ETHNOBOTANICAL AND NUTRITIONAL VALUE OF PULPS, LEAVES, SEEDS AND KERNELS OF *Tamarindus indica L.*: A REVIEW

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ABSTRACT

Tamarindus indica L., a widely distributed tropical plant, is highly valued as a cash crop in Asia but remains underutilized in Africa. This review aims to present the current scientific knowledge on the nutritional value of *Tamarindus indica L*., specifically focusing on its pulp, leaves, seeds, and almonds. The data was collected by introducing the groups of keywords related to the species in the engines of research. The results collected vary according to the authors and show that several studies were interested in the pulp and the seeds of the species unlike the leaves. 100 grams of *Tamarindus indica L*. pulp contains on average 60.99 g of sugars; 4.05g of raw ash; 18.40g of tartaric acid and 6.12g of total fiber. *Tamarindus indica L*. seeds are a good source of protein (20.21g), potassium (217.04mg), calcium (45.33mg), magnesium (31.32mg) and iron (14.28mg). These organs have a balanced profile of α -amino acids and secondary metabolites. The average alkaloid, trypsin inhibitor, tannin and phytate contents of treated seeds were significantly reduced compared to whole seeds. This review offers five recommendations for future research efforts on the valorization of *Tamarindus indica L*. in Benin.

Key words: *Tamarindus indica L.*, nutrients, secondary metabolites, Benin.

RESUME

VALEUR ETHNOBOTANIQUE ET NUTRITIONNELLE DES PULPES, FEUILLES, GRAINES ET AMANDES DU Tamarindus indica L. : UNE REVUE

Tamarindus indica L*. est une plante tropicale très appréciée comme culture de rente en Asie mais sous-utilisée en Afrique. Cette revue présente les connaissances scientifiques actuelles sur les valeurs nutritionnelles de la pulpe, des feuilles, des graines et amandes de* Tamarindus indica L*. Les données ont été collectées par l'introduction des groupes de mots-clés liés à l'espèce dans les moteurs de recherche. Les résultats varient selon les auteurs et montrent que plusieurs études se sont intéressées à la pulpe et aux graines de l'espèce contrairement aux feuilles. 100 grammes de pulpe de* Tamarindus indica L. *renferment en moyenne 60,99 g de sucres ; 4,05g de cendre brute ; 18,40g d'acide tartrique et 6,12g de fibres totales. Les graines de* Tamarindus indica L. *constituent une bonne source de protéines (20,21g), de potassium (217.04 mg), de calcium (45.33 mg), de magnésium (31.32 mg) et de fer (14.28 mg). Ces organes présentent un profil équilibré d'acides* α *-aminés et en métabolites secondaires. Les teneurs moyennes en alcaloïdes, inhibiteurs de trypsine, tanins et phytates des graines traitées ont été significativement réduites par rapport à celles des graines entières. Cette revue propose cinq recommandations pour les futurs efforts de recherche sur la valorisation de* Tamarindus indica L*. au Bénin.*

Mots clés : Tamarindus indica L.*, nutriments, métabolites secondaires, Bénin*

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INTRODUCTION

In developing countries, the livelihoods of millions of households heavily rely on non-timber forest products (NTFPs) to meet their basic needs (Azokpota, 2012). One such example is *Tamarindus indica L.*, an underutilized agroforestry species (Fandohan *et al.,* 2015), commonly known as "Pirbè" among the Yom community in northern Benin. This species belongs to the Fabaceae family and is believed to have originated in Tropical Africa, Madagascar, and Asia. Today, it is widely distributed across tropical regions (Diallo *et al.,* 2010; Vitoekpon & Fandohan, 2021).. For its domestication potential and its local and economic values, it has been identified as one of the priority food plants to be promoted in some African countries including Benin (Akinnifesi *et al.*, 2008; Assogbadjo *et al.*, 2014). As a result, *Tamarindus indica L.* has been the subject of several scientific studies, some results of which have shown that its organs are sources of nutrients (Gitanjali *et al.*, 2020; Uzodinma *et al.,* 2020) but under-exploited (Vitoekpon & Fandohan,2021). Indeed, recent scientific research work has focused on nutritional and physicochemical properties (Ahodegnon *et al.,* 2018; Gitanjali *et al.,* 2020; Piba *et al.,* 2021), biological activities (Doughari, 2006; Mehdi *et al.,* 2019) of its organs. The literature reviews carried out by De Caluwé *et al.* (2010), Havinga *et al.* (2010), Saideswara & Mathew (2012), Vitoekpon & Fandohan (2021) and Samarou *et al.* (2022) on the species provided substantial information on the taxonomy of the species, its distribution, the usage of its organs and their nutritional and pharmacological properties in general and specifically the pulp which has been more investigated than the other organs. Tamarind is highly prized for its pulp rich in sugars (60.99g/100g DM) and organic acids (8.51g/100g DM) responsible for the sour and sweet taste characterizing the species, in potassium (318.56 mg), calcium (131.63100mg), phosphorus (70.40 mg/100g DM), iron (3.95 mg/100 g DM) and vitamins B1 (0.34 mg/100 g DM), B2 (0.13 mg/ 100 g DM), B3 (1.31 mg/100 g DM) and C (7.4 mg/100g DM) which make it an ideal food. The richness in protein (23.07 g/100 g DM) of the almonds of its fruits constitutes an affordable alternative source of vegetable proteins for humans and can contribute to the fight against protein-energy malnutrition, which is very widespread in many countries developing. Moreover, *Tamarindus indica L.* is also rich in bioactive compounds such as phenolics, alkaloids, saponins, steroids, terpenoids (Adeniyi *et al.*, 2017) highly beneficial to humans (Abukakar *et al.*, 2008; Santosh *et al.*, 2011). Its laxative, anti-infectious (Rana *et al*., 2018) and anti-inflammatory (Borquaye *et al*., 2020), antitumor, antioxidant and antidiabetic properties (De Caluwé *et al*., 2010; Piba *et al.*, 2021; Highab *et al*., 2022) have been widely discussed in the literature. Its leaves relieve hypercholesterolemia and high blood pressure. With its many nutritious assets, *Tamarindus indica L*. could therefore be valorized, thus constituting a means of fighting against hunger, poverty and malnutrition in developing countries. It is therefore important to collect information on its nutritional composition and that of its derived products for the adequate estimation of their nutritional contributions both at individual and collective level as well as in food security. In the Beninese context, these data remain limited; which makes it difficult to make any lavish claims about the optimal use of the tree as a source of nutrients. This study review the current body of scientific literature pertaining to the nutritional and functional aspects of *Tamarindus indica L.*. Its principal aim is to elucidate the prospects for research on *Tamarindus indica L.* within the realm of the food sector. By synthesizing and critically evaluating the existing knowledge, this study intends to contribute to the identification and evaluation of potential avenues for scientific inquiry and exploration, thus facilitating advancements in leveraging *Tamarindus indica L.* as a valuable resource in the food industry.

METHODOLOGY

STUDY SPECIES

With an extensive lateral root system, *Tamarindus indica L*. is a fruit plant (Photo 1.a) that can reach ten to thirty meters in height (Singh *et al.*, 2007). It is characterized by a wide crown of about twelve meters, short and thick trunks with cracked bark. Its leaves paripinnate and rounded at the base (Photo 1.b) are composed of ten to eighteen green leaflets. Its small yellow or pinkish flowers (Photo 1.b) mixed with red at the level of the petals produce hanging pods (Photo 1.c) five to eighteen centimeters long, more or less bumpy, thick, curved or velvety green color at the immature stage and brown or reddish-brown at maturity with a fibrous pulp (Photo 1.d) tangy, sweet, fragrant and thick surrounded by three rigid fibers, branched from the base to the apex and crossed by cavities that can contain four to twelve flattened, brown, shiny seeds of variable sizes (Photo 1.e).

Source: Kanfon, February 2020

Figure 1: Photos of the *Tamarindus indica* L. tree with its trunk (a), leaves and flowers (b), fruits (c), mature fruit pulp (d) and seeds (e).

Photos de l'arbre du Tamarindus indica *L. avec son tronc (a), ses feuilles et fleurs (b), ses fruits (c), sa pulpe de fruit mûre (d) et ses graines (e).*

COLLECTION OF DATA

A numerical approach was mainly used for data collection. To this end, "*Tamarindus indica L.*" and "tamarind tree" have been introduced alone or in combination with groups of words such as "nutrition", "derived products", "local knowledge", "nutritional value", "biological activities ", "ethnobotany", "physicochemical property" in Sciences Direct search engines (https://www.sciencedirect.com), Agora (http://www.fao.org/agora/fr/), Web of Science (https://www.webofscience.com), Scopus (https://www.scopus.com), Google scholar (https://www.cabi.org) and Google (https://sites.google.com). Some additional key words were also added : West Africa, Sahel, Benin. Zotero connections were created to receive updated *Tamarindus indica L.* related publications and bibliographie of available articles.

DOCUMENT SELECTION CRITERIA

The literature search was limited to the French and English languages only. The titles and abstracts of the documents collected were briefly analyzed and the full articles of the relevant documents were collected for in-depth reading. After analysis of the full text, the documents (articles, theses, reports) presenting secondary data (reported by other previous articles), duplicates or whose results were presented only in the form of graphs or ranges of values without figures specific and those relating to other species have been excluded. Of the two hundred and thirty-five (235) documents explored, only sixty-three (63) documents were used, including forty-six (46) scientific articles, six (06) theses, four (04) conference reports, three (03) books and two (02) dissertations (01 for engineers and 01 for a bachelor's degree).

