American Journal of Food Science and Technology, 2023, Vol. 11, No. 2, 61-69
Available online at http://pubs.sciepub.com/ajfst/11/2/6
Published by Science and Education Publishing
DOI:10.12691/ajfst-11-2-6

Nutritional value and functional properties of leaves, petioles and roasted kernels of *Tamarindus indica* L. from Benin

Rose E. Kanfon[1,2,3,*], Flora J. Chadare[1,3], C. Pascal Agbangnan D.[2], Paulin Azokpota[3]

[1]Laboratoire des Sciences et Technologies de l'Alimentation et des Bioressources et de la Nutrition Humaine (LaSTABNH), Centre Universitaire de Sakété, Université Nationale d'Agriculture, Bénin
[2]Laboratoire d'Etudes et de Recherche en Chimie Appliquée / Ecole Polytechnique d'Abomey Calavi / Université d'Abomey Calavi, 01BP : 2009 Cotonou, Bénin
[3]Ecole des Sciences et Techniques de la Nutrition et de l'Alimentation, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi (ENSTA/FSA/UAC), Abomey-Calavi, Bénin
*Corresponding author: Rose E. Kanfon, kanfonrose@gmail.com

Received July 02, 2023; Revised August 03, 2023; Accepted August 10, 2023

Abstract *Tamarindus indica L.* is a non-timber forest product *that* offers an exceptional richness in macronutrients and micronutrients. The present work aims to evaluate the nutritional and functional value of dry depetiolated leaves, dry petioles and kernels of seeds roasted between 100°C and 110°C for 15 minutes of *Tamarindus indica L.* from Benin. The proximal composition of the samples was determined by standard methods and the mineral composition by atomic adsorption spectrometry. The results show that 100 g of leaves of *Tamarindus indica L.* contain on average (94.47 ± 0.31) g dry matter , (5.37 ± 0.09) g ash , (37.49 ± 0.11) g lipid, (14.92 ± 0. 10) g of protein and (50.12 ± 0.01) g of sugars. Roasted almonds showed the highest protein content (22.08 ± 0.10) g. The dry petioles were richer than the leaves and kernels in dry matter (95.33 ± 0.36) g. The most representative mineral of the leaves was phosphorus (701.5 ± 0.21) g and potassium for the almonds (1010.24 ± 2.45) mg per 100g of dry matter. The contents of magnesium, calcium, iron and copper were also high with average values ranging from (22.08 - 157.17) mg, (100.24 - 1346.71) mg, (16.77 - 62.71) mg and (5.43 - 11.54) mg respectively for roasted almonds and dry depetiolated leaves. Manganese was the least important mineral for almonds (5.43 mg) and leaves (7.09 mg) low, respectively below 1 and 0.5. These results show that the organs of *Tamarindus indica L.* prospected in this study present a rather interesting nutritional profile and reveal their functional character. They could play an important role in human nutrition and food security as food ingredients or incorporated into the formulations of products useful to humans.

Keywords: *Tamarindus indica L., Nutrients, Seeds, Roasted almonds, Leaves*

Cite This Article: Rose E. Kanfon, Flora J. Chadare, C. Pascal Agbangnan D, and Paulin Azokpota, “Nutritional value and functional properties of leaves, petioles and roasted kernels of Tamarindus indica L. from Benin.” American Journal of Food Science and Technology, vol. 11, no. 2 (2023): 61-69. doi: 10.12691/ajfst-11-2-6.

1. Introduction

Sources of nutrients and raw materials, agroforestry resources have been used since the dawn of time by man to meet his many needs. This is the case of *Tamarindus indica L.*, a versatile plant (Garba et al., 2019) belonging to the Leguminosae family (Fabaceae) and widely distributed in southern Asia and in certain regions of Africa [1] where it is referred to as “Nirtile” in the " Lokpa " ethnic group in northern Benin. “Nirtile” is highly prized for its nutrient-rich fruit pulp [2]. It is used in the production of beverages and serves as an ingredient or flavoring agent in confectionery, curries and food preparations. It also finds many applications in traditional medicine [3,4,5]. However, although the seeds represent 34% of the fruit, they are a co-product of fruit processing and underutilized [1]. As a source of natural hydrocolloids and endowed with gelling, coagulant, thickening, adhesive and therapeutic properties [5], the seeds can be transformed into flour for an optimal use after elimination of their integuments which are sources of antinutrients responsible for the disorders of digestion in consumers [6].

In addition, in certain regions, the leaves of “Nirtile” are involved in the preparation of porridge, pasta and sour sauces or generally intended as fodder for animals [7]. The knowledge of its nutritional value would be important beforehand for the formulation of products with “added values” of the organ.

However, little scientific data is available on the nutritional composition of leaves and roasted kernels of

Tamarindus indica L. from Benin. It is in this context that the present study was initiated and has the general objective of evaluating the nutritional and functional potential of the edible organs of Tamarindus *indica L.* from Benin through the determination of the proximal and mineral composition of roasted almonds, leaves and petioles of the species.

The results of this study will help to address the major challenges related to human malnutrition, food security and poverty in developing countries through the use of plants on the one hand and to explore the various voices valorization of prospected organs in the agri-food industry.

2. Material and methods

2.1. Plant material:

The plant material essentially consists of the leaves of *Tamarindus indica* L. harvested in the district of Sékou and seeds (Figure 1) obtained from the fruits of *Tamarindus indica L.* collected in the commune of Bassila in northern Benin in April 2022.

2.2. Treatment of plant material

The leaves of *Tamarindus indica L.* were carefully washed, depetiolated, dried in the shade and at room temperature for 21 days and then reduced to powder (Figure 2).

Seeds from *Tamarindus indica L. fruits* have been manually sorted to remove bad seeds and other contaminants. They were weighed and roasted at a temperature of 100°C to 110°C for 15 minutes in an open pan placed on a gas stove and peeled to release the almonds. These were then ground into flour using an attrition mill (Figure 3). Samples were packaged in clean bottles and stored at room temperature for later analysis.

Figure 1. Photos of some foods derived from Tamarindus indica L.

