo JO, Eifediyi K. Phytochemical, nutritional and medical properties of some leafy vegetables consumed by Edo people of Nigeria. African Journal of Biotechnology. 2008; 7(14):2304-2309.