



Chemical Composition and mineral bioavailability of *Tetrapleura tetraptera* (Schumach & Thonn.) Taub. Fruit Pulp Consumed as Spice in South-eastern Côte d'Ivoire.

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ARTICLE INFO	ABSTRACT
<p><i>Research Article</i></p> <p>Received : 12/05/2019 Accepted : 10/09/2019</p> <p>Keywords: Chemical composition Nutrients Mineral bioavailability <i>Tetrapleura tetraptera</i> Côte d'Ivoire.</p>	<p>The aim of this study was to evaluate the chemical composition and mineral bioavailability of <i>T. tetraptera</i> fruit pulp, an aromatic wild edible plant, using standard methods. The pulp were extracted from mature dried fruits obtained from plants at Awabo (5°30'14.2"N and 4°01'30.6"W) and Loviguié villages (5°48'24.5"N and 4°20'15.8"W), all in south-eastern Côte d'Ivoire. The results of chemical analysis revealed that <i>T. tetraptera</i> fruit pulp contains carbohydrates (63.73±0.51%), crude protein (7.01±0.66%), crude fat (1.18±0.01%), ash (5.38±0.18%), fibre (11.78±0.02%), moisture (40.52±0.18%) and an energy value of 254.74±0.15 kcal/100g. Besides, the results showed a relative high amount of vitamin A (2.11±0.02%) and vitamin B₉ (261.78±0.01 µg/100g) while vitamin E, B₁ and B₂ in trace concentration. Otherwise, the phytochemical analysis (mg/100g) based on dry weight revealed an appreciable amount of total phenol (2407.10±8.36), flavonoids (14.29±0.56), tannins (55.11±0.44), catechin (392.93±1.01) and also carotenoids (108.19±7.42 µg/100g). Organic acids profile (mg/100mL) showed citric acid (175.06±0.02) and salicylic acid (109.85±0.01) as major organic acids. Mineral composition (mg/100g) on dry weight basis revealed that potassium (1303.67±0.58) is the most abundant followed by phosphorus (303.33±5.77), calcium (187.33±0.58) and magnesium (141.33±0.57). Furthermore, the Phytates:Zn, Phytates:Ca, Oxalates:Ca and Phytates*Ca:Zn molar ratios recorded were all below than recommended threshold values, implying a bioavailability of zinc and calcium. These data indicate that the pulp of this fruit could be a good source of ingredient for both medicine and food industries in production.</p>

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Introduction

Tetrapleura tetraptera (Schumach & Thonn.) Taub. is a single-stemmed deciduous plant that belongs to the Mimosaceae family. It is found in the wild of central and west Africa and distributed across the Guineo-Congolian phytogeographical region, therefore stretching from Senegal to Democratic Republic of Congo to Uganda and Sudan (Agbotui, 2015). In Côte d'Ivoire, the plant is found in some parts of south-eastern rainforest region (Djaha et Gnahoua, 2014; Malan et al., 2015).

T. tetraptera is a medicinal food plants and have a folkloric and ethnomedical uses in western Africa. Indeed, the tree, known as *Aridan* in western Nigeria or *Prekessa* for the Akan people from Ghana, has molluscidal,

antimicrobial, antiseptic, neuromuscular, anticonvulsant, anti-inflammatory, cardiovascular, hypoglycaemic, hypotensive, anti-ulcerative, trypanocidal, hirudinical properties (Kuate et al., 2015). The leaves, bark, roots, kernels of the plant has been exploited in ethnomedicine to treat diseases like hypertension, convulsions, leprosy, rheumatic pains, diabetes, arthritis, etc. In cosmetics industries, flowers and fruits of the plant are also used to make perfumes (Orwa et al., 2009; Nwaichi, 2013). Also, in Nigeria, Ghana and Cameroon, *T. tetraptera* fruits are commonly used in local cooking as popular seasoning spice (Kuate et al., 2015). These fruits has four winged pods (two woody and two soft) including the pulp and a

small black hard seeds encapsulated in the body of the pod which appears green when tender but dark-purple-brown when mature and ripened. The fleshy pulp have a characteristically pungent aromatic odor, which contributes to its insect-repellent and flavouring property (Ogbunugafor et al., 2017).