DATA COMPILATION

Data on the uses, nutritional compositions, physicochemical properties and processing technologies of *Tamarindus indica L*. were extracted from the selected documents and entered into Excel exactly as they were presented in the original article. For each component, the reported values are, where possible, converted and recalculated in grams per hundred grams of dry matter (g/100 g DM) for the proximal composition, in milligrams per hundred grams of dry matter (mg/100 g DM) for minerals, vitamins, α-amino acids and antinutrients to allow comparisons between studies. Their mean, minimum and maximum values were determined and reported. Unconverted data is presented as originally reported.

RESULTS AND DISCUSSION

ANALYSIS OF COLLECTED METADATA

Table 1 presents the proportion of scientific publications exploited according to the region and reveals that research efforts on *Tamarindus indica L.* have been invested in Europe (14.06%), in Asia (20.31%) but especially in Africa (60.94%) with more than half of the documents analyzed. Also, it shows an increase in the number of scientific documents used and published between 2001 and 2021 with falls in 2008, 2013, 2014 and 2017 and a resurgence of 2020 publications in Africa. These results bear witness to the growing attention aroused by the species among Asian and African scientists, particularly in Nigeria (38.46%) and Benin (28.21%).

Of the sixty-three (63) scientific documents selected, analyzed and exploited for their relevance, fourteen (14) related to ethnobotany, twenty-two (22) to nutritional composition, twenty-five (25) to chemical composition and biological activities, thirteen (13) on foods derived from *Tamarindus indica L*. This observation shows the great interest accorded to the species by researchers, especially for its nutritional and functional virtues.

Table 1: Frequency of scientific publications analyzed by year, region, African country and field of study.

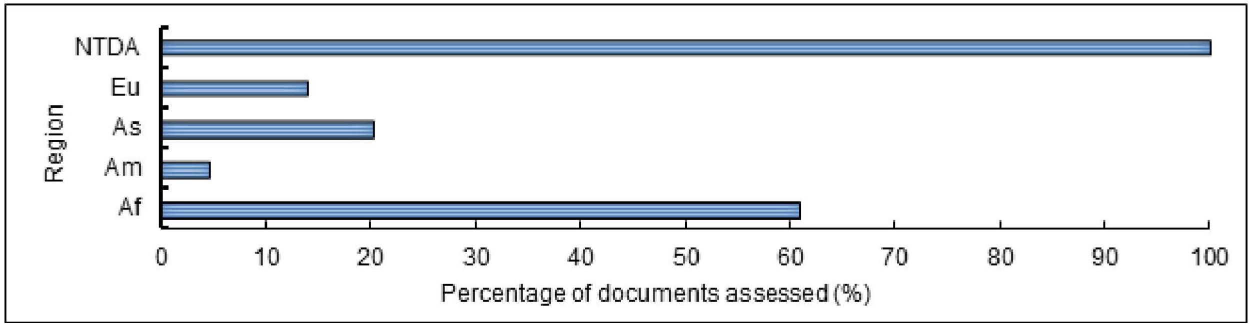
Fréquence de publications scientifiques analysées par année, région, pays africain et domaine d'étude.

	Frequency of exploited documents publiished by year and by continent in percentage (%)																		Total
year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Africa	1.59	0.00	0.00	4.76	3.17	6.35	4.76	1.59	3.17	1.59	1.59	6.35	4.76	1.59	4.76	3.17	6.35	4.76	60.32
America	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	0.00	0.00	1.59	0.00	0.00	0.00	1.B59	0.00	4.76
Asia	0.00	0.00	0.00	0.00	1.59	0.00	0.00	1.59	3.17	0.00	0.00	0.00	1.59	1.59	1.59	3.17	4.76	1.59	20.63
Europa	0.00	0.00	1.59	3.17	0.00	0.00	4.76	3.17	0.00	0.00	0.00	0.00	0.00	1.59	0.00	0.00	0.00	0.00	14.29
Total	1.59	0.00	1.59	7.94	4.76	6.35	9.52	6.35	6.35	3.17	1.59	6.35	7.94	4.76	6.35	6.35	12.70	6.350	100.00

	Frequency of exploited documents published in Africa between 2004 and 2021 in percentage (%)					
Country	Benign	Burkina Faso	Ivory Coast	Senegal	Sudan	Chad	Africa
Frequency %	28.95	5.26	2.63	2.63	2.63	2.63	100.00

	Frequency of documents published by areas investigated in percentage (%)				
Areas investigated	Ethnobotany	Nutritional composition	Chemical composition	Biological activities	Derived foods
Frequency (%)	17.95	32.05	28.2	5.13	16.67

Legend : NTDA = Total number of documents analyzed NTDA = Nombre total de documents analysés



Legend: NTDA = Total number of documents analyzed; Af = Africa; As = Asia; Am = America; Eu = Europe

Figure 2: Percentage of publications used by continents on *Tamarindus indica L.*

Pourcentage de publications utilisées par continents sur Tamarindus indica *L.*

APPELLATIONS OF TAMARINDUS INDICA

Formed from " tamar" and " hendi" which mean "palm date of India" (Ramalanjaona, 2013), *Tamarindus indica L.* is designated in french by "tamarinier" or "tamarindier" , in english by "Tamarind", " Sweet tamarind " or " Indian date " and by "tamarindo" in spanish. Several native names are attributed to it in Africa and Asia (Table 2).

Table 2: Different names of *Tamarindus indica L.*

Différentes appellations locales du Tamarindus indica *L.*

Regions	*Country*	*Groups Socio-linguistic*	*Local names*
Africa	Benin	Fulani	Djetami
		Fulani	Djabbe
		Fon	Jɛvivi, bokoso, mupɛn
		Bariba	Mɔsɔsɔ, Mɔkɔsɔ, Bomɔmɔmbo
		Dendi	Bobose
		Somba	Dipi, Mɔsɔsɔ
		Yoruba, Nagot	Ajagbɔn
		Waama	Pusika
	Cameroon	Massah	Chitna
		Kapsiki	Oumbla
	Ethiopia	Amharic	Humar, Homor, Tommar
		Hausa	Samia
	Ghana	Dagare, Kusasi	Mash potatoes
	Mali	Moshie (Moa)	Pusa
		Bambara	Budahar
		Mandinka	Tomi, Timbingo, Tombi
	Nigeria/ Niger	Hausa	Tsamiya
	Senegal	Wolof	Daharg, Dakah, Dakhar
		Djola	Budahar
	Sudan	Arab	Aradeib, Tamarihindi
Asia	China	Sino-Tibetan	Khaam, Mak kham
	India	Hindi	Ambli, Amli, Imli
		Bengali	Tintul, Tintiri, Tetul

Source: (Akoègninou *et al.,* 2006; Chimsah *et al.*, 2020; Fandohan, 2011; Van der Stege *et al.*, 2011)

FOOD USES OF *TAMARINDUS INDICA L.*

Pulp

Tamarindus indica L. is highly appreciated for its fibrous pulp which remains the most used part of the tree. It is therefore the main wealth of the tree and has been the subject of many traditional and industrial uses (Favet *et al.*, 2011). Hard and too sour to be eaten directly, the green pulp of immature fruits is used in the preparation of curries in Asia and certain sauces in Africa (Hemalatha & Parameshwari, 2021; Mansingh *et al.* ,2021) or eaten as an accompaniment to meat, game and fish. Sticky and acceptable, the ripe pulp is often used in culinary preparations such as jams, pickles, syrups, ice creams, sweets and various drinks in the form of infusions or nectar, porridge and local sauce tart (Favet *et al.*, 2011; Hemalatha & Parameshwari, 2021).

Leaves

The leaves of *Tamarindus indica L*. are also edible. Consumed as vegetables especially in times of famine, the leaves of *Tamarindus indica L.* are used in a variety of dishes such as soups, soups, salads, stews and "curries". The leaves are also a real vegetable component acidifying soups, sauces, porridges and cereal pasta. They are also used to acidify cereal pastes and sanitize them for three days (Chimsah *et al.*, 2020; Ebifa-Othieno *et al.*, 2020).

Seeds

The seeds of *Tamarindus indica L.* are unfit for consumption but become edible after removal of their integuments by soaking, cooking or roasting (De Caluwé *et al.* 2010). They constitute raw material for the preparation of jams, the manufacture of a carbohydrate and gelling pectin recommended as a stabilizer in ice cream, mayonnaise, cheese and ice cream (Favet *et al.*, 2011). Locally, they are used as a thickener for soup and the seed powder is often used for the preparation of cakes and bread (Sheikh & Shivanna, 2022). The oil extracted from the seeds seems to bear similarities to flaxseed oil, is edible and even of "culinary quality". In Nigeria, roasted seeds of *Tamarindus indica L*. are used instead of coffee (Rana *et al.*, 2018).

THERAPEUTIC USES OF *TAMARINDUS INDICA L.*

All parts of the tree are well known for their medicinal properties.