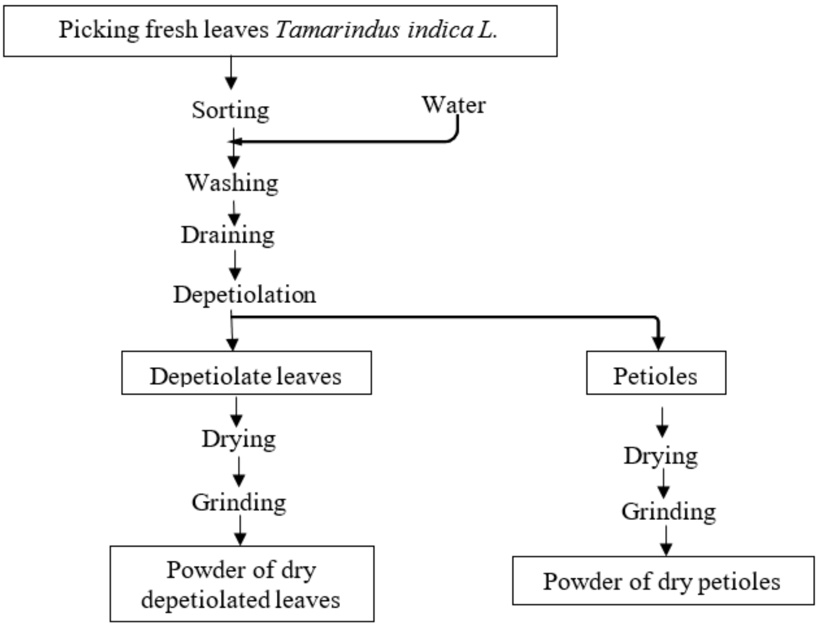

Figure 2. Technology for the production of powder from the leaves and petioles of *Tamarindus indica L.*

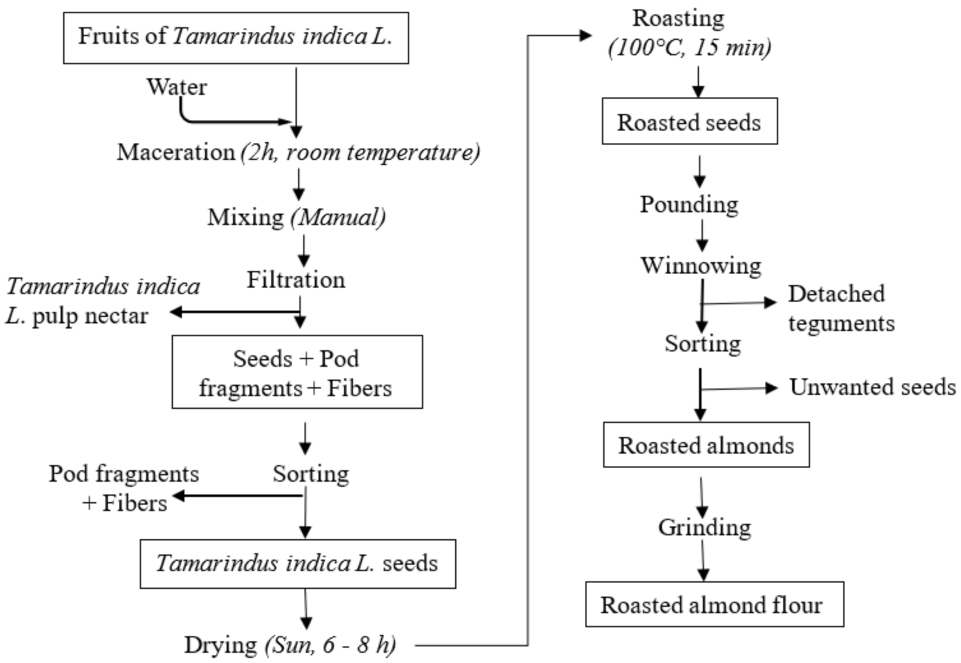

Figure 3. Technology of production of almond flour from roasted seeds of *Tamarindus indica L.*

2.3. Nutritional composition of leaves, petioles and roasted kernels of *Tamarindus indica* L.

The evaluation of the nutritional value of roasted almonds, dry depetiolated leaves, dry petioles of *Tamarindus indica L.* from Benin consisted in determining their proximal and mineral compositions. All estimates were made in triplicate.

2.3.1. Determination of proximal composition of leaves, petioles and roasted kernels of *Tamarindus indica*

To determine the nutritional potential of the leaves, petioles and roasted kernels of *Tamarindus indica L.*, the water and volatile compound, dry matter, crude ash, fat, protein and total sugar contents of the organs of *Tamarindus indica L.* were determined. determined by standard methods.

2.3.1.1. Determination of dry matter, water and volatile matter content

The dry matter (***TMS***) and water and volatile compounds (***TE) content of*** *Tamarindus indica* organ samples *I.* was determined by differential weighing before and after stoving at (103 ± 2)°C for 24 hours [8] then calculated according to the formulas:

$$\text{TMS} = \frac{m_1 - m_0}{m_{éch}} \text{ x } 100 \text{ and } \textbf{TE} = 100\% - \text{TMS} \quad (1)$$

Where m_1 = Mass of the crucible containing the dry sample after stoving; $m_{éch}$ = Mass of the sample before baking; m_0 = Mass of the empty crucible.

2.3.1.2. Determination of crude ash content

The ashes of the organ samples of *Tamarindus indica I.* were obtained by incineration at 550°C in a muffle furnace until a constant mass was obtained [8]. The crude ash content (TC) was estimated by the formula:

$$\textbf{CT} = \frac{m_2 - m_0}{m_{éch}} \text{ x100} \quad (2)$$

Where m_2 = Final mass (crucible + ashes) obtained after incineration; $m_{éch}$ = Mass of the sample weighed before incineration; m_0 = Empty mass of the crucible.

2.3.1.3. Determination of lipid content

Fat content (***TL***) *Tamarindus indica* organ samples *I.* was evaluated by the Soxhlet extraction method, continuously for 6 hours in hexane heated to 69°C [8]. The hexane was then evaporated using a rotary evaporator. The elimination of traces of solvent in the extracted oil was carried out by stoving at 50° C. for one hour then cooled in a desiccator. The mass of oil was weighed and related to that of the sample to estimate the fat content (***TL***) according to the formula:

$$\boldsymbol{TL} = \frac{m_3 - m_b}{m_{éch}} \text{ x100} \quad (3)$$

Where m_3 = Final mass (flask + fat) obtained after extraction followed by evaporation and steaming; m_b = Mass of the empty balloon; $m_{éch}$ = Mass of sample taken before extraction.