In Côte d'Ivoire, there is a lack of documented information on all aspects of *T. tetraptera*, although known and used by populations. However, chemical composition researches would be useful in the food industries as well as the medicine. Besides, many researches on the chemical composition of fruits performed in other countries show a great changeability of contents. Thus, the main objective of this study was to promote the utilisation and consumption of this plant by generating data on the chemical including proximate, mineral, phytochemical, vitamin composition and also mineral bioavailability of *T. tetraptera* fruit from Côte d'Ivoire.

Material and Methods

Fruit samples collection and preparation

Mature dried fruits of *T. tetraptera* were randomly harvested from the plant at Awabo village (5°30'14.2"N and 4°01'30.6"W) and also purchased from local market of Loviguié (5°48'24.5"N and 4°20'15.8"W). Fruit were authenticated at the Department of Botany, Nangui Abrogoua University (Côte d'Ivoire) and once in laboratory, unblemished fruits were selected and washed. The pulp were removed and were homogenized in a grinder (Binatone: BLG 550) to obtain 50 g pulp of the fruit. Moisture content in the pulp was determined immediately. For others analysis, fruit pulps were dried in an oven at 45°C for 72 hours. The dried samples were mechanically milled into powder (0.5 mm), packed in air-tight plastic vials and stored at -4°C until analysis.

Proximate Composition Analysis

Ash, moisture, crude fibre, crude protein, crude fat and carbohydrates contents were determined according to the standard methods of AOAC (2000). Moisture content was determined by the difference of weight before and after drying 10 g of sample in an oven (Mettler, Germany) at 105°C until constant weight at least or 72 h. Crude protein content (N × 6.25) was estimated by the macro-Kjeldahl nitrogen assay method using a digestion apparatus. The fat content was determined by Soxhlet extraction using hexane as a solvent. Ash fraction was determined by incineration of dried sample (5 g) in a muffle furnace (Nabertherm, Germany) at 550°C for 12 h. The percentage residue weight was expressed as ash content. Fibre estimate was obtained from the loss in weight of dried residue following the digestion for fat-free samples with 1.25% each of H₂SO₄ and NaOH solutions.

pH and Total Titratable Acidity (TTA)

This determination was carried out according to the method of Sadler and Murphy (2010). One gram of the crushed sample was completely dissolved in 50 mL distilled water and 5 ml of the sample with 2 drops of phenolphthalein indicator were added to a 100 mL conical flask. The mixture was titrated against 0.1 N solution of sodium hydroxide until the end-point which reached when

a changed of colour was observed. The pH was measured directly using a pH-meter (Bentchop Model) as described by Sadler and Murphy (2010).

Minerals and Vitamin Analysis

Minerals such as Ca, Fe, Mg, Zn, Cu and I were determined using AOAC (2000) method. Pulp powder was digested with a mixture of concentrated sulfuric acid (18.01 mol/L), perchloric acid (11.80 mol/L) and nitric acid (14.44 mol/L) and analysed using an atomic absorption spectrophotometer. Na and K were determined by flame emission photometer while total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent (AOAC 2000). Vitamin A, C, E and B-complex vitamins (B₁, B₂ and B₉) were estimated according to AOAC (1990) methods using a HPLC system (Shimadzu SPDA 20A) equipped with UV detector and C18 ODS column (250 x 4.6 mm, Cluzeau France) in isocratic mode.