Pulp

Historically, the pulp of *Tamarindus indica L*. is also consumed for its therapeutic virtues. It is said to be laxative, digestive, febrifuge, anti-gastralgic, antiscorbutic and tenifuge (De Caluwé *et al*., 2010). It would also relieve fever, sore throat, bile disorders, blood sugar, rheumatism, alcohol poisoning, sunburn and other ailments such as malaria (Ouédraogo *et al.*, 2010; Abdelrahman & Mariod, 2019). More anecdotally, the pulp of *Tamarindus indica L.* would be a remedy against poisoning with Datura (poisonous plant of the Solanaceae family) or against the effects of cannabis (Asad *et al*.,2022). It is also used in massage (Fandohan, 2011). *Tamarindus indica L.* fruit juice, mixed with Calotropis latex gigantea is taken orally to relieve menstrual pain (Bourou, 2012).

Leaves

The leaves of *Tamarindus indica L*. are used in the treatment of diarrhea, sprains, inflammations, wounds, rheumatism, conjunctivitis, dysentery, jaundice and circulatory disorders. They are used as antibiotics or to fight heart disease and hypoglycemia. The leaves of *Tamarindus indica L.* soaked in water are applied as a poultice to relieve eye disorders. In Côte d'Ivoire, the concentrate of the leaf and root extract taken orally is used to treat trypanosomiasis (Diarrassouba, 2009; Komakech *et al.*, 2019).

Seeds

The seeds are used to deworm especially schistosomiasis. Powdered, they are used in the treatment of diarrhea and chronic dysentery (Bowe, 2010 in De Caluwé *et al.*, 2010; Hemalatha & Parameshwari, 2021).

OTHER USES OF THE PULP, LEAVES AND SEEDS OF *TAMARINDUS INDICA L.*

Tamarinds indica L. pulp mixed with salt can be used to fix dyes and to polish brass, copper or silver (Bowe, 2007 in Van der Stege C. *et al.,* 2011).

In cosmetics, tamarind pulp and seeds are used for their restorative and regenerating properties.

In breeding, the foliage has a high value as fodder, although rarely pruned for this purpose for lack of fruit yields (Bourou, 2012 in De Caluwé *et al.*, 2010).

The cooked seeds can also be used to feed animals (Bourou, 2012). Seed powder of *Tamarindus indica L*. is used as a textile hardener, binder in the plywood or paper industry and as a thickener and stabilizer in the food industry. The oil extracted from the seeds can be used in the manufacture of paint and varnish (Singh *et al.*, 2007).

Socio-economic value: tamarind fruits and leaves are also sold in local and regional markets (Bourou, 2012).

NUTRITIONAL AND FUNCTIONAL VALUE OF *Tamarindus indica L.*

Pulp of *Tamarindus indica L.*

Proximal composition

Table 3 presents the main major compounds of the pulp of *Tamarindus indica L.* and shows that for 100 grams (g) of dry matter (DM), the pulp would contain on average (23.79 ± 4.09) g of water with the lowest water content reported in 2018 in Benin (5.09 g) by Ahodègnon *et al.* (2018) then the highest water content was reported by Singh *et al.* (2007) in Asia (40.10g) . The highest contents of total sugars (82.72 g) and crude protein (10.3g) were respectively reported by Sadiq *et al.* (2016) for the pulp from the state of Sokoto in Nigeria while that in fat (17.02 g) was reported by Bourou (2012) . The average crude ash and total fiber contents reported in the literature were respectively (3.48 ± 1.18) g and (4.98 ± 1.47) g. At the 5% threshold, the macromolecule compositions of the pulp obtained in the sub-region and in Asia vary significantly according to the authors and therefore depend on the locality of the pulp studied (p-value < 0.05). These differences would be related to the intrinsic and extrinsic factors of the pulp. According to Favet *et al.* (2011) , the richness of the fruit pulp of *Tamarindus indica L.* in sugars and tartaric acid would be the consequence of the sweet and sour taste that characterizes it.

Minerals and vitamins

The data available and exploited on the mineral composition of the pulp of *Tamarindus indica L.* (Table 4) shows that it contains significant quantities of minerals which varied according to the study region and according to the authors (p-value < 0.05). For 100 grams, the dry pulp of *Tamarindus indica L.* contains on average (153.85 ± 61.15) mg of calcium, (44.91 ± 14.56) mg of sodium, (42.52 ± 11.42) mg of magnesium and (260.75 ± 71.01) mg of potassium (Table 4). The highest reported calcium content (675.38 mg) was reported by Ahodègnon *et al*. (2018) in Benin while that of potassium (790.11 mg), sodium (112.72mg), phosphorus (155 mg) and magnesium (79.34 mg) were reported by Almeida *et al.* (2009), Gali *et al*. (2016) in Adamawa State in Nigeria, Singh *et al*. (2007) and Makalao *et al*. (2016) in Chad. These authors reported iron (3.95 mg), copper (5.77 mg), manganese (6.78 mg) and zinc (1.42 mg) for very low nickel contents (0.24 mg) of the pulps examined. It is richer in potassium than in calcium, phosphorus and magnesium. Pulp of *Tamarindus indica L.* seemed to be richer in phosphorus (123-140 mg) and sodium (5 mg) than néré pulp according to the report by Ayosso (2015).

According to the values collected, the pulp of *Tamarindus indica L.* constitutes a source of water-soluble vitamins (De Caluwé *et al*., 2010; Favet *et al.*, 2011) . It contains an average of 0.34 mg of thiamine, 0.13 mg of riboflavin, 1.31 mg of niacin and 23.96 mg of vitamin C per 1 g of dry matter. The data on the vitamins of the pulp of *Tamarindus indica L.* reported by some authors showed a non-significant variation at the threshold of 5% (p- value > 0.05). The thiamine contents of the pulp reported in the exploited literature are in the same vein as those reported for baobab pulp and that of Blighia sapida respectively (00 - 0.6) mg/g DM and 0.13 mg/g DM reported by Ayosso (2015) while in niacin, the pulp of *Tamarindus indica L.* is richer than that of baobab (1.8 -2.7 mg/g DM) reported by the same author. However, the pulp of *Tamarindus indica L*. contains a high quantity of vitamin C greater than that of the pulp of Vitex donania sweet (6.42 mg/g of DM) reported by Makalao *et al.* (2016) and that of Parkia biglobosa (0.005-24.2 mg/g DM) obtained by Olujobi (2012) and cited in Ayosso (2015) but lower than that of baobab pulp (209 - 360 mg/g DM) and Blighia sapida (26 mg/g DM). Indeed, the importance of vitamin C lies among other things in its antioxidant power inhibiting the harmful effect of free radicals on DNA and the synthesis of carcinogenic compounds such as nitrosamines. In addition, vitamin C is a cofactor in oxygenation reactions (Amiot-Carlin *et al*., 2007) and is essential for iron absorption, tissue repair and blood vessel formation via collagen synthesis. (Makalao *et al.*, 2016). Several studies have reported its beneficial action in the treatment or prevention of rheumatism, type 2 diabetes (Akajiaku *et al.,* 2014; Amiot-Carlin *et al.,* 2007) and cardiovascular diseases (Depezay, 2007) .

Amino acids

Very few authors are interested in the amino acid composition of the pulp of *Tamarindus indica L.* Data collected are presented in table 6. It reveals that the proteins of this organ of the tree present a rather interesting composition in essential α-animated acids. For 100 g of dry pulp, the authors reported 17.13 g of tryptophan; 5.97 g leucine; 5.24 g of lysine and 5.03 g of arginine, 12 g of aspartic acid and 9.17 g of glutamic acid against 1.35 g of cysteine and 1.34 g of methionine.

Fatty acids

Only De Caluwé *et al*. (2010) and shows that the oil extracted from the pulp, greenish yellow in color and liquid at room temperature, contains up to sixteen fatty acids reported the fatty acid composition of the fruit pulp of *Tamarindus indica L.* molecular weight unlike Omega-3 and Omega-6 essential fatty acids (Table 7).

Secondary metabolites

African and Asian researchers have reported the presence of fourteen secondary metabolites in aqueous, ethanolic and hexanoic extracts in the pulp of *Tamarindus indica L.* (Table 8). Alkaloids (07), flavonoids (06), saponins (08) and tannins (06) were the most identified according to the twelve results explored on the secondary metabolites of this organ. Four of the authors identified the alkaloids in the aqueous extract while two reported it in the ethanolic extract and only one in the hexane. Anthocyanins, coumarins, cyanogenic derivatives, leucoanthocyanins, mucilages, steroids and terpenoids have not been explored enough in the literature. Of the two authors who explored the presence of anthocyanins, steroids and coumarins, only Ouédraogo *et al.* (2010) and Ahodègnon *et al*. (2018) reported their presence respectively in the semi-ethanolic and dichoromethyl extract of the pulp (Table 8).

Antinutrient factors

Responsible for the non-availability and assimilation of minerals by the body and the inhibition of the activity of certain enzymes, antinutrients constitute a group of chemical compounds present in a part of the plant. The most important are alkaloids, oxalates, trypsin inhibitors, phytates, tannins, saponins and cyanogenic derivatives. The literature used in this study did not report any data on the antinutrient content of the pulp of *Tamarindus indica L*. (Table 9).