2.3.1.4. Determination of protein content

The Kjeldahl method was used for the determination of the protein content (TP) of the organ samples of *Tamarindus indica* L according to the standard according to the ISO 2005 standard [9]. It was deduced from that in total nitrogen (**TN**) obtained after mineralization, distillation and titration of the sample by multiplying TN by the conversion factor (6.25).

2.3.1.5. Determination of total carbohydrate content

The total sugars of samples of dry depetiolated leaves and roasted almonds of *Tamarindus indica* were assayed by the colorimetric method of Dubois et *al.* [10] or phenol-sulfuric acid method based on the Beer-Lambert law.

2.3.1.6. Energetic value

The caloric value was estimated by summing the products of the content of each organic component by the value of its physiological fuel (respectively 4, 9 and 4 kcal/g for proteins, lipids and carbohydrates.

2.4. Determination of the mineral composition of dry petiolate leaves and roasted *Tamarindus indica* almonds

Calcium, sodium, magnesium, potassium, phosphorus, iron and manganese contents of *Tamarindus indica* organ samples *L.* were estimated by Atomic Absorption spectrophotometry [11] after digestion in 10mL of HNO_3 (1M) and 10 ml of 3N hydrochloric acid on a hot plate for 30 min of the ashes obtained after incineration of roasted almonds and dry depetiolated leaves of the *Tamarindus indica*.

2.4.1. Statistical analysis

The calculations of the content of organic nutrients and mineral elements of the samples were carried out using Excel software. Estimates reported for nutrient contents are presented as means ± standard deviation. Values were calculated using SPSS version 26 software.

3. Results and discussion

3.1. Nutritional characterization of dry depetiolated leaves, roasted almonds and petioles of *Tamarindus indica I.*

Table 1 presents the proximal composition of dry depetiolated leaves, roasted almonds and petioles of *Tamarindus indica L.* from Benin. The values obtained are presented as the average of three replicates plus or minus (±) the standard deviation.

3.1.1. Proximal composition of roasted almonds

The roasted almonds of *Tamarindus indica L.* prospected in this study were very rich in dry matter (90.11±0.18)g/100g of DM and constitute a potential source of proteins (22.08±0.10) g/100g of DM. They contain (45.25 ± 0.11) g / 100g of carbohydrates, (12.48 ± 2.45) g / 100g of lipid and (3.68 ± 1.64) g / 100g of crude ash for a value energy equal to 381.61 Kcal/100g. The lipid content obtained for roasted almonds of *Tamarindus indica L.* in this study is higher than those reported for roasted almonds of the same species (4.55%), (7.03%) and (5.70%) reported respectively in 2014 and 2016 by [12] and [13] in Nigeria then in 2020 by [14] in India. However, it is lower than the lipid content of unroasted almonds (14.59%) reported in 2016 by [13] in Nigeria. This difference could be due to the duration (short or long) and the specific methods (steaming or intense combustion) of roasting specific to each author. They are an inexpensive source of vegetable protein. The protein content observed in the present study is lower than that reported for raw almonds (31.44%) reported by [12]. Nevertheless, it is in the same wake (19.46% to 26.86%) as those reported by [13] in Nigeria then in India in 2020 by [14] and [15] for roasted almonds. This significant decrease in protein content observed for roasted and raw almonds could be explained by the pretreatment method. Indeed, [16] reported that prolonged heating of food at high temperatures decreases the availability of amino acids, the constitutional units of proteins. However, the values of protein content of roasted almonds were higher than that of wheat flour (13.4%) reported by [17]. They can therefore be used as a component in bakery flours. The protein content of roasted kernels of *Tamarindus indica L.* is of nutritional importance and as such, the involvement of this organ in food would not only increase the dietary protein intake of consumers but also help reduce overdependence conventional protein supplements, including soybeans and other common legumes.

3.1.2. Proximal leaf composition

The dry leaves of *Tamarindus indica L.* showed low water content (5.53±0.31) g/100g DM, a fairly high dry matter content (94.47±0.31) g/100g DM, carbohydrates (50.12 ± 0.01) g/100g DM , lipids (37.49±0.11) g/100g DM and proteins (14.92±0.10) g/100g DM (Table 1) and explains why these leaves are so appreciated by Burkinabè consumers [18] . The estimated energy value of the leaves of *Tamarindus indica L.* prospected from their proximal composition is 597.57 g/100 Kcal. Compared to other leaves commonly used as vegetables or in salads, the protein content of the dry leaves of *Tamarindus indica* L. is higher than those of *Solanum macrocarpon leaves* (0.3759 g/100g of DM reported by [19] in 2021 and those of most leafy vegetables such as *Momordica balsamina* (11.29%) considered as important sources of protein [20]. The lipid content obtained in the present study (37.49±0.11g/100g of DM) is significantly higher than that indicated by [18], in 2010 (3.90 g/100g of DM). On the other hand, those in dry matter (94.47±0.31), protein (14.92±0.10) and ash are corroborated by the work of [18] reporting that 100g of fresh leaves of *Tamarindus indica L.* contained 96.10g of dry matter, 14.00g of protein and 5.50g of ash. These results show that the leaves of *Tamarindus indica L.* are a vegetable source of total minerals, lipids and proteins. Moderate consumption *Tamarindus indica* leaves *L.* as vegetables would contribute to improving the recommended daily protein intake which varies from 13.5g to 15.5g [21].

3.1.3. Proximal petiole composition

The proximal composition obtained in this study from the petioles of *Tamarindus indica L.* shows that this plant constitutes a source of organic matter. The petioles of *Tamarindus indica* contain a low water content (4.67±0.36) g against (95.33±0.36) g of dry matter per 100 g of samples of which (4.22±0.52) g of ash, (38.12 ± 0.20) g of carbohydrates, (31.48 ± 0.11) g of lipids and (10.24 ± 0.52) g of proteins per 100g of dry matter. The estimated calorific energy for 100g of petioles is 476.76 Kcal.