Organic Acids Determination

Organic acids were extracted from 1 g of sample with 50 mL of 80% methanol saturated with NaCl and were analysed according to the method of Karadeniz (2004) using a HPLC system (Shimadzu Corporation, Japan) consisting of a pump (Shimadzu LC-6A Liquid Chromatograph, Japan), a UV detector (Shimadzu SPD-6A, Japan) and an integrator (Shimadzu CR 6A Chromatopac, Japan). All separations were carried out in isocratic mode with an ICsep ICE ORH-801 ion exclusion column (40 cm × 5 µm, Interchrom, France) maintained at 35°C using a MetaTherm™ furnace (Interchrom, France). Calibrations were carried out with standards (citric, salicylic, oxalic, tartaric, quinic, ascorbic, succinic and fumaric acids) obtained from Sigma-Aldrich. The levels of the organic acids in the samples were obtained by comparing the retention times of the eluted compounds with the retention times of the reference solutions.

Extraction of Phenolic Compounds

Extraction of phenolic compounds were carried out according to Singleton et al. (1999) method. A sample (10 g) of *T. tetraptera* fruit pulp powder was extracted by stirring with 50 mL of methanol 80% (v/v) at 25°C for 24 h and filtered through Whatman paper N°4. The residue was then extracted with 2 additional 50 mL portions of methanol. The combined methanolic extracts were evaporated at 35°C in a rotary evaporator (Heildolph, Germany) until 25 mL, prior to phenolic compound contents determination.

Determination of Total Phenolic Compounds Content

Contents of total phenolic compounds were estimated according Folin-Ciocalteu's method (Singleton et al., 1999). A volume of 1 mL of methanolic extract of each sample was added to 1 mL of Folin-Ciocalteu solution in a test tube. After 3 min, 1 mL of 20% sodium carbonate solution was added to the mixture and adjusted to 10 mL with distilled water. The mixture was allowed to stand at room temperature in a dark environment for 30 min. Absorbance was measured against the blank reagent at 725 nm. Gallic acid was used for the calibration curve with a concentration

range of 50-1000 µg/ml. Results were expressed as mg gallic acid equivalent (GAE) per 100g dry weight.

Individual Phenolics by HPLC:

Individual phenolic acids were analysed with Shimadzu SPD 6A (Model: LC-6A, Serial No C20112912005LP), RP 18 AB 250 x 4.6 mm column. The column temperature was maintained at 30°C and a UV detector set at 280 nm. For calibration of HPLC system, some standard solutions of acid (gallic, flavanone, cinnamate, coumarin, quercetin, benzoic and catechin acids) purchased from Sigma-Aldrich, were used. The calculated results were expressed as mg per 100 g dry weight (Ho et al., 1999).

Determination of Flavonoids

Total flavonoids content was determined according to the method of Meda et al. (2005), but slightly modified. A volume of 0.5 mL of methanolic extract of sample was diluted in 0.5 mL of distilled water. Then, 0.5 mL of aluminium chloride 10% (p/v) and the same volume of sodium acetate 1 M were added. Finally, 2 mL of distilled water was added and absorption reading at 415 nm was carried out after 30 min against a blank sample consisting of a 4 mL methanolic extract without aluminium chloride. Quercetin was used for the calibration curve with a concentration range of 0-100 µg/mL. Results were expressed as mg of quercetin equivalent (QE) per 100 g dry weight.

Determination of Tannins

Tannins content was determined using the method described by Bainbridge et al. (1996). A volume of 1 mL of each methanolic extract was collected and mixed with 5 mL of reaction solution [vanillin 0.1 mg/mL in sulphuric acid 70% (v/v)]. The mixture was left to stand at room temperature in a dark for 20 min. The absorbance was measured at 500 nm against a blank (without extract). Tannic acid was used for the calibration curve with a concentration range of 0-100 µg/mL. The results were expressed as mg of tannic acid equivalents (TAE) per 100 g dry weight.

Antinutritional Factors

The oxalate assay was performed according to Day and Underwood (1986) procedure using KMnO₄. 1 g of the ground sample was added to 75 mL of 3 N H₂SO₄. The mixture was carried under magnetic stirring for 1 h and filtered using Whatman filter paper N°1. Thus, 25 mL of the filtrate was collected and titrated against 0.05 N KMnO₄ solution until a faint pink colour appeared that persisted for 30 s.