Whole seeds and kernels of *Tamarindus indica L.*

Proximal composition

The macronutrient compositions of the reported whole seed, roasted, soaked and unsoaked seed kernels of *Tamarindus indica L*. have been recorded in Table 2. It shows that per 100 grams of dry whole seeds, the water content varied from 2.07 g to 11.75 g respectively reported by Sadiq *et al*. (2016) in Sokoto State (Nigeria) and Yusuf *et al.* (2007) in Kaduna State (Nigeria) with an average content of (9.12 ±1.11) g . Reported protein contents ranged between 4.45 g reported by Sadiq *et al.* (2016) and 25.16 g reported by Yusuf *et al.* (2007) while crude ash contents were between 1.5 g reported by Ajayi *et al.* (2006) and 8.33 g mentioned by Yusuf *et al.* (2007) . These last authors and Sadiq *et al.* (2016) found for whole seeds, oxidizing sugar contents between 10.38 and 91.5 g against total fiber contents of (0.51-8.33) g. One of the nutritional importance of *Tamarindus indica L.* seeds is their high crude fiber content. Indeed, fibers help maintain the health of the gastrointestinal tract (Ajayi *et al.*, 2006) by acting on satiety, faecal excretion, motor activity of the intestine, metabolic parameters including plasma lipids and on the characteristics of the colonic flora. They have a hypocholesterolemic effect. These reported values for total fiber appeared to be higher than those of néré seeds (4.1-16.09 g/100 g DM) but lower than those of baobab seeds (16.09-49.7 g/100 g DM) reported in Ayosso (2015) .

The work of Akajiaku *et al*. (2014) and Uzodinma *et al.*, (2020), reveal that for 100 g of processed or untreated seeds of *Tamarindus indica*, the average water content varies from 15.96 g for almonds, 8 g for roasted seed almonds (AGTO) and 10.5 g for soaked seed almonds (AGTR). For these authors, the ash content for these three categories of almonds is between 4.53 g and 5.87 g while the sugar content varies from 54.92 to 63.13 g for roasted almonds (Table 2). It appears from these data that the elimination of the tegument decreases the content of organic matter, in particular crude fibers, while it served to increase the water and ash content, thus increasing the mineral content of the seeds. Similarly, soaking the seeds in water appeared to decrease the lipid content and increase the protein and carbohydrate content of the almonds. These same results were obtained by Yusuf *et al*. (2007) who reported an increase in total mineral content and a decrease in organic matter and calorific value of seeds by the removal of seed coats. The optimal use of the seeds of *Tamarindus indica L*. would therefore be in roasted form.

At the 5% threshold, the data on the composition of total lipids, carbohydrates, ash and fiber vary significantly according to the different treatments of the seeds and the authors (Table 2). It could be due to the analytical methods and/or solvents, the origin of the samples, the types of organs, etc.

Minerals and vitamins

Previous work carried out on the seeds of *Tamarindus indica L.* showed that 100 g of dry seeds contain on average 874.7 mg of potassium; 148.95 mg of phosphorus; 144.67 mg of calcium; 124.3 mg of magnesium and 20.37 mg of iron (Table 4). The seeds of *Tamarindus indica* L. have a high content of potassium, calcium, magnesium and phosphorus. The highest calcium content (265.4 mg) was reported by Favet *et al.* (2011) while those of Yusuf *et al* . (2007) on seeds from

Kaduna State in Nigeria in 2007 (10 mg) were the lowest levels reported. Ajayi *et al*. (2006) reported the highest potassium content (1308 mg) for the same portions of dry seeds while the highest phosphorus was reported by Lockett *et al.* (2000) reported in De Caluwé *et al.* (2010) . *Tamarindus indica L.* seed has a zinc content of (1.42 ± 0.58) mg/100 g DM. The pretreated almonds showed average potassium (488.40 mg/100 DM), magnesium (255.58 mg/100 g DM), sodium (66.20 mg/100 g DM), phosphorus (735.00 mg/100 g DM) and iron (18.29 mg/100 g DM) significantly higher than those of whole seeds (Table 4). Additionally, roasting or soaking the seeds of *Tamarindus indica L*. seemed to improve the nutritional value of almonds. The food valorization of the seed of *Tamarindus indica L.* would be very interesting for the content of its almonds in mineral elements. The data used show a significant variation in the calcium and magnesium contents of the prospected organs of *Tamarindus indica*. *L*. unlike those in sodium, potassium, iron, copper, manganese and zinc (Table 4).

In vitamin (Table 5), only the ascorbic acid content of the seeds was evaluated and reported by Sadiq *et al.* (2016) . For these authors, dry seeds from Sokoto State in Nigeria contained 41.16 mg of vitamin C for a 100 g serving. The contents of other vitamins have not been explored in the literature but it specifies that the seeds of *Tamarindus indica L.* contain vitamins of group B.

Amino acids

Amino acid profile of *Tamarindus indica L.* seeds (Table 6) showed that these organs have a good balance of amino acids essential to humans, of which six of the nine are present in high levels and three in low levels (Phenylalanine: 2.96 g/ 100 g dry seeds; Methionine: 0.12 g/100 g dry seeds; Tryptophan: 0.14 g/100 g dry seeds). The arginine content of the seeds of *Tamarindus indica L.* is 205.28 g/100 g while that of tyrosine is 3.08 g/100 g of dry seeds. Favet *et al*. (2011) and Sadiq *et al.* (2016) reported that the kernel and seed proteins of *Tamarindus indica L*. are rich in basic, aliphatic, hydroxy and dicarboxylic α -amino acids and low in sulfur and aromatic α -amino acids.

Fatty acids

The literature data (Table 7) used in show that the oil extracted from the seeds of *Tamarindus indica* L. is characterized by an amber color and a sweet taste and resembles linseed oil. It contains about fifteen fatty acids mainly palmitic (14-20% wt), stearic (6-7% wt), oleic (15- 27% wt), linoleic (36-49%), arachidic (2-4% wt), behenic acids (3-5% wt), lignoceric (3-8% wt) and phytosterols such as β-sitosterol (66 - 72% wt), campesterol (16-19% wt) and stigmasterol (11-14% wt) and constitute therefore a good source of fatty acids (. Glew *et al.*, 1997; Ishola *et al.*, 1990; Uzukwu *et al.,* 2016). In addition, it is richer in ethylenic fatty acids (55.6% wt) than saturated fatty acids (44.4%) (Ajayi *et al*., 2006).

Secondary metabolites

Sixteen data on various seed secondary metabolites have been collected from the literature and reported in Table 8. However, very few (08) have been researched in the seed kernels of *Tamarindus indica L*. In Nigeria in 2017, Adeniyi *et al.* reported the presence of five secondary metabolites (alkaloids, flavonoids, saponins, reducing sugars and terpenoids) in the aqueous extract of seeds without their pericarp against four (alkaloids, flavonoids, saponins and terpenoids) in the ethanolic extract of these same organ categories while for Mahima *et al.* (2018) in India, only three secondary metabolites (alkaloids, glucosides and saponins) are present in aqueous and methanolic extracts of seed kernels. In addition to the absence of tannins also notified by Adeniyi *et al.* (2017), the latter also mentioned that of flavonoids. Anthocyanins, anthraquinones, coumarins, cyanogenic derivatives, leucoanthocyanins, mucilages and steroids have not been determined in this organ.

Antinutrient factors

Antinutrient contents of whole seeds and/or parts of processed seeds are presented in Table 9. According to the documentation, 100 g of dry seeds contain 30.05 mg of alkaloids; 20.05 mg of trypsin inhibitor; 4.21 mg of tannins and 0.74 g of hydrogen cyanide (Uzodinma *et al.*, 2020). Those stripped of the integuments contain on average 8.89 mg of alkaloids and 1.91 mg of tannins against 1.18 mg of phytates and a high content (201.41 mg) of trypsin inhibitor. Alkaloid, oxalate and hydrogen cyanide contents decreased in roasted seed kernels and particularly in soaked and shelled seeds. Untreated (control), autoclaved and boiled seed kernels showed the same contents of phytates (2.18-2.36) mg and tannins (2.63-3.81) mg. All kernels contain traces of oxalate (0.002-0.003 mg) and cyanide ions (0.24-0.86) mg which decreased with different seed treatments. The highest alkaloid and tannin contents were reported by Uzodinma *et al.* (2020) while those in trypsin inhibitor and phytates were reported by Makinde & Ayodele (2022) for treated or untreated seeds from Nigeria.

Data reported in the literature and converted into the same unit reveal that whole seeds of *Tamarindus indica L.* are richer in antinutrients than treated ones. The high levels of antinutrients of the whole seed are significantly higher than those of control kernels and treated seeds, particularly in alkaloids, tannins and saponins (Bashir *et al.,* 2016; Makinde & Ayodele (2022) . These differences observed in the literature could perhaps be related to the type of treatment undergone by the seeds of *Tamarindus indica L.* It therefore emerges from this analysis that the antinutrients of whole seeds are much more concentrated in the integuments than in the almonds. Indeed, according to Makindé & Ayodele (2022), the attachment to shelled almonds of a portion of integuments after treatment would increase the oxalate content of autoclaved seeds and those soaked. Also, some authors have notified that shelling, roasting or soaking the seeds of *Tamarindus indica L.* would reduce the antinutritional character of tannins, phytates, saponins and alkaloids contained in the organs of *Tamarindus indica* (Bashir *et al.,* 2016; Makinde & Ayodele, 2022; Uzodinma *et al.*, 2020) . For Bashir *et al.* (2016) , the low tannin content in the control almond or the treated almonds would be a consequence of the elimination of the seed coats or that of the hydrolysable tannins by leaching or that of the tannins condensed by roasting. These same results were confirmed by Makinde & Ayodele (2022) who reported that all processing techniques adopted (soaking, roasting or autoclaving) significantly reduce the phytate content of *Tamarindus indica* seeds. For these, heat treatments would be very effective in reducing antinutrient factors and thus improving the nutritional value of plant organs. These various pre-treatment methods could therefore be used to reduce the antinutrient content to a minimum level of consumption for humans. However, this reduction is a function of temperature-time combinations.