Table 1 reveals low water contents for the various organs surveyed, 4.64g to 9.89g per 100g of dry matter (DM). The highest content was observed for roasted almonds (9.89±0.18) g/100g DM while the petioles are the least rich in water (4.67±0.36) g/100g DM. The ash contents of the three prospected organs (Table 2) varied significantly from (3.68±1.64) g/100g of DM for roasted almonds to (5.37±0.09) g/100g of DM for leaves. These variations observed in water and the type of organs considered or the treatment methods to which they were subjected could explain ash for the various organs. However, this low water content obtained in this study for the three organs of *Tamarindus indica L.* prospected indicates that the leaves or petioles and roasted kernels of *Tamarindus indica* are not susceptible to microbial attack during storage and are not highly perishable. The ash contents of the three surveyed organs reflect their richness in mineral salts. A more in-depth study is therefore necessary to determine the types of mineral elements and their contents because they are essential for the proper functioning of tissues and are necessary for daily needs. Knowledge of the mineral composition of these organs of *Tamarindus indica L.* is essential for their efficient use. In protein, the highest content was noted for roasted almonds of *Tamarindus indica L.* (22.08±0.10) g/100g of DM whereas the lowest is recorded at the level of the leaves of the tree (14.92±0.10) g/100g of DM. These results show a significant difference at the 5% threshold between leaves and roasted almonds that could be due to organ types or environmental conditions. They are considered a good source of protein because their protein content contributes more than 12% of the calorific value of these organs [22]. The values of the lipid content of the different organs (Table 2) vary significantly between the roasted almonds and the aerial organs (leaves and petioles) surveyed. They oxidize between (12.48±2.45) g and (37.49±0.11) g per 100g of DM. The highest lipid content was recorded for the leaves while the roasted almonds showed the lowest lipid content. One of the nutritional interests presented by the consumption of roasted almonds and dry leaves (depetiolated or not) of *Tamarindus indica L.* would therefore contribute to the daily lipid requirements [22] and improve the health of human beings. For the organs of *Tamarindus indica L.* studied in the present study, carbohydrates are more abundant in the dry depetiolated leaves (50.12 g) than in the roasted almonds (45.25 g) and the petioles (38.12 g). These values are much lower than the carbohydrate content reported (78.74 g) in 2018 by [23] for the flour from the fruits of *Artocarpus altilis* from Benin. This suggests that dry depetiolated leaves, roasted almonds and leaf stalks of *Tamarindus indica L.* are on their own poor sources of carbohydrates compared to other food sources like vegetables. The energy values of the three prospected organs of *Tamarindus indica L.* vary from 381.64 to 597.57 Kcal per 100g of dry matter. The leaves are more energizing than the petioles while the roasted almonds are the least energizing organs of *Tamarindus indica L.* These three organs are low in energy organs and can therefore be used in dietary diets.

Table 1. Proximal composition for 100g of dry organs of Tamarindus indica L.

Organs	*RA*	*DPL*	*DP*
Water (g)	9.89 ± 0.18	5.53 ± 0.31	4.67 ± 0.36
Dry matter (g)	90.11 ± 0.18	94.47 ± 0.31	95.33 ± 0.36
Ashes (g)	3.68 ± 1.64	5.37 ± 0.09	4.22 ± 0.52
Lipids (g)	12.48±2.45	37.49 ± 0.11	31.48 ± 0.11
Protein (g)	22.08 ± 0.10	14.92 ± 0.10	10.24± 0.10
Sugars (g)	45.25 ± 0.11	50.12±0.01	38.12 ± 0.20
Calorific energy (Kcal)	381.64 ± 0.015	597.57 ± 0.00	476.76 ±0.00

Legend: RA = Roasted Almonds; DPL = Dry Depetiolate Leaves; DP= Dry Petioles

3.2. Mineral composition of dry depetiolated leaves and roasted kernels of *Tamarindus indica L.*

Minerals are essential substances for a wide range of vital processes, from the formation of bones and teeth to the proper functioning of the heart and digestive system. Table 2 presents the composition in essential minerals of the dry depetiolated leaves and that of the roasted almonds of *Tamarindus indica L.* from Benin. It reveals a significant difference in the richness in micronutrients of these two organs of *Tamarindus indica L.* from Benin. Dry depetiolated leaves are richer in minerals than roasted seed kernels. Calcium represents the mineral most abundantly present in the leaves (1346.71 ± 0.31) mg/100g of DM whereas in the almonds, it is potassium (1010.04 ± 0.34) mg/100g of MS which presented the highest content. The main minerals present in roasted almonds are calcium, magnesium and sodium. The phosphorus and potassium contents of roasted almonds are very low (Table 2).