Phytates content were estimated according to the method described by Latta and Eskin (1980). 1 g of sample was homogenized in 20 mL of 0.65 N HCl in a mechanical shaker for 12h at the room temperature. The extract was centrifuged at 12,000 rpm for 40 min and the supernatant was used for phytates estimation. To 0.5 mL of the supernatant, 3 mL of wade reagent (0.03% solution of FeCl₃.6H₂O and 0.3% of sulfosalicylic acid in distilled water) was added and the mixture was allowed to stand at room temperature for 15 min. Absorption was measured at 490 nm against a blank. Sodium salt of phytic acid (0-10 µg/mL) was used as standard for construction of

calibration curve. Result was expressed as mg phytic acid equivalent (PAE) per 100g dry weight.

Determination of Molar Ratio of Anti-Nutrients to Minerals

The molar ratio of anti-nutrients to minerals was obtained by dividing the mole of anti-nutrient with the mole of minerals (Sengev et al., 2016).

Statistical Analysis

All chemical analyses and assays were performed in triplicate. Results were expressed as mean values ± standard deviation (SD). Analysis of variance (ANOVA), followed by Duncan's test, was conducted to analyse data at the 95% confidence level, using STATISTICA software (version 12, ©StatSoft, Inc. 1984-2014).

Results and discussion

Proximate Composition

The investigated proximate composition of *T. tetraptera* mature dried fruit pulp have been summarized in Table 1. Moisture content of the raw pulp (40.52±0.18%) was higher than those reported by Godfrey (2015) and Essien et al. (1994) on the same section of the fruit (19.90 and 21.12% respectively). These differences could be attribute to the maturity stage and the origin of the fruit. Moisture content of any food is an index of its water activity and is used as a measure of stability and susceptibility to microbial contamination (Uyoh et al., 2013). The high moisture content of *T. tetraptera* pulp makes the fruit vulnerable to microbial attack, hence spoilage (Nwofia et al., 2012). Because of high moisture content of the pulp, the fruits need to store in cool condition if they are to be kept for a long period without spoilage or dehydrate to improve its self-life and preservation (Gemedede et al., 2016).

Table 1 Proximate composition and estimated energy value of *T. tetraptera* mature dried fruit pulp expressed on dry weight basis.

Parameter	Value
pH	6.40±0.00
Total titratable acidity (%)	0.34±0.02
Moisture* (%)	40.52±0.18
Protein (%)	7.01±0.66
Fat (%)	1.18±0.01
Carbohydrates (%)	63.73±0.51
Ash (%)	5.38±0.18
Fibre (%)	11.78±0.02
Caloric energy (kcal/100g)	254.74±0.15

Values are the mean ± standard deviation of three measurements (n=3). * on wet weight basis

The carbohydrate was found to be the major chemical constituent of proximate composition in *T. tetraptera* mature dried fruit pulp (63.73±0.51%). This result confirmed those of Essien et al. (1994) and Godfrey (2015) which obtained in the mature fruit pulp, a values of 58.53% and 40.12% respectively. Besides, the carbohydrate content for the fruit pulp was high and suggests the ability of this fruit in stability of plasma level, provides energy to the body cells and preventing easy degradation of body

protein to obtain energy (Alagbaoso et al., 2015). The calculated food energy value for the fruit pulp (254.74 ± 0.15 kcal/100g) was important, but the energy content of the fruit components may be insignificant since *T. tetraptera*, like other spices, is not taken in large quantities.

The founded crude fat content ($1.18 \pm 0.01\%$) was lower than those of Gbadamosi and Yekini (2016) and Olubunmi (2013) who have also noticed a relatively low lipid contents in the same fruit (2.20 and 4.45% respectively). Our result indicated that the studied spice wasn't a source of lipid accumulation. Otherwise, due to its low fat content, *T. tetraptera* pulp powder could be incorporated into the diet of individuals suffering from overweight and obesity.