Leaves of *Tamarindus indica L.*

Proximal composition

Unlike the pulp and whole seeds of *Tamarindus indica L.* the leaves of the tree have been less investigated. Table 3 presenting the data available from the literature on the proximal composition of the leaves of *Tamarindus indica L.* reveals that a portion of 100 g of dry leaves contains on average a high content of total sugars (72.38 ± 1.88 g) and water (63.86 ± 2.16 g) reported by Singh *et al.* (2007), De Caluwe et al (2010) . and Favet *et al.* (2011) . For the same portion and for the same organ, these authors reported a relatively high content of protein (19.35 g) while those of total fiber (7.98 g), lipids (6.77g) and ash crude (4.97g) were relatively low. According to the values treated in this study, the proximal composition of the leaves of *Tamarindus indica L*. did not vary significantly (p-value = 0.05).

Minerals and vitamins

The mineral composition of the leaves of *Tamarindus indica L*. has been very little investigated. However, the information used shows that they are rich in calcium, magnesium and potassium (Table 4). Singh *et al.* (2007) and Favet *et al.* (2011) reported that 100 g of dry leaves contain high levels of potassium (1048.55 mg), phosphorus (509.14 mg), calcium (511.69 mg) , magnesium (275.73 mg) while those sodium (31.07 mg) , zinc (15.81 mg) and copper (7.77 mg) are low. These data vary significantly at the 5% level (p-value ? 0.05). The leaves of *Tamarindus indica L*. are rich in vitamins C (10.72 mg/100 g), B1 (0.52 mg/100 g), B2 (0.42 mg/100 g) and B3 (9.41 mg/100 g). Consumption of the leaves would therefore be beneficial to humans. They will contribute to covering the needs of man in vitamin B1, B2, B3 and C. Indeed, intervening in the energy metabolism of cells, vitamin B1 is very sensitive to heat, to light at neutral or alkaline pH and humidity, it can deteriorate during cooking depending on the food, the method of preparation or by the action of food additives. Its deficiency in serious cases would cause conditions such as polyneuritis, oedema, myocarditis and beriberi, while in less serious cases, vitamin B1 deficiency leads to neurological disorders, fatigue, loss of appetite and weight. Unlike vitamin B1, vitamin B2 is heat resistant but very sensitive to light, pH and can partially disappear in cooking water. A heat treatment of *Tamarindus indica L*. leaves would be beneficial for humans in terms of vitamin B2. In addition, the consumption of 100g leaves would be enough to meet the recommended daily requirement of vitamin B2 for children, which varies from (0.6 - 1.4) mg. However, in adolescents, men and pregnant or breastfeeding women, the doses of the leaves must be supplemented to meet the recommended daily allowances which are between (1.5 - 1.8) mg per day. Vitamin B2 plays a crucial role in the metabolism of organic substances and its deficiency would lead to eye disorders, skin lesions and mucous membranes (tongue + lips). It is essentially linked to digestive malabsorption, insufficient food intake or excessive alcohol consumption. As for vitamin B3 again, it is required not only in the metabolism of organic substances but also constitutes a precursor of nucleotides. The recommended nutritional intakes of vitamin B3 are 6 to 14 mg per day for children, 15 to 18 mg for adults and 20 mg during pregnancy or breastfeeding. It is both heat and light resistant. Its deficiency can lead to scalp conditions in addition to inflammation of the digestive mucous membranes.

Amino and fatty acids

No scientific data on the amino acid composition of the leaves of *Tamarindus indica L.* was identified in the documentation used in this study.

Secondary metabolites

Table 8 presents the secondary metabolites reported on these leaves. Six results reported by four different authors on the secondary metabolites of the leaves of *Tamarindus indica L.* were exploited. They all revealed the presence of the alkaloids, saponins and terpenoids in the aqueous and ethanolic extracts. Four of them reported the presence of flavonoids in leaf extracts including three (03) for the aqueous (Adeniyi *et al.*, 2017; Doughari, 2006; Highab *et al.*, 2022; Mehdi *et al.*, 2019) and one (01) for the ethanolic (Adeniyi *et al.*, 2017) . The presence of steroids has been reported by Doughari (2006) and Highab *et al.* (2022) in the aqueous extract of the leaves of *Tamarindus indica* L. from Nigeria while Mehdi *et al*. (2019) documented their absence in the same India leaf extract. Doughari (2006) reported the presence of tannins in the aqueous and ethanolic extracts whereas for Adeniyi *et al*. (2017) and Highab *et al.* (2022) , aqueous leaf extracts are steroid-free. The work carried out by Adeniyi *et al.* (2017) , Highab *et al.* (2022) and Mehdi *et al* . (2019) revealed the presence, among other things, of aqueous and alcoholic reducing sugars in the leaves of *Tamarindus indica L*. Anthocyanins, anthraquinones, coumarins, cyanogenic derivatives, glycosides, leucoanthocyanins, mucilage and steroid have not been explored in the leaves of *Tamarindus indica L.*

Antinutrient factors

The levels of antinutritional compounds in the leaves of *Tamarindus indica L*. have been poorly documented. Leng *et al.*(2017) reported that dried leaves are more concentrated in flavonoids than roasted and fresh ones. For these authors, the fresh leaves of *Tamarindus indica L*. contain 39.31 mg/100 g of flavonoids while the treated leaves (roasted and dried) contain respectively 47.74 mg and 139.87 mg for the same leaf portion considered (Table 9). These variations in flavonoid content would be a function of temperature and treatment time. However, consumption of sauted or dried leaves of *Tamarindus indica L*. would provide significant phenolic content to promote human health but inhibit mineral bioavailability.

Table 3 : Proximal composition for 100 grams of pulp, whole seeds, almonds and leaves of *Tamarindus indica L.*

Composition proximale pour 100 grammes de pulpe, graines entières, noyaux et feuilles de Tamarindus indica *L.*

Organs		Water (g)	Lipid (g)	Protein (g)	Carbohydrate (g)	Raw ash (g)	Total fibers (g)	Tartric acid (g)	(F) -	p-value -	Reference
Pulp	Mean	23.79b	4.36	6.29a	60.99	3.48	4.98	18.51			Singh *et al.* (2007) ; Khanzada *et al.* (2008) ; Favet *et al.* (2011) ; Hamacek *et al.* (2013) ; Gali *et al.* (2016) ; Makalao *et al.* (2015) ; Sadiq *et al.* (2016) ; Ahodegnon *et al.* (2018).
	ES	4.66	1.96	0.91	11.99	1.18	1.47	5.91			
	Val. Min	5.09	0.1	2.50	1.44	2.9	2.9	10.4			
	Val.Max	40.10	17.02	10.3	82.72	7.03	7.16	28.62			
Whole seeds	Mean	9.12b	7.23	20.21b	55.08	3.42	8.22	-	160.87	0.0001	Ajayi *et al.* (2006) ; Yusuf *et al.* (2007) ; Huda (2009) ; Favet *et al.* (2011) ; Bashir *et al.* (2016) ; Sadiq *et al.* (2016) ; Gitanjali *et al.* (2020) ; Uzodinma *et al.* (2020).
	ES	1.11	1.54	2.35	8.24	0.74	2.41	-	-	-	
	Val. Min	2.07	1.53	4.45	10.38	1.5	0.51	-	-	-	
	Val. Max	11.75	12.95	25.16	91.5	8.33	18.34	-	-	-	
Almonds	Mean	15.96b	8.04	23.07b	57.40	5.87	5.09	-	66.78	0.0001	Yusuf *et al.* (2007) ; Huda (2009) ; Favet *et al.* (2011) ; Bashir *et al.* (2016) , Uzodinma *et al.* (2020) ; Makinde *et al.* (2020).
	ES	1.84	1.67	1.46	16.97	2.01	0.87	-	-	-	
	Val. Min	10.66	4.13	19.9	11.11	3.64	2.91	-	-	-	
	Val.Max	19.99	12.18	26.53	82.87	11.57	6.51	-	-	-	
Processed almonds	Mean	9.79b	6.31	23.85b	60.30	4.40	6.09	-	2.33	0.9931	Akajiaku *et al.* (2014) ; Bashir *et al.* (2016) ; Uzodinma *et al.* (2020) ; Makinde *et al.* (2020) ; Mahajani (2020).
	ES	0.90	1.33	0.80	2.69	0.36	0.77	-	-	-	
	Roasted	8	7.39	24.53	63.13	4.95	6.85	-	-	-	
	Soaked	10.5	7.88	24.76	62.84	4.53	6.87	-	-	-	
Leaves	Mean	72.38a	6.77	19.35b	63.86	4.97	7.98	-	0.87	0.9900	Singh *et al.* (2007) ; De Caluwe *et al.* (2010) ; Favet *et al.* (2011).
	ES	1.88	0.36	0.32	2.16	0.12	1.54	-	-	-	
	Val. Min	70.25	6.41	19.03	61.7	4.85	6.44	-	-	-	
	Val. Max	74.25	7.12	19.66	66.02	5.08	9.51	-	-	-	
(F)		7.31	0.62	18.38	0.07	0.94	0.43	-	-	-	
Significance		0.001	0.656	0.0001	0.992	0.459	0.785				

Legend: g = gram; Val. Min = Minimum value; Val. Max = Maximum value; ES = Standard Error; F = Value of the statistic.