The calcium content presented by the dry depetiolated leaves is (1346.71 ± 0.31) mg/100g of DM against (100.24 ± 2.45) mg/100g of DM for the roasted seed kernels. They are therefore sources of calcium. These levels obtained for roasted almonds, although higher than those reported in 2018 in Nigeria (31.0 ± 0.02 mg/100g) by [24], are in the same wake as those notified in India in 2020 (109, 25 ± 0.11 mg/100g of DM) and 2021 (145.2 mg/100g of DM) respectively by [14] and [25]. Compared to some leafy vegetables commonly consumed in households, the leaves of *Tamarindus indica L.* prospected in this study are richer in calcium than those of *Solanum macrocarpon* (157.10 mg/100g DM) and *Moringa oleifera* (1.27 ± 0.04 mg/100g DM) respectively reported by [19] in 2021 then [26] in 2004. The consumption of 100g of dry leaves can help to meet the nutritional need for calcium recommended by the World Health Organization (WHO), which varies from 800 mg to 1300 mg per day depending on age [27]. The integration of roasted almonds and/or *Tamarindus indica* leaves *L.* in food rations would be very beneficial for humans because it would strengthen the human skeleton, bones and teeth significantly reduce the frequency of cramps, back pain, various rheumatisms, bone fractures, muscle weakness, forgetfulness and confusion in the subjects. In fact, calcium is the most abundant mineral in the body. It contributes to the constitution of bones and teeth as well as to the maintenance of their health and ensures the rigidity and hardness of the skeleton and teeth. It is mainly stored in the bones, of which it is an integral part. 99% of calcium is found in the bones in the form of calcium phosphate. The small remaining fraction (1%) is present in the body in free ionized form, in the blood and in the intra and extracellular spaces. In this form, it is involved in many body functions such as blood coagulation and muscle contraction including the heart, transmission of nerve impulses, permeability of cell membranes, release of certain hormones, activation of enzymes, maintenance blood pressure, etc. [28]. Known for its action against osteoporosis and bone demineralization (osteomalacia), calcium could also lower blood pressure and prevent colon cancer. It would thus limit the risk of intestinal and prostate cancer. A calcium-rich diet has been shown to be as effective as some medications in lowering blood pressure [29]. The Recommended Dietary Intake (ANC) in calcium being 900 mg per day for adults. The leaves and roasted almonds of *Tamarindus indica L.* are integral calcium providers in solid foods such as dairy products. This contribution is therefore not to be neglected in our diet [30]., especially that of children who have difficulty consuming enough dairy products, as well as in the elderly and pregnant and breastfeeding women However, these high levels of calcium in the leaves and roasted kernels of *Tamarindus indica L.* are not sufficient (less than 2500 mg per day) to inhibit the assimilation of zinc, magnesium and especially iron by the body. Indeed, a very high calcium intake not only prevents the body from properly assimilating the aforementioned minerals but can also cause kidney stones in certain predisposed subjects [29].

The phosphorus content is (701.50 ± 0.21) mg/100g DM for the depetiolated dry leaves and (750.0 ± 0.5) mg/100g DM for the roasted kernels of *Tamarindus indica* L. Compared to other leaves commonly used as vegetables, the dry depetiolated leaves of *Tamarindus indica L.* are much richer in phosphorus than those of *Vernonia amygdalina* (0.873g/100g), *Solanum macrocarpon* (0.032mg/100g), *Moringa oleifera* (0.36±0.00 g/100g) reported respectively by [19] and [26]. Also, these values obtained are higher than the satisfactory intake of phosphorus which varies from 100 to 440 mg/day for infants and children (6 months to 10 years), men and women (breastfeeding and pregnant) d at least 18 years and adolescents (640 mg / day). The leaves are therefore a plant source of phosphorus and their consumption can help strengthen bones and teeth in breastfeeding women and especially in children. Indeed, phosphorus is an azonide associated to 85% with calcium. It is an essential component of all cells. It plays an important role in the activation of many enzymes and in the metabolism of basic molecules such as carbohydrates, nucleic acids, adenosine triphosphate (ATP) and membrane phospholipids [31].

The magnesium content of the organs of *Tamarindus indica L.* prospected in the present study varies significantly from (22.08 ± 0.10 mg/100g of DM) to (157.17 ± 0.10 mg/100g of DM) respectively for the roasted almonds and the dry depetiolated leaves of the species. The values found at the end of the present investigations are higher than those reported in Nigeria (13.2 mg/100g) by [24] but lower than the results obtained in India (247.57 mg/100g) by [14] on roasted almonds from *Tamarindus indica L.* In a previous report, [32] reported that 100g of almond flour treated with *Tamarindus indica L.* contain 2.95 to 3.56 mg of magnesium. Roasted almonds and the leaves of *Tamarindus indica L.* are therefore sources of magnesium. The consumption of 100g of roasted almonds is sufficient to meet the daily nutritional needs of adult women and men, which vary between 220 and 260 mg/day [33]. The nutritional value of eating roasted almonds and *Tamarindus indica* leaves *L.* lies in the fact that magnesium participates in bone development, the construction of proteins, the actions of enzymes, muscle contractions including the heart, healthy teeth, the proper functioning of the immune system and ionic balance cells. It is also important in the formation of the body's main energy compound (ATP = Adenosine TriPhosphate) and in the transmission of nerve impulses [34].

Potassium contents obtained after investigation of *Tamarindus indica leaves and roasted almonds L.* varied significantly depending on the type of organ considered. For one hundred grams of samples, the dry depetiolated leaves presented (359.54 ± 0.07) mg of potassium against (1010 ± 0.34) mg/100g of DM for the roasted almonds. This content is lower than 1440 mg reported in 2014 by [12] for whom the potassium content of roasted almonds was the highest of all minerals. The roasting temperature and duration could justify this significant difference. A high content of potassium in the leaves of *Tamarindus indica L.* is of nutritional importance in that potassium promotes high iron assimilation and is beneficial for the control of high blood pressure and the decongestion of iron retention water in human tissues [35]. It is a determining factor in the metabolism of energy and in the transmission of nerve impulses. Potassium (K) also participates in the ionic balance of cells and prevents bone demineralization, thus preventing the loss of calcium in the urine [29]. The consumption of the leaves of *Tamarindus indica L.* would contribute to covering the recommended daily requirement in potassium, which varies according to the subject. Indeed, the WHO recommends per day (400 - 750) mg for infants (0 to 6 months), (800 - 1800) mg for children (1 - 10 years), 3500 mg for adolescents (15 - 17 years), adults and pregnant women, 4000 mg for breastfeeding women. Depetiolated dry leaves and roasted almonds of *Tamarindus indica L.* can therefore be recommended for subjects with a history of or victims of arterial hypertension, children, women and the elderly.

Sodium is one of the major constituent minerals of the prospected organs of *Tamarindus indica L.*. The dry depetiolated leaves are richer in it than the roasted almonds are respectively (13.02 ± 0.18) mg and (20.06 ± 0 .11) mg/100g of DM. The sodium contents obtained in this study are three times higher than those reported in Nigeria for roasted almonds (3.8 ± 0.05 mg/100g of DM) by [23]. However, they are lower than the sodium content of boiled, roasted or autoclaved almonds reported by [32] and which vary from 73.35 to 122.26 mg/100 g. The sodium content of *Tamarindus indica organs L.* is nutritionally significant since sodium is required for the regulation of acid-base balance, osmotic pressure, and membrane exchange and transport reactions in the body [29]. As a macro-mineral, the WHO recommended daily sodium intake is 500 mg for adults and 400 mg for children. The results indicate that the sodium content of roasted almonds and dry depetiolated leaves are much lower than those recommended by the WHO.