The obtained ash content ($5.38 \pm 0.18\%$) was higher than the 3.17% value found by Akin-Idowu et al. (2011) for the same section of fruit. It was also higher than most of the values reported (0.56 to 7.60%) for some nigerian and ghanaiian spices (Adeyeye and Fagbohun, 2005; Borquaye et al., 2017). The ash content is a reflection of the nutritionally important mineral present in the food material. High obtained ash content for *T. tetraptera* fruit, indicated that it would provide essential valuable and useful minerals needed for body development.

The protein content ($7.01 \pm 0.66\%$) was within the range of 5.48 to 7.84% founded in samples accessions from Cross River State by Uyoh et al. (2013). This is also in agreement with Abii and Amarachi (2007) and Akintola et al. (2015) who reported in the fruit pods, a values of 5.60% and 5.61-6.69% respectively. It is well know that a diet is nutritionally satisfactory if it contains high caloric value and a sufficient amount of protein (Gemedede et al., 2016). However, spices are generally not consumed for their high protein content but rather for their ability to improve the flavour of foods and to another extent for their intake of essential micronutrients (Borquaye et al., 2017). Added to the other elements of the meal, this spice could play an important complementary role.

The crude fibre content of the fruit pulp was found to be $11.78 \pm 0.02\%$. This value was significantly higher than those recorded in some common spices in Nigeria (0.8-1.3%) by Ogunka-Nnoka and Mepba (2008). The recommended daily intake (RDI) of fibre for children, adult and pregnant women are 19-25, 21-38 and 28% respectively (Trumbo et al., 2002). Therefore, the contribution of the fruit pulp as spice in a high-fibre diet would not be insignificant. Dietary fibre plays an essential role in a good nutrition aspect. High intake of dietary fibre is associated with weight control and the prevention of several diseases such as coronary disease and colorectal cancer risk (Vincente et al., 2014).

The total titratable acidity value of the fruit pulp powder ($0.34 \pm 0.02\%$) was within the range obtained by Tsegay et al. (2013) on sweet pepper var. Telmo-Red (0.39-0.69%). This was probably due to the presence of various organic acids such as tannic (0.075%), citric (0.17%) and salicylic acid (0.10%) as revealed by the HPLC organic acids profiles (Table 2). Among these organic acids detected in the fruit pulp, citric acid was the predominant. It's well know that citric acid is an acidulate and flavouring agent, naturally present in many plants, known to enhance the flavours of citrus fruits like orange and lemon (Shukla et al., 2017). Also tartaric acid was

signalled as major constituent between acids components of the fruit (Enwereuzoh et al., 2015). On the other hand, the presence of all these organic acids could benefit consumers of *T. tetraptera* fruit because their decrease the pH in the stomach and creates an unfavourable environment for certain pathogenic microorganisms to survive and grow.

Phytochemical Content

Phytochemical screening revealed that the pulp of *T. tetraptera* had a various amounts of tannins, oxalates, phytates, flavonoids, carotenoids and phenolic compounds (Table 3). The presence of these metabolites could be considered responsible for the varied biological and pharmacological properties of the fruit (Kuate et al., 2015). The pulp possess a relative low quantities of oxalates (300.62 ± 11.32 mg/100 g) and phytates (9.99 ± 0.38 mg/100 g) compared to those found in five local ghanaiian spices varying between 1500-4270 mg/100 g for phytates and 80-760 mg/100g for oxalates (Borquaye et al., 2017). The tannins (55.11 ± 0.44 mg/100 g) and total phenolics (2407.10 ± 8.36 mg/100 g) levels were higher than those reported by Erukainure et al. (2017) in the same fruit peels (23.87 and 21.70 mg/100g respectively). The found rates of tannins, flavonoids and carotenoids (108.19 ± 7.42 µg/100 g) were lower than 1,097.50 mg/100 g (tannins), 410.75 mg/100 g (flavonoids) and 1642 µg/100 g (carotenoids) recorded by Gbadamosi and Yekini (2016) in the mature fruit pod. These variations are probably due to phenolic composition of extracts, genotypic factors, biotic conditions (organ and physiological stage) and abiotic (edaphic factors) in which this plant grow. Furthermore, the role of phenolic compounds is widely shown in the protection against certain diseases because of their antioxidant, antimicrobial, antitumor, anti-inflammatory, anticancer, hepatoprotective, immunomodulatory, antiangiogenic, antidiabetic and antihyperlipidemic properties. Polyphenols are also used in the agro-food industry as an additive, dye, flavouring or preservative (Kim et al., 2014; Sevindik et al., 2017; Mohammed et al., 2018). Tannins known to be anti-nutrients in diets, are responsible for astringency and poor taste of food and drink. Tannins have also been reported to have anti-mutagenic, anti-thrombotic, anti-proliferative effects, anti-inflammatory, anti-atherogenic, anti-diabetic, antibacterial, antiviral and anti-carcinogenic properties (Godfrey, 2015; Oroian and Escriche, 2015). Carotenoids have been shown to play a range of roles in the prevention against various health disorders, including cancer, metabolic disease and possibly cardiovascular disease (Vincente et al., 2014).