Means with the same superscript letters on each row are not significantly different ($p \geq 0.05$)

g = gramme ; Val. Min = valeur minimale ; Val. Max = valeur maximale ; ES = erreur standard ; F = Valeur de la statistique.

Les moyennes avec les mêmes lettres en exposant sur chaque ligne ne sont pas significativement différentes ($p \geq 0,05$)

Table 4: Mineral composition for 100 grams of pulp, seeds and leaves of *Tamarindus indica L.*

Composition minérale pour 100 grammes de pulpe, graines et feuilles de Tamarindus indica *L.*

Organs		Ca (mg)	K (mg)	Mg (mg)	Na (mg)	P (mg)	Fe (mg)	Cu (mg)	Mn (mg)	Ni (mg)	Zn (mg)	References
Pulp	Mean	131.63[a]	318.56	38.58[a]	38.21	70.40[a]	3.95	5.77	6.78	0.24	1.42	Singh *et al.* (2007) Khanzada *et al.* (2008) : Favet *et al*. (2011) : Makalao *et al. (*2015) : Gali *et al.* (2016) : Sadiq *et al.* (2016) : Ahodegnon *et al.* (2018).
	ES	56.88	99.34	11.19	13.47	20.63	1.13	5.35	4.08	0.14	0.58	
	Val. Min	0.19	0.65	0.12	1.09	0.12	0.004	0.076	0.06	0.08	0.09	
	Val. Max	675.38	790.11	79.34	12.76	155	10.83	21.8	21.50	0.5	4.22	
Whole seeds	Mean	108.08[a]	488.01	89.29[b]	14.09	76.70[a]	27.87	3.37	3.1	-	3.31	Yusuf *et al.* (2007) : De Caluwe *et al.* (2010) ; Favet *et al.* (2011) ; Bashir *et al.* (2016) ; Sadiq *et al.* (2016) ; Makinde *et al.* (2020).
	ES	45.33	217.04	31.32	3.95	37.72	14.28	1.77	2.25	-	1.04	
	Val. Min	10	8.4	1.5	2.1	21	2.38	0.26	0.51	-	0.7	
	Val. Max	265.4	1308	247.51	24	220	75.9	10.3	7.0	-	12.1	
Processed almonds	Mean	83.88	488.40	255.58	66.20	735.00	18.25	-	-	-	-	Akajiaku *et al.* (2014) ; Bashir *et al.* (2016) ; Uzodinma *et al.* (2020) ; Makinde *et al.* (2020) ; Hemalatha *et al.* (2021).
	ES	43.34	427.32	94.28	28.20	705.00	6.38	-	-	-	-	
	Val. Mi n	14.08	40.16	131	38	30	11.37	-	-	-	-	
	Val. Max	45.2	1245.11	478.86	94.4	1440	31.04	-	-	-	-	
Leaves	Mean	511.69[b]	1048.55	275.73	31.07	509.14[b]	15.81	7.77	-	- -		Singh *et al.* (2007) Favet *et al.* (2011)
	ES	169.32	-	-	-	34.56	1.83	-	-	-	-	
	Val. Min	342.37	1048.55	275.73	31.07	474.58	13.98	7.77	-	-	-	
	Val. Max	681	-	-	-	543.69	17.63	-	-	-	-	
(F)		4.436	1.85	10.72	0.94	36.24	3.56	0.64	0.624		2.73	
Significance		0.031	0.199	0.003	0.419	0	0.055	0.554	0.452		0.133	

Legend: mg = milligram; Val. Min = Minimum value; Val. Max = Maximum value; ES = Standard Error; (F) = Value of the statistic. Means with the same superscript letters on each row are not significantly different ($p \geq 0.05$).

mg = milligramme ; Val. Min = valeur minimale ; Val. Max = valeur maximale ; ES = erreur standard ; (F) = Valeur de la statistique. Les moyennes avec les mêmes lettres en exposant sur chaque ligne ne sont pas significativement différentes ($p \geq 0,05$).

Table 5: Content of thiamine, riboflavin, niacin and ascorbic acid in the pulp and dry leaves of *Tamarindus indica L.* expressed in (mg/100 g DM).

Teneur en thiamine, riboflavine, niacine et acide ascorbique dans la pulpe et les feuilles sèches de Tamarindus indica *L. exprimée en (mg/100 g de MS).*

Organs		*Thiamine (mg)*	*Riboflavin (mg)*	*Niacin (mg)*	*Ascorbic acid (mg)*	*Reference*
Pulp	Mean	0.34	0.13	1.31	23.96	Favet *et al.* (2011); Hamacek *et al.* (2013); Sadiq *et al. (2016)* ; Ahodegnon *et al.* (2018)
	ES	0.10	0.03	0.57	6.93	
	Val. Min	0.16	0.07	0.6	7.4	
	Val. Max	0.6	0.2	3.01	52.38	
Leaves	Mean	0.52	0.42	9.41	10.72	Singh *et al. (*2007) De Caluwe *et al.* (2010) Favet *et al.* (2011)
	ES	0.19	0.16	3.10	3.76	
	Val. Min	0.17	0.105	3.45	4.5	
	Val. Max	0.81	0.58	13.9	17.48	
(F)		-0.94	-1.87	-2.56	0.12	-
p value		0.39	0.19	1.19	0.27	

Legend: Val. Min = Minimum value; Val. Max = Maximum value; ES = Standard Error; (F) = Value of the statistic

Table 6: Composition in α -amino acids of pulp and seeds of *Tamarindus indica L*. expressed in grams per 100 grams of dry matter (g/100g DM).

Composition en acides α -aminés de la pulpe et des graines du Tamarindus indica *L. exprimée en grammes pour 100 grammes de matière sèche.*

	Pulp		Seeds			
	Mean	ES	Mean	ES	you	sig. (bilateral)
Isoleucine (g)	3.24	1.96	119.12	118.44	- 0.758	0.504
Leucine (g)	5.97	2.93	209.68	206.66	- 0.764	0.501
Lysine (g)	5.24	2.99	177.55	174.73	- 0.764	0.501
Phenylalanine	3.47	1.31	2.96	2.25	0.198	0.861
Threonine (g)	3.78	2.28	94.42	93.79	- 0.749	0.508
Valine (g)	4.38	2.59	136.87	136.06	- 0.754	0.506
Histidine (g)	2.46	0.91	83.45	82.77	- 0.758	0.504
Methionine (g)	1.34	1.14	0.12	0.02	1,070	0.397
Alanine (g)	4.8	1.4	124.28	123.36	- 0.750	0.508
Arginine (g)	5.03	3.71	206.44	205.28	- 0.760	0.503
Aspartic acid	12	-	468.4	466.6	- 0.565	0.673
Glutamic acid (g)	9.17	7.53	1.81	1.01	0.969	0.435
Glycine (g)	3.60	1.56	195.89	194.55	- 0.766	0.5
Serine (g)	4.81	2.08	148.95	148.03	- 0.754	0.505
Cysteine (g)	1.35	-	0.33	0.03	23,671	0.027
Tyrosine (g)	4.34	-	3.08	2.13	0.344	0.789
Proline (g)	4,935	2,675	179.33	178.84	- 0.755	0.505
Tryptophan (g)	17.13	16.09	0.14	0.04	1,417	0.252

Source: Sadiq *et al.* (2016); Favet *et al.* (2011); De Caluwe *et al.*, 2010.

Legend: ES = Standard error of the mean; sig. (bilateral) = Bilateral significance

Table 7: Fatty acid composition of the pulp and seeds of *Tamarindus indica L.*

Composition en acides gras de la pulpe et des graines du Tamarindus indica *L.*

		Pulp	Seed			
Fatty acids µg/g DM		A	B	C	D	E
Lauric acid	C12:0	0.01				
Myristic acid	C14:0	0.01	-	-	tracks	-
Pentadecyclic acid	C15:0	0.01	-	-	-	-
Palmitic acid	C16:0	1.80	15.20	27.41	0.54	14-20
Palmitoleic acid	C16:1 w -7	0.12	-	-	n/a	-
Stearic acid	C18:0	0.70	4.19	13.8	60.17	6 - 7
Oleic acid	C18:1w-9	2.29	24.50	24.13	1.07	15-27
Linoleic acid	C18:2 w -6	3.42	48.30	24.75	1.65	36-49
Linolenic acid	C18:3 w -3	0.21	2.50	-	0.01	-
Arachidic acid	C20:0	0.07	-	2.25	0.06	2-4
Gadoleic acid	C20:1	0.02	-	3.13	-	-
Arachidonic acid	C20:2 w-6	0.01				
Behenic acid	C22:0	0.03	5.20	0.39	-	3-5
Erucic acid	C22:1 w-9	0.01				
Lignoceric acid	C24:0	0.03	-	-	-	-
Nervonic acid	C24:1 w-9	0.20	-	-	-	-
Phytosterols	β-sitosterol	-	-	-	66-72	-
	Campesterol	-	-	-	16-19	-
	Stigmasterol	-	-	-	11-14	-

Source: A= De Caluwé *et al.* (2010); B = Siddhuraju *et al.* (1995) ; C = Ajayi *et al*. (2006); D = Glew *et al.* ; E = Andriamanantena *et al.* (1983)