In the present study, iron was the most abundant mineral among the trace elements of roasted almonds and dry depetiolated leaves of Tamarindus indica L. The iron contents obtained are (16.77 ± 0.25) mg/100g of DM for the roasted almonds and (62.71 ± 0.18) mg/100g DM for the leaves. These results show that the leaves are four times richer in iron than roasted almonds. These values obtained for roasted almonds are lower than those found in Nigeria in 2007 are (102.40 ± 0.1) mg then in 2016 (2.33 ± 1.09 mg) respectively by [24] and [36]. Nevertheless, they are higher than those reported in 2014 (15.28 ± 0.01 mg) by [12] and in 2020 (11.37 ± 0.01 mg) by [14] for roasted seed kernels of the same species. This indicates that roasted almonds and dry depetiolated leaves of Tamarindus indica L. could be a good source of iron since the daily requirement is around 9 mg for men and postmenopausal women and 16 mg for older women, young due to menstruation and pregnancy [29]. Indeed, iron plays an essential role in metabolic functions. Essential element of hemoglobin and myoglobin, it ensures the transport of oxygen in the blood and thus allows respiration and cellular energy metabolism. It is involved in the storage of oxygen within muscle cells and participates in the proper functioning of a large number of enzymes and the immune system. The consumption of 100g of roasted almonds or 25g of the leaves of Tamarindus indica L. could alleviate problems related to iron deficiency such as fatigue, shortness of breath with less effort, pallor, heart palpitations, lower resistance to infections in the subjects. They can also be the cause of concentration difficulties in adults, poor school results in learners. In pregnant women, iron deficiency can cause anemia with increased risk of bleeding and bacterial infection during childbirth and even maternal death and developmental delay in babies [29].

Manganese plays an essential role in the production of energy by each cell. Mineral analysis revealed that the dry petiolate leaves (7.09 ± 0.18) mg are richer in manganese than roasted almonds (1.71 ± 0.09) mg. As a result, they constitute a source of manganese for women and for men. The integration of the leaves and roasted almonds of *Tamarindus indica L.* into diets would be beneficial for the good health of the organism. Indeed, manganese is a trace element that is essential for the synthesis of bones and amino acids, for the proper functioning of the thyroid gland and the immune system. It also participates in the prevention of damage caused by free radicals. It acts as a cofactor for several enzymes that facilitate a dozen different metabolic processes, is used to relieve inflammation, and sprains [37]. Manganese deficiency can lead to fertility problems, diabetes problems and joint pain. Despite its essential character, the accumulation of manganese in the blood is toxic to the central nervous system [38]. The WHO recommended daily value for manganese is -11 mg for adults but higher than the 2-6 mg per day recommended for children [39].

Copper is one of the constituents of many proteins and enzymes in the human body. It is essential for many vital processes and allows the proper use of lipids. Its insufficiency could increase the risk of cardiovascular disease and cause fatigue, fragility and discoloration of the hair, but also hypertension, anemia, bone malformations and sterility [29]. The average copper content is respectively (5.43 ± 0.03) mg and (11.54 ± 0.25) mg/100g of DM. The prospected leaves are two times richer in copper than the roasted almonds explored in this study. The values obtained for a portion of 100g of leaves and roasted kernels of Tamarindus indica L. are higher than the recommended value for copper, which varies from 1.5 mg/day to 3 mg/day depending on the age and sex of the subject. These two organs can be considered a good source of dietary copper.

The average zinc content of the roasted almonds of *Tamarindus indica L.* is (2.12 ± 0.01) mg/100 g of DM whereas those of the dry depetiolated leaves are about four times higher (7.89 ± 0. 17) mg/100g DM. These values obtained are higher than those reported (0.50± 0.01) mg/100 g of DM by [36] on seeds of *Tamarindus indica L.* from Nigeria. However, the consumption of 100g of roasted kernels of *Tamarindus indica* L. would cover about 20% of the daily intake recommended by the WHO, which is 10 mg for women and 12 mg for men, while for the same portion, the leaves would provide more than half of the needs of women and those of men, respectively 78.9% and 65.75% . The dry depetiolated leaves and roasted almonds of *Tamarindus indica L.* therefore prove to be excellent sources of zinc. Indeed, zinc is intimately involved in many mechanisms of the body. Activator of enzymes responsible for the constitution of genetic material, it plays a crucial role in cell synthesis and immune processes. Zinc also has antioxidant activity and is involved in sexual maturation, reproduction and fertility, taste and smell. It alleviates certain digestive disorders, skin problems (skin lesions by burns, wounds, acne, etc.) and ensures the good condition of the hair [29]. Therefore, the incorporation of the leaves and roasted almonds of *Tamarindus indica L* in diets could help the body protect itself from many ailments and aggressions. Zinc deficiency can cause loss of appetite, stunted growth, weakened immune function, increased risk of infections. It is also a determining factor in the deaths of children caused by diarrhoea.

Table 2 presents the Na/K and Ca/P ratios obtained from the mineral composition of the dry depetiolated leaves and almonds of the roasted seeds of *Tamarindus indica L.* these reports account for the hypotensive property and the assimilation of the calcium present in this food. Dry petiolate leaves and roasted almonds Tamarindus *indica L.* showed a Na/K ratio of less than 1 respectively $5.6.10^{-5}$ and 0.01. The Ca/P ratio obtained in this study was 0.13 for roasted almonds and 0.002 for dry depetiolated leaves (Table 2).

The sodium/potassium (Na/K) ratio in the body is important for proper cardiac pressure balance. Thus, the values of the ratio (Na/K) obtained for the dry depetiolated leaves and for the roasted almonds of *Tamarindus indica L.* s have less than 1. Therefore, these two organs could be helpful in lowering blood pressure. However, the hypotensive function of the leaves is more enhanced than that of roasted almonds.