Table 2 Organic acids content in *T. tetraptera* mature dried fruit pulp

Parameter	Content (mg/100 mL)
Citric acid	175.06 ± 0.02
Salicylic acid	109.85 ± 0.01
Tannic acid	75.38 ± 0.01
Fumaric acid	nd
Oxalic acid	nd
Tartaric acid	nd

Values are the mean \pm standard deviation of three measurements (n=3), nd: not detected

Table 3 Phytochemical content of *T. tetraptera* mature dried fruit pulp (expressed on dry weight basis).

Components	Value
Total phenols (mg GAE/100g)	2407.10±8.36
Flavonoids (mg QE/100g)	14.29±0.56
Tannins (mg TAE/100g)	55.11±0.44
Phytates (mg PAE/100g)	9.99±0.38
Oxalates (mg OAE/100g)	300.62±11.32
Carotenoids (µg/100g)	108.19±7.42
Sodium cinnamate (mg/100g)	23.75±0.02
Catechin (mg/100g)	392.93±1.01
Gallic acid (mg/100g)	17.17±0.02
Tannin H ₂ O (mg/100g)	7.82±0.03

Values are the mean ± standard deviation of three measurements (n=3)

Table 4 Vitamin content (%) in *T. tetraptera* fruit pulp powder

Vitamin	Value (%)
Vitamin A	2.11±0.02
Vitamin B ₁	nd
Vitamin B ₂	nd
Vitamin B ₉ (µg/100g)	261.78±0.01
Vitamin C	0.42±0.01
Vitamin E	nd

Values are the mean ± standard deviation of three measurements (n=3), nd: not detected

Table 5 Mineral contents of *T. tetraptera* mature dried fruit pulp (expressed on dry weight basis)

Mineral	Value (mg/100g)
Phosphorus (P)	303.33±5.77
Magnesium (Mg)	141.33±0.57
Calcium (Ca)	187.33±0.58
Potassium (K)	1303.67±0.58
Sodium (Na)	0.43±0.00
Iron (Fe)	0.83±0.00
Iodine (I)	0.10±0.01
Copper (Cu)	0.27±0.00
Zinc (Zn)	0.23±0.00
Ratio Na:K	0.00
Ratio Ca:P	0.62
Ratio Mg:Ca	0.75

Values are the mean ± standard deviation of three measurements (n=3)

The chromatographic analysis of individual phenolic compounds revealed that *T. tetraptera* pulp are rich in phenolic acids (cinnamic and gallic acids) and flavonoids (catechin) (Table 3). These two classes of natural phenolics compounds are regarded to be of pharmacological importance, as they possess diverse health benefits, including anti-inflammatory activity (Hu et al., 2011). They can modulate the expression of pro-inflammatory signals and ameliorate inflammatory diseases such as arthritis like other natural polyphenolics (Khanna et al., 2007). The best-described flavonoids and phenolic acids properties is their antioxidant activity and their ability to trap free radicals that appear in several situations, such as anoxia, inflammation and lipid self-oxidation (Dufour et al., 2007; Ironi et al., 2016). Thus, all these phytochemical compounds, combined or not, could explain the widespread ethno-medicinal use and consumption of the fruit.