Table 8: Secondary metabolites of pulp, leaves and almonds of *Tamarindus indica L.*

Métabolites secondaires de la pulpe, des feuilles et des graines de Tamarindus indica *L.*

	Pulp												Leaves						Almonds			
Authors	A	B	C		D	E	F	G		H		I	C		J		K	I	C		H	
Solvents	Woter	EtOH	Woter	EtOH	Woter	DCM	Woter	EtOH	Woter	Woter	MeOH	Hex	Woter	EtOH	Woter	EtOH	Woter	Woter	Woter	EtOH	Woter	MeOH
Alkaloids	+	nd	+	+	nd	nd	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+
Anthoeyanins	nd	-	nd	nd	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Anthraquinones	nd	+	nd	+	+	nd	+	-	-	nd	nd	nd	nd	nd	nd	nd	-	nd	nd	nd	nd	nd
Coumarins	nd	+	nd	nd	nd	nd	nd	nd	-	nd	nd	nd	nd	nd	nd	nd	nd	+	nd	nd	nd	nd
Cyanogenic derivatives	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Flavonoids	-	+	+	nd	nd	nd	-	+	+	+	+	-	+	+	nd	nd	+	+	+	+	-	-
Glycosides	-	-	nd	+	+	nd	+	nd	nd	-	-	-	nd	nd	nd	nd	nd	nd	nd	nd	+	+
Cardiac glycosides	-	+	nd	+	nd	nd	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-	nd	nd
Glycosides	nd	nd	nd	nd	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	+	nd	nd	nd	nd	nd
Leucoanthocyanins	nd	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mucilage	nd	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Saponins	-	+	+	+	nd	nd	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
Steroids	-	nd	nd	nd	nd	+	nd	nd	-	nd	nd	nd	nd	nd	+	+	+	-	nd	nd	nd	nd
Reducing sugars	+	-	+	nd	nd	nd	-	nd	+	nd	nd	nd	+	+	nd	nd	+	+	+	nd	nd	nd
Tannins	nd	+	-	nd	nd	nd	-	+	+	+	+	+	-	-	+	+	-	+	-	-	-	-
Terpenoids	-	nd	+	nd	nd	+	nd	-	-	nd	nd	nd	+	+	+	+	+	nd	+	+	nd	nd

Legend: A = Krishna *et al.*; B = Ahodègnon *et al* . (2018); C = Adeniyi *et al.* (2017); D = Ouedraogo *et al.* (2010); E = Ouedraogo *et al.* (2010); F = Abukakar *et al.* (2008); G = Daniyan and Mohammad (2008); H = Mahima *et al.* (2018); I = Adeola *et al.* (2010); J=Doughari (2006); K = Highab *et al.* (2022); L = Medhi *et al.* (2019); DCM = Dichloromethane; EtOH=Ethanol; MeOH=Methanol; + = Present; - = Absent; nd = Not determined.

Table 9: Contents of few antinutrients per 100 grams of organs of *Tamarindus indica L.*

Teneur en quelques antinutriments pour 100 grammes d'organes du Tamarindus indica *L.*

		References	Seeds and seed hernels						Leaves		
			GE	AGT	AGTR	AGTo	AGA	AGB	FF	FR	FS
	Val. Min	Makinde *et al.* (2020)	-	0.003	2.39	0.002	0.002	0.003	-	-	-
		Bashir *et al.* (2016)	-	0.004	-	0.007	-	-	-	-	-
Alkaloid	Val. Max	Uzodinma *et al.* (2020)	30.05	26.66	-	23.34	24.49	28.45	-	-	-
(mg)	Mean	-	-	8.89	-	7.78	12.25	-	-	-	-
	ES	-	-	11.85	-	10.37	12.24	-	-	-	-
	Val. Min	Uzodunma *et al.* (2020)	20.05	18.66	-	17.57	13.59	7.87	-	-	-
Trupsin inhibitor	Val. Max	Makinde *et al.* (2020)	-	384.16	-	420.61	742.07	664.23	-	-	-
(mg)	Mean	-	-	201.41	-	219.09	368.83	335.95	-	-	-
	ES	-	-	182.75	-	201.52	355.24	328.28	-	-	-
	Val. Min	Bashir *et al.* (2016)	-	0.002	-	0.002	-	-	-	-	-
Tannins (mg)	Val. Max	Uzodinma *et al.* (2020)	4.21	3.81	-	3.98	2.68	2.63	-	-	-
	Mean	-	-	1.906	-	1.99	-	-	-	-	-
	ES	-	-	1.904	-	1.98	-	-	-	-	-
	Val. Min	Bashir *et al.* (2020)	-	0.007	-	0.008	-	-	-	-	-
Phytates (mg)	Val. Max	Makinde *et al.* (2020)	-	2.36	-	2.21	-	-	-	-	-
	Mean	-	-	1.18	-	1.11	-	-	-	-	-
	ES	-	-	1.17	-	1.10	-	-	-	-	-
HCN (mg)		Uzodinma *et al.* (2020)	0.74	-	0.86	0.67	0.64	0.24	-	-	-
Sapnins (mg)		Bashir *et al.* (2016)	-	0.002	-	0.004	-	-	-	-	-
Oxalates (mg)		Makinde *et al.* (2020)	-	6.13	5.74	-	6.19	6.24	-	-	-
Flavonoids (mg)		Leng *et al.* (2020)	-	-	-	-	-	-	39.31	47.74	139.87

Legend: Val. Min = Minimum value; Val. Max = Maximum value; ES = standard deviation; GE = Whole Seed; AGT = seed almond (control); AGTR = Soaked Seed Almond; AGTo = roasted seed almond; AGA = Autoclaved Seed Almond; AGB = Boiled seed almond; FF = Fresh leaves; FR = Sauteed or roasted leaves; FS = Dry leaves; - = Not determined.

LINKS BETWEEN THE NUTRITIONAL AND FUNCTIONAL VALUES OF *Tamarindus indica L.*

Table 10 presents the correlation between the parameters of the macronutrient, mineral and vitamin composition of the pulp of *Tamarindus indica L*. There are very strong negative correlations, significantly at the 0.5% threshold, between manganese and calorific energy, lipids, proteins, carbohydrates and ash. Although not statistically significant, the manganese content of the pulp of *Tamarindus indica L*. is strongly correlated with that of calcium, potassium, phosphorus, iron and copper. In addition, there is also a very strong significant and positive correlation between the water content and that of potassium and phosphorus, and negative for vitamins B1, B2 and B3. It is important to note that vitamin B1 and B2 content (seeming to display the same behavior in the pulp of *Tamarindus indica L.* is strongly negatively correlated with calories, water, ash while it is positively correlated with fibers, phosphorus, potassium, magnesium and copper. Thus, the evidence of the data makes it possible to affirm that the water content in the pulp of *Tamarindus indica L*. would inhibit that in vitamin B1, B2, B3, but would favor that of manganese, potassium and phosphorus.

Referring to the correlation between the nutrients of the seeds of *Tamarindus indica L*. (Table 11), we notice a strong positive correlation between the water content of the seeds and the lipids, proteins, iron, manganese and zinc. On the other hand, we note a strong, significantly negative correlation at the 5% threshold between sugars and proteins with iron, unlike that between phosphorus and fibers. However, this strong correlation is negative for carbohydrate and sodium content. Furthermore, there is also a very strong negative and statistically significant correlation between manganese content and magnesium, potassium, phosphorus and iron. For seeds and at the 1% threshold, the phosphorus content presents a significantly positive correlation with copper, potassium, manganese, vitamins B1, B2, B3 and tartaric acid (Table 10). The coefficients of the correlograms without arteritis indicate a non-significant correlation between the nutrients.

Table 10: Correlation between the nutrients of the pulp of *Tamarindus indica L*.

Corrélation entre les nutriments de la pulpe du Tamarindus indica *L.*

	Calorie	Water	Lipids	Proteins	Carbohydrates	Ashes	Fibers	That	mg	N/A	P	K	Fe	Cu	Min	Zn	Vit B1	Vit B2	Vit B3	Vit C	TA
Calorie	1	0.495	0.014	0.604	0.797*	0.453	0.646	-0.262	-0.593	0.305	0.339	0.467	-0.062	-	-1.00**	-0.998*	-0.994	-0.998*	0.346	0.235	0.578
Water		1	-0.616	-0.199	0.685	-0.389	0.326	-0.487	0.58	-0.358	0.951*	0.992**	0.405	-	1.00**	-0.359	-1.00**	-1.0**	-1.0**	-0.248	0.918
Lipids			1	0.369	-0.487	0.515	0.136	0.864**	-0.301	0.757	-0.481	-0.847*	-0.58	-	-1.00**	-0.717	-0.154	-0.32	0.996	0.761	-0.711
Proteins				1	0.236	0.595	0.363	-0.064	-.913*	0.67	-0.072	-0.331	-0.148	-	-1.00**	-0.752	0.048	-0.123	0.957	0.536	0.236
Carbohydrates					1	0.22	0.85*	-0.615	-0.375	-0.323	0.527	0.837*	0.215	-	1.00**	-1.00*	0.359	0.513	-0.993	-0.301	0.927
Ashes						1	0.555	-0.677	-0.771	0.789	0.417	-0.397	-0.215	-	-1.00**	-0.271	-1.00**	-1.0**	1.0**	0.128	0.5
Fibers							1	-0.334	-1.0**	0.238	0.81	0.69	0.688	-	-	-	1.00**	1.00**	-1.0**	0.67	1.00**
Ca								1	0.363	0.123	0.605	-0.321	-0.296	1.0**	0.938	0.181	-0.074	-0.243	0.985	0.723	-0.617
Mg									1	0.238	0.988	0.678	0.55	1.0**	0.953	0.619	-	-	-	-0.177	1.00**
N/A										1	0.85	0.228	-0.31	1.0**	-0.065	1.0*	-	-	-	-0.204	1.00**
P											1	0.964**	0.486	1.0**	1.00**	0.973	1.00**	1.00**	-1.0**	-0.485	0.985
K												1	0.758*	1.0**	0.845	0.998*	1.00**	1.00**	-1.0**	-0.792	1.00*
Fe													1	1.0**	0.996	0.926	0.89	0.954	-0.659	-0.283	0.634
Cu														1	1.0**	1.0**	-	-	-	-1.0**	-
Mn															1	1.0**	-	-	-	-0.966	-
Zn																1	-	-	-	-1.0**	-
Vit B1																	1	0.965*	-0.29	0.256	0.17
Vit B2																		1	-0.119	0.088	0.418
Vit B3																			1	0.875	0.671
Vit C																				1	-0.632
TA																					1