Furthermore, the concept of the Ca/P ratio was introduced in 1988 and takes into account the fact that modern diets, rich in animal protein and phosphorus, promote the loss of calcium in the urine [24] . For a low Ca/P ratio, a large amount of calcium can be released in the urine thereby causing a decrease in the calcium content of the body. On the other hand, when it is greater than 2, the absorption of calcium in the small intestine increases [40]. A food source is considered good if the Ca/P ratio is greater than 1 and poor when it is less than 0.5 reported in [24]. Therefore, the leaves (Ca/P ratio = 0.002) and roasted almonds (Ca/P ratio = 0.13) of *Tamarindus indica L.* are not good dietary sources of minerals involved in bone formation. However, the calcium present in roasted almonds is more assimilable than that present in the dry depetiolated leaves of *Tamarindus indica. I.*

Table 2. Mineral composition for 100g of roasted almonds and dry depetiolated leaves of Tamarindus indica I.

Organs	*AT*	*FSD*
P (mg)	0.75 ± 0.50	701.50 ± 0.21
K (mg)	1010±0.34	359.54 ± 0.07
Na (mg)	13.02 ± 0.18	20.06 ± 0.11
Mg (mg)	22.08 ± 0.10	157.17 ± 0.10
Ca (mg)	100.24 ± 2.45	1346.71 ± 0.31
Mn (mg)	1.71 ± 0.09	7.09 ± 0.18
Fe (mg)	16.77 ± 0.25	62.71 ± 0.18
Cu (mg)	5.43 ± 0.03	11.54 ± 0.25
Zn (mg)	2.12 ± 0.01	7.89 ± 0.17
Na/K	0.01	$5.6.10^{-5}$
Ca/P	0.13	0.002

Legend: AT = roasted almonds; FSD = Depetiolate Dry Leaves

4. Conclusion

The results obtained in this study show that the roasted leaves and kernels of Tamarindus indica L. from Benin have a good nutritional profile with high contents of ash, protein, calcium, potassium, magnesium, phosphorus, iron, zinc, copper and manganese. . They can be used as a source of protein and essential minerals to relieve protein malnutrition and the "hidden hunger" prevalent in many developing countries. The flour of the roasted almonds and/or that of the leaves can be incorporated into formulations of food, cosmetic or therapeutic products for humans. However, an in-depth study of their antinutrient components and methods of reducing their possible actions is necessary to account for the availability of nutrients in the foods studied. Due to its very interesting profile in chemical compounds beneficial to human health, Tamarindus indica L. could play an important role in human nutrition. It can therefore be promoted to rural populations.

References

[1] Vitoekpon, I., Fandohan, AB, Ayimasse, AF, & Adekanmbi, DI (2021). Germination and growth performance of three provenances of tamarind (*Tamarindus indica L.*) in the Guinea-Congolese region. *Moroccan Review of Agronomic and Veterinary Sciences, 9* (4), 770 -779.

[2] Favet R., Frikart MJ & Potin J. (2011). Wealth and potential of agro-resources in developing countries: Valorization of tamarind. Montpellier SupAgro - Institute of Hot Regions, 28p.

[3] Mehdi, MA, Alarabi, FY, Farooqui, M. & Pradhan, V. (2019). Phytochemical screening and antiamebic studies of *Tamarindus indica* of leaves extract. *Asian Journal of Pharmaceutical and Clinical Research*, 507-512.

[4] Borquaye, LS, Doetse, MS, Baah, SO & Mensah, JA (2020). Anti-inflammatory and anti-oxidant activities of ethanolic extracts of *Tamarindus indica* L. (Fabaceae). *Cogent Chemistry*, *6* (1), 1743403.

[5] Krishna, RN, Anitha, R. & Ezhilarasan, D. (2020). Aqueous extract of *Tamarindus indica* fruit pulp exhibits antihyperglycaemic activity. *Avicenna Journal of Phytomedicine* ; 10 (5): 440.

[6] Havinga, RM, Hartl, A., Putscher, J., Prehsler, S., Buchmann, C. & Vogl, CR. (2010). T *amarindus indica L.* (Fabaceae: Patterns of use in traditional African medicine. *Journal of Ethnopharmacology* ;16.

[7] Van der Stege Christine (2010). The ethnobotany of baobab (*Adansonia digitata L.*) and tamarind (*Tamarindus indica L.)* in West Africa: Their importance in rural subsistence and potential for participatory domestication to guarantee future access for the rural poor; Doctoral Thesis; University of Natural Resources and Life Sciences, Vienna, 369 p.

[8] Official methods of analysis, Association of Official Analytical Chemists (AOAC), 15th Edition, Washington DC, Washington, (2000).

[9] ISO 5983 (2005). Animal feeding stuffs - Determination of nitrogen content and calculation of crude protein content - Part 1 Kjeldahl method Switzerland: ISO.

[10] Dubois M, Gilles DA, Hamilton JK, Rebers PA & Smith F. (1956) .Colorimetric methods for determination of sugar and related substances. Anal. Chem; 28 (3):350-356.

[11] Kanninkpo, C. (2014). Apparatus and procedure for the determination of metals by Atomic Absorption Spectrophotometry. *Laboratory of Soil, Water and Environmental Sciences (LSSEE/CRA Agonkanmey/INRAB)*; Synthesis of working documents, version updated in June 2014.

[12] Akajiaku, LO, Nwosu, JN, Onuegbu, NC, Njoku, NE & Egbeneke, CO (2014). Proximate, mineral and anti-nutrient composition of processed (Soaked and Roasted) tamarind (*Tamarindus indica*) Seed nut. Curr. Res. Nutr. Food Science; 2: 136–145.

[13] Bashir, AY, Abdullahi, SA, Suleiman B. (2016). Effect of roasting on the proximate, mineral and anti-nutrient composition of *Tamarindus indica* seed nuts. *Fuw Trends in Science & Technology Journal*; 1 (2): 493–496.

[14] Gitanjali, Vishakha S. & Shashi J. (2020). Nutritional Properties of Tamarind (*Tamarindus indica)* Kernel Flour. *Int.J.Curr.Microbiol.App.Sci;* 9 (05): 1359-1364.

[15] Mahajani, K. (2020). Physicochemical, functional properties and proximate composition of tamarind seed. *Journal of AgriSearch*; 7 (1): 51-53.