Vitamin Content

The vitamin content of *T. tetraptera* mature dried fruit pulp are shown in table 4. The raw pulp contained 2.11±0.02 g/100 g vitamin A, 261.78±0.01 µg/100 g vitamin B₉ and 0.42±0.01 g/100 g vitamin C, while vitamins B₁, B₂ and E were not detected. Compared to those found by Akintola et al. (2015) and by Ugwuona (2014) for the entire fruit, vitamin A, C and B₉ content are low in the pulp. This could be due to heating effect during sun drying of the spice. Vitamin A (retinol) is a collective name for a group of lipophilic biomolecules that are required to perform different vital metabolic functions in a body. It is need for vision, healthy skin, mucous membranes, bones and tooth growth and immune system. The RDA of vitamin A is 400 to 600 µg/day for children and 750 to 1.000 µg/day for adults (Igwe and Eleazu, 2018). Vitamin C (ascorbic acid) is an important antioxidant vitamins that protect human tissue against free radical damage by giving up electrons to provide stability to oxidant compound such as reactive oxygen species. The RDA for vitamin C is 75-90 mg/day for adults. Vitamin B₉ (Folic acid) is used to treat deficiencies, which can cause megaloblastic anaemia. Folate deficiencies are more common in people who have digestive problems, kidney or liver disease, or who abuse alcohol. This vitamin also plays an important role in DNA synthesis and homocysteine metabolism. The RDA of vitamin B₉ is 400 µg/day for adults and 600 µg/day for pregnant women. Regarding RDAs, the consumption of 100 g pulp powder of the studied fruit can permit to reach subsequently the vitamin A, C and B₉ body requirement.

Mineral Content

Using standard procedures, the mineral composition of *T. tetraptera* mature dried fruit pulp were determined and presented in table 5. This table showed that the fruit pulp contained P, Mg, Ca and K as macro elements. The pulp contained also Na, Fe, I, Cu and Zn as microelements. The calcium content of the fruit pulp was 187.33±0.58 mg/100 g which was similar to 187.48 mg/100 g reported by Akin-Idowu et al. (2011) in the same fruit part. Ca enters in the structure and constitution of bone and teeth but also in the proper functioning of cardiovascular and nervous systems (Vincente et al., 2014). P is related to calcium for bone, teeth and muscles growth and maintenance. The obtained P content was 303.33±5.77 mg/100g which is appreciably lower than 721.18 mg/100 g (Ironi et al., 2013) but relatively higher than 34.75 to 42.32 mg/100 g from the fruit pod (Uyoh et al., 2013). The availability of Ca in the body depends on Ca to P ratio and the presence of antinutritional factors. For good Ca intestinal absorption, Ca:P ratio must be 1:1 (Umar et al., 2007). Ca:P ratio for *T. tetraptera* fruit pulp was 2:3 which indicated that diet required to be supplemented with calcium sources. Mg is useful in energy production, synthesis of protein, muscle contraction, transmission of nerve impulses and Ca metabolism in bones (Vincente et al., 2014). The value of 141.33±0.57 mg/100g reported here was higher than 42.8 mg/100g reported by Essien et al. (1994) in the same section of the fruit and also higher than 96 mg/100g for the fruit pod (Abdou-Bouba et al., 2012).