Legend : TA = Tartaric acid

* The correlation is significant at the 0.05 level (two-sided);

** The correlation is significant at the 0.01 level (two-sided); c Calculation impossible, because at least one of the variables is a constant.

Table 11: Correlation between the nutrients of the seeds of *Tamarindus indica L.*

Corrélation entre les nutriments des graines du Tamarindus indica *L.*

	Water	Lipids	Proteins	Carbohydrates	Ashes	Fibers	That	mg	N/A	P	K	Fe	Cu	Mn	Zn
Water	1	0.663	0.985**	-0.794*	0.444	0.396	-0.02	-0.016	-0.538	0..262	0.191	0.632	0.503	0.65	0.786
Lipids		1	0.638	-0.663	0.593	0.054	0.06	-0.558	-0.391	-0.278	-0.228	0.627	0.951	-0.022	0.421
Proteins			1	-0.787*	0.392	0.428	-0.026	0.048	-0.542	0.321	0.246	0.613	0.24	0.838	0.807
Carbohydrates				1	-0.733*	-0.179	0.475	0.349	0.863	0.123	0.011	-0.941*	0.16	-0.985	-0.966*
Ashes					1	-0.298	-0.327	-0.538	-0.623	-0.315	-0.7	0.722	0.546	-0.971	-0.435
Fibers						1	0.099	0.795	-0.203	0.984*	0.898	-0.025	-0.99	0.458	0.797
Ca							1	0.258	0.841	0.358	-0.079	-0.728	0.795	-0.834	-0.354
Mg								1	0.34	0.95	0.932	-0.466	-0.82	-0.27	0.234
N/A									1	0.415	-0.02	-0.980*	1.000**	-1.000**	-0.833
P										1	0.584	-0.329	1.000**	-1.000**	0.8
K											1	-0.047	-1.000**	1.000**	0.971
Fe												1	0.399	0.997*	0.947
Cu													1	-0.329	-0.388
Mn														1	0.998*
Zn															1

* The correlation is significant at the 0.05 level (two-sided);

** The correlation is significant at the 0.01 level (two-sided).

RESEARCH PERSPECTIVES ON *Tamarindus indica L.*

Several research carried out in Africa and Asia on the chemical composition of the pulp of *Tamarindus indica L.* unlike those of its leaves and seeds. They revealed a rather interesting nutritive potential for the pulp, the seeds and the leaves that have been very little investigated. However, the nutritional data collected on these organs present significant variations. Like the nutritional composition, very few authors have also taken an interest in the screening of leaves and seeds. By characterization reactions and that of thin layer chromatography implemented for the search for the presence of secondary metabolites of *Tamarindus indica L.*, the revealed and exploited physicochemical compositions of the organs vary from one author to another. These variations would be due to differences in the genetic strains, the stages of maturity of the prospected organs, environmental and edaphic factors of its organs as well as the different analytical methods such as the time-temperature combinations for the water and ash contents, time-solvent and the nature of the solvents for the extractions. It is therefore important that other studies be undertaken in time and space on the nutritional composition of *Tamarindus indica L.* from Benin, in particular its leaves and seeds, in order to better appreciate their nutritional value and their contribution to the fight against protein malnutrition and "hidden hunger", especially infantile ones, and certain conditions in developing countries.

Data from the literature on the secondary metabolites identified in the organs are presented in Table 8 revealed that several relationships explored in this study were more interested in the pulp of the fruit of the tree. Very few data concerned the screening of leaves and kernels. By characterization reactions and thin layer chromatography, the presence of secondary metabolites was investigated by the authors. However, very few were searched for and identified in aqueous (H2O) and organic (Methanol, Ethanol) polar solvent extracts used by these authors. Reports on the composition of secondary metabolites in organs show significant variation from one author to another. This would be explained by the nature, the instability and the degree of solubility of the secondary metabolites in aqueous or organic solvents. It is therefore imperative that more investigations be carried out on the determination of the major chemical families of the pulp, seeds and leaves of *Tamarindus indica L.* with mixed solvents in order to optimize the extraction of secondary metabolites from its organs and better account for the composition of the different organs of *Tamarindus indica L*. with a view to better valorization of this plant whose several virtues have been documented with or without scientific evidence.

From 2016 to 2020, very little scientific data has been published on the antinutrient contents of treated and untreated seeds. Those of the pulp were non-existent while for the leaves, the dosage of antinutrients was limited only to that of flavonoids and reported by Leng *et al.* (2017). It would also be important that future physicochemical analyzes extend to the determination of the content of antinutritional components of the seeds and especially the pulp and the leaves which is hitherto almost non-existent in the literature to better estimate the availability of minerals, vitamins and other nutrients contained in the pulp, leaves and seeds of *Tamarindus indica L.* from Benin and better appreciate the functional nature of its latter.

Several virtues have been attributed in the literature in the existing literature to *Tamarindus indica L*. with or without scientific evidence. These virtues vary according to the qualitative and quantitative diversity of the organs of *Tamarindus indica L.* in natural bioactive substances. This is the case of the antioxidant or antiradical properties which are inversely proportional to the content of phenolic compounds in the organ extracts. However, until now, the existing literature seems to neglect this aspect. To better account for the degree of the organs to capture free radicals, it becomes necessary that surveys be undertaken on the antiradical potential of the organs of *Tamarindus indica L.* from Benin.

The data collected on the nutritional and physicochemical composition of the organs of *Tamarindus indica L*. revealed a sensitivity of the latter to dehydration, to the proliferation of microorganisms, to heat and consequently, a deterioration in a very short time of their qualities, both nutritional and organoleptic. However, until now, the available literature has neglected the best methods of treatment, conservation and consumption of these organs of *Tamarindus indica L*. it is therefore necessary to conduct studies on the techniques of treatment, transformation, conservation and consumption of *Tamarindus indica L.* products to benefit from their taste, nutritional and functional advantages. Surveys on the formulation or enrichment of functional foods based on edible organs of *Tamarindus indica L*. should also be carried out to find local solutions to fight poverty, malnutrition and hunger in developing countries.

The existing data on the oil extracted from the kernels of the seeds of *Tamarindus indica L.* show that the extracted oil is characterized by a yellow color and presents an interesting profile in fatty acids mainly those unsaturated. However, they are very limited and go back in time. In addition, physicochemical analyzes relating to the quality indices of this oil are almost non-existent in the literature used. However, knowledge of these indices is essential for the rational and efficient use of an oil. Consequently, future research on the physicochemical characterization of the oil extracted from the almonds of *Tamarindus indica L*. deserves to be carried out or resumed to account for the edible character, the nutritional and/or functional advantages of this oil in order to define the voice of valuation of seeds for an increase in added value of the species. They would also constitute an indicator of the various possible applications of this oil.

Prospecting in food technology and the possibilities of formulating or enriching foods based on edible organs of *Tamarindus indica L.* should also be explored for the search for local solutions to fight against poverty, malnutrition and hunger in the developing countries. Thus, presenting various potentialities in several fields, the pulp of *Tamarindus indica L*. could be a raw material in the development of improved drinks, particularly in developing countries. It is also necessary to carry out further research activities on other types of formulations of products derived from the organs of *Tamarindus indica L.*

Although the leaves can be used as vegetables, data on the antinutritional factors of the leaves and the impact of culinary treatments on the nutritional and physicochemical composition of the leaves of *Tamarindus indica L.* remain almost non-existent in the literature and need to be investigated. Undertaken in order to know the mode of integration of the leaves of *Tamarindus indica L.* in african dishes.

CONCLUSION

The present study consisted in taking stock of the state of knowledge on the ethnobotanical and nutritional value of *Tamarindus indica L*. and allowed to conclude that *Tamarindus indica L*. presents a very interesting profile of biochemical compounds beneficial to human health that makes him a species worthy of interest. It could play an important role in human nutrition, especially infant nutrition. However, the information collected through this analysis of literature revealed that the valuation of *Tamarindus indica L.* remains very limited and have opened up new avenues of study in food science, not only that of the physicochemical characterization of the leaves, roasted almonds and other organs of the species in Benin, that of the oil extracted from roasted almonds, the diagnostic study of the culinary effects on the nutritional values of the leaves as well as on the technological potential of these organs.

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