[16] Kumar, CS & Bhattacharya S. (2008) Tamarind Seed: Properties, Processing and Utilization. *Critical Reviews in Food Science and Nutrition*; 48:1–20.

[17] Nwosu, JN (2013). Production and Evaluation of Biscuits from Blends of Bambara Groundnut (Vigna Subterrane) and Wheat (Triticum eastrum) Flours. International Journal of Food and Nutrition Science; 2 (1): 4-9.

[18] De Caluwé, E., Van Damme, P., Halamová, K. (2010). *Tamarindus indica L.*: A review of traditional uses, phytochemistry and pharmacology. *AfricaFocus*; 23 (1): 53-83.

[19] Koudoro, YA, Agbangnan, DCP, Bogninou, GSR, Gbagan, S., Kanfon, R., Avlessi, F., Sohounhloue, CKD Phytochemical and nutritional analyzes of *Solanum macrocarpon* leaves harvested in Benin. *International Journal of Green and Herbal Chemistry*; 11(1): 046-054.

[20] Asaolu, SS, Adefemi, OS, Oyakilome IG, Ajibulu, KE, Asaolu, MF (2012). Proximate and Mineral Composition of Nigerian Leafy Vegetables. J. Food Res; 1(3): 214

[21] Food Agriculture Organization FAO. (2003). Tropical fruits – their nutritional values, their biodiversity and their contribution to health and nutrition (Third session) CCP:BA /TF 03/15, Puerto de la Cruz (Spain), 11-15 December.

[22] Antia, BS, Akpan, EJ, Okon, PA & Umoren, IU (2006). Nutritive and anti-nutritive evaluation of sweet potatoes (Ipomoea batatas) leaves. Pakistan Journal of Nutrition.

[23] Agbangnan, DCP, Bothon, FTD, Kanfon, RE, Medoatinsa, SE, Bahou, G., Wotto VD & Sohounhloue, DCK (2018). Nutritional Quality, Phenolic Compound Content and Radical Scavenging

Potential of Artocarpus altilis of Benin. American Journal of Food Science and Technology; 6 (4):195-198.

[24] Yusuf, AA, Mofio, BM, Ahmed, AB (2007). Proximate and mineral composition of *Tamarindus indica Linn* seeds. *Science World Journal*; 2 (1): 1-4.

[25] Hemalatha, C. & Parameshwari S. 2021. The scope of tamarind (*Tamarindus indica L.*) kernel powder in diverse spheres: A review. Materials Today: Proceedings, 45: 8144–8148.

[26] Tchiégang, C. & Kitikil A. (2004). Ethnonutritional data and physico-chemical characteristics of leafy vegetables consumed in the Adamaoua savannah (Cameroon). *Tropicultura*; 22 (1): 11-18

[27] FAO/WHO. (1989). Codex Alimentarius Commission. Report of the sixteenth session of the codex committee of the nutrition and foods for special dietary uses Bonn-Bad Godesberg, Federal Republic of Germany, 29 september- 7 october.

[28] Depezay L. (2007). Vegetables in the diet: their nutritional effects, Louis Bonduelle Foundation, 7p.

[29] Pacaud, G., Cheneut, G., Charliat, D., Glachant E., Wattel, S., Thomas, D. (2002). Guide to vitamins and minerals for good health. Selection from Reader's Digest, Canada. 398p.

[30] Ahodegnon, DK., Gnansounou, M., Bogninou, RG., Kanfon, ER., Chabi, B., Dossa, PCA., Anago, EA., Ahoussi, E., Wotto, V. & Sohounhloue, DC. (2018). Biochemical profile and antioxidant activity of Parkia biglobosa and *Tamarindus indica* fruits acclimated in Benin. *International journal of advanced research*; *6*(11), 702 -711.

[31] Paul, SH, Usman AA, Gana IN, Manase A., Adeniyi OD & Olutoye MA (2018). Comparative study of mineral and nutritional composition of a multifunctional flora composite formulated from seven medicinal plants and their applications to human health. *Engineering Technology Journal*, 1(5**)**: 001-0014

[32] Uzodinma, EO, Osagiede, EG, Chikwendu, JN (2020). Effect of different processing methods on chemical and pasting properties of tamarind (*Tamarindus indica L.*) seed flours. *Journal of Tropical Agriculture, Food, Environment and Extension*; 19 (1): 1 – 10.

[33] FAO (2004). Handbook on Human Nutrition Requirements: FAO Food and Nutrition Vitamin and Mineral Requirements: Second edition. www.fao.orgAccessed on 07-12-2019.

[34] Ajayi, IA, Oderinde, RA, Kajogbola, DO & Uponi JI (2006). Oil content and fatty acid composition of some underutilized vegetables from Nigeria. *Food Chemistry,* 99, 115-120

[35] Nair, AG, Pradeesh S., Devi, CM, Mini, I., Swapna, TS (2013). Diplazium esculentus: A Wild Nutrient-Rich Leafy Vegetable form western Ghats. Prospects in Bioscience; 1:293–301.

[36] Sadiq, IS, Duruminiya, NI, Balogun, JB, kwada, D., Izuagie, T., 2016. Nutritional and Anti-nutritional Value of Tamarind Fruit (*Tamarindus indica*). Int. J.Appl. Res. Technology. 5, 50–56.

[37] Erickson, KM, Syversen, T., Aschner, JL, Aschner, M. (2005). Interactions between excessive manganese exposures and dietary iron-deficiency in neurodegeneration. About Toxicol Pharmacol; 19:415–421.

[38] Sidoryk-Wegrzynowicz, M. & Aschner, M. (2013). Manganese toxicity in the central nervous system: the glutamine/glutamate-γ-aminobutyric acid cycle. Journal of internal medicine; 273 (5): 466–477.

[39] Baquer, NZ, Sinclair, M. & Kunjara, S. (2003). Regulation of glucose utilization and lipogenesis in adipose tissue of diabetic and fat fed animals: Effects of insulin and manganese. *J. Biosci* ; 28 (2): 215–221.

[40] Alinor, IJ & Oze, R. (2011). Chemical evaluation of the nutritive value of *Pentaclethra macrophyllabenth* (African Oil Bean) seeds. Pakistan Journal of Nutrition; 10(4): 355 – 359.