K content of *T. tetraptera* fruit pulp (1303.67±0.58 mg/100g) was higher than that reported on the same fruit part (863.11 mg/100g) by Akin-Idowu et al. (2011). Uyoh et al. (2013) also reported 241.64 to 270.18 mg/100g as K content in the fruit pods accessions. It's well know that, Na in combination with K is involved in maintaining proper acid-balance and nerve transmission in the body, energy release from fat, carbohydrates and protein (Vincente et al., 2014). So, a diet with a high K to Na ratio is often recommended particularly in foods for a hypertension patients (Appiah et al., 2011). The high K to Na ratio obtained in this work, indicates that consumption of *T. tetraptera* pulp powder could help control blood Na levels, sometimes with adverse health effects. Fe is essential micronutrient present in myoglobin and haemoglobin. It prevents fatigue, cures iron deficiency anaemia and helps to fight diseases (Vincente et al., 2014). The fruit pulp content in Fe (0.83±0.00 mg/100g) was lower than 30.90 mg/100g reported in the whole fruit by Abdou-Bouba et al. (2012) and 6.51 mg/100g (Akin-Idowu et al., 2011). Since it had lower amount of Fe, its consumption should be supplement by Fe sources such as meat products particularly for menstruating and lactating women.

The Cu concentration in the pulp of *T. tetraptera* mature dried fruit (0.27±0.00 mg/100g) was almost similar to 0.40 mg/100g and 0.42 mg/100g reported by Akin-Idowu et al. (2011) and Ironi et al. (2013) respectively. The value was lower than the Cu RDA (1.5-3.0 mg/day), therefore 100 g of *T. tetraptera* could not provide the required value. Cu sources like grains and legumes (21%) or nuts and soy (20%) should be complete the consumption of the fruit pulp. Cu is necessary to form haemoglobin and critical for the oxidative defence system (Vincente et al., 2014).

Molar Ratios and Bioavailability of Minerals

It's well know that the bioavailability of nutrients in any given spice or food can be reduced by the presence of some anti-nutrients such as phytates and oxalates. Indeed, these compounds are able to create insoluble complexes with divalent cations (Ca^{2+} ; Zn^{2+} and Fe^{2+}), thus reducing their absorption (Kumar et al., 2010). In order to predict the bioavailability of elements such as calcium, iron and zinc, the molar ratios of antinutrients to minerals were determined and presented in Table 6. The calculated molar ratios of [Phytates] / [Zn], [Phytates] / [Ca] and [Oxalates] / [Ca] were 4.30, 0.00 and 0.73 respectively. According to Sengev et al. (2016) and Borquaye et al. (2017), all these values can be considered below the recommended threshold values of 15.00, 0.24 and 1.00 respectively. These results would suggest that the levels of phytates and oxalates in the fruit pulp do not interfere with the bioavailability of zinc and calcium. Moreover, the fact that molar ratio of [Phytates]×[Ca]/[Zn] were lower than the critical value (0.5 mol/kg) would suggest that calcium promotes zinc bioavailability in the powder sample. Otherwise, Borquaye et al. (2017) argue that [Phytates]/[Fe] ratio should not exceed 1.00 for adequate iron bioavailability. This ratio for the pulp powder (1.02) was over the critical value which indicates that iron in the pulp may not be bioavailable. Thus, the consumption of this spice should be complemented with other food components rich in iron.

Table 6 Molar ratio of anti-nutrients to mineral

Molar ratio	Value	Critical value*
[Phytates]/[Ca]	0.00	0.24
[Oxalate]/[Ca]	0.73	1.00
[Phytates]/[Zn]	4.30	15.00
[Phytates]/[Fe]	1.02	1.00
[Phytates] × [Ca]/[Zn]	0.20	0.50

*Sources: Borquaye et al. (2017); Sengev et al. (2016)

Conclusion

The data reported in present study delivered some basic information on the mineral, phytochemical and proximate composition of *T. tetraptera* fruit pulp, a locally consumed spice. Regarding the obtained results, this spice can be considered as potential source of crude fibre, ash, citric and salicylic acids and also minerals like K, P and Ca. The phenolic compounds such as flavonoids and tannins in fruit are unneglectable. Besides, antinutritional factors in the pulp sample were low, implying a high bioavailability of minerals such as Ca and Zn. The richness and diversity of chemical content of the pulp could make the fruit a good ingredient for medicinal adjuncts. Also, added to the other elements of the meal, this spice could play an important complementary role. However, because of the high moisture content of pulp, the fruit should be dried suitably to prevent it decay.

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