Sudan University of Science and Technology

College of Graduate Studies

Preparation and Characterization an Anti - acid from *Tamaridus –indica* Fruit Pulp

تحضير وتوصيف مضاد للحموضة من لب ثمار العرديب

A Thesis Submitted in Partial Fulfillment of the Requirements for a Master Degree in Chemistry

By

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استهلال

(الَّذِي جَعَلَ لَكُمُ الْأَرْضَ فِرَاشًا وَالسَّمَاءَ بِنَاءً وَأَنزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجَ بِهِ مِنَ الثَّمَرَاتِ رِزْقًا لَّكُمْ ۖ فَلَا تَجْعَلُوا لِلَّهِ أَندَادًا وَأَنتُمْ تَعْلَمُونَ)

(البقرة ٢٢)

Dedication

To my parents ,

brothers and sisters

Acknowledgment

Praise to Allah Almighty for protection and grace throughout my life .
Sincere gratitude to my supervisor, Prof. M. Elmubark for suggesting constructive criticism and the systematical methods in doing my research thorough follow up of my progress, encouragement and support.
I also would like to take this opportunity to acknowledge and thank my co- supervisor, Dr. Qurashi for his guidance and his willingness to help at various stages during my research.
I wish to acknowledge the cooperation and technical support I received from Mr. Zahir and Ms.Tahani (Kerry laboratory) and from Dr. Mohmmed (Khartoum refinery company ltd.
Thanks to all my colleagues and friends for their moral support throughout the years.

Abstract

The aim of this study was to prepare an anti-acid from *Tamarindus -indica* fruit pulp and to determine some of the physicochemical characteristics of tamarind fruit pulp and the product (anti-acid).

Samples of tamarind fruit were collected from North Kordofan (Elobeid) , the preparation of tamarindus acid was carried out using ion exchange chromatography. then , by reacting of tamarindus acid with magnesium bicarbonate the magnesium anti-acid was prepared.

The study of the physicochemical properties of tamarind pulp showed that, the moisture content was (22.54%) , ash content : (3.69%) , pH : (2.78) ,viscosity : (12 cp) , colour : (28) and specific rotation : (+40) .

The physicochemical properties of the prepared anti-acid were, the moisture content : (22.34%) , ash content : (48.38%) , pH : (6.19) , viscosity : (7.5 cp) , colour : (5) and specific rotation : (+0.5) .

The minerals content measurement using ICP/OES spectroscopy showed that the mineral contents of the pulp sample were Sodium : (83.905 ppm) , Magnesium : (828.588 ppm) and Calcium : (489.36 ppm) . The mineral contents of the prepared anti-acid were Sodium : (15712 ppm) , Magnesium : (16.431 ppm) and Calcium : (55.386 ppm) .

المستخلص

الهدف من هذه الدراسة هو تحضير مضاد للحمض من لب ثمار التمر هندي (العرديب) ولتحديد بعض الخصائص الفيزيائية والكيميائية للب ثمار العرديب وللمنتج (مضاد الحموضة).
جمعت عينات من ثمار العرديب من شمال كردفان (الأبيض). تم تحضير حمض التمر هندي باستخدام كروماتوغرافيا التبادل الأيوني. بعد ذلك ، عن طريق تفاعل حمض التمر هندي مع بيكربونات المغنيسيوم ، تم تحضير مضاد للحموضة.
أظهرت القياسات للب ثمرة العرديب أن محتوى الرطوبة كان (22.54٪)، محتوى الرماد: (3.69٪) ، الأس الهيدروجيني: (2.78) ، اللزوجة: (12 سنتي بواز) ، اللون: (28) والدوران النوعي: (+40).
أظهرت قياسات الخواص الفيزيائية والكيميائية لمضاد الحموضة المحضر ، أن محتوى الرطوبة: (22.34٪)، محتوى الرماد: (48.38٪) ، الأس الهيدروجيني: (6.19) ، اللزوجة: (7.5 سنتي بواز) ، اللون: (5) والدوران النوعي: (+0.5).
أظهر قياس المحتويات المعدنية للب ثمرة العرديب أن محتوى الصوديوم : (83.905 جزء في المليون) ، المغنيسيوم: (828.588 جزء في المليون) والكالسيوم: (489.36 جزء في المليون) .
كانت المحتويات المعدنية لمضاد الحموضة المحضر هي الصوديوم: (15712 جزء في المليون) ، المغنيسيوم: (16.431جزء في المليون) والكالسيوم: (55.386 جزء في المليون).

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1.1 Introduction

Tropical fruits, which are at present underutilized, have an important role to play in satisfying the demand for nutritious, delicately flavored and attractive natural foods of high therapeutic value. They are in general accepted as being rich in vitamins, minerals and dietary fiber and therefore are essential ingredient of a healthy diet. (Girma, 2014)

Medicinal plants are the back bone of Traditional medicine. They have been used in various systems, as they have potential against numerous diseases. (Bhadoriya, et al., 2011) .

Aradeib is scientifically known as *Tamarindus-indica L.*, fruit which belongs to the dicotyledonous family Leguminosae, sub-family Caesalpinioideae, is an important wild food plants in the tropics. It is a multipurpose tree of which almost every part finds at least some use either nutritional or medicinal. (Kumar and Bhattacharya, 2008)

Tamarindus Indica has been used for centuries as a medicinal plant; its fruits are the most valuable part which have often been reported as curative in several pharmacopoeias (Bhadoriya, et al., 2011).

1.2 Taxonomical classification

Kingdom	*Plantae*
Phylum	*Spermatophyte*
Class	*Angiosperm*
Sub class	*Dicotyledone*
Family	*Leguminosae*
Subfamily	*Caesalpiniaceae*
Genus	*Tamarindus*
Species	*indica*
Arabic name	Aradeib , tamrihindi.

(Bhadoriya, et al., 2011).

It is thought that Linnaeus gave the specific epithet indicus because the name tamarind itself was derived from Arabic which combined Tamar meaning 'date' with Hindi meaning 'of India'. The full Arabic name was Tamar-u'l-Hind and the word date included because of the brown appearance of tamarind pulp. (El-Siddeg, et al., 2006) .

1.3 Plant description and morphology:

Tamarindus Indica is Evergreen tree up to 20m high with a stout bole and compact rounded crown with drooping branches which cast a heavy shade beneath , dark grey to grey black rough fissured , branches unarmed. (Elamin, 1990)

Leaves are 5-16 cm long , pubescent . leaflets 10-18 pairs . oblong , rounded or emarginated at the apex and asymmetrical at base . glabrous except for tuftof yellow hairs at base. Sometimes pubescent up midrib and margin, 1.2-3.2cm long and 0.3-1.1cm wide, racemes up to 22cm long (Elamin, 1990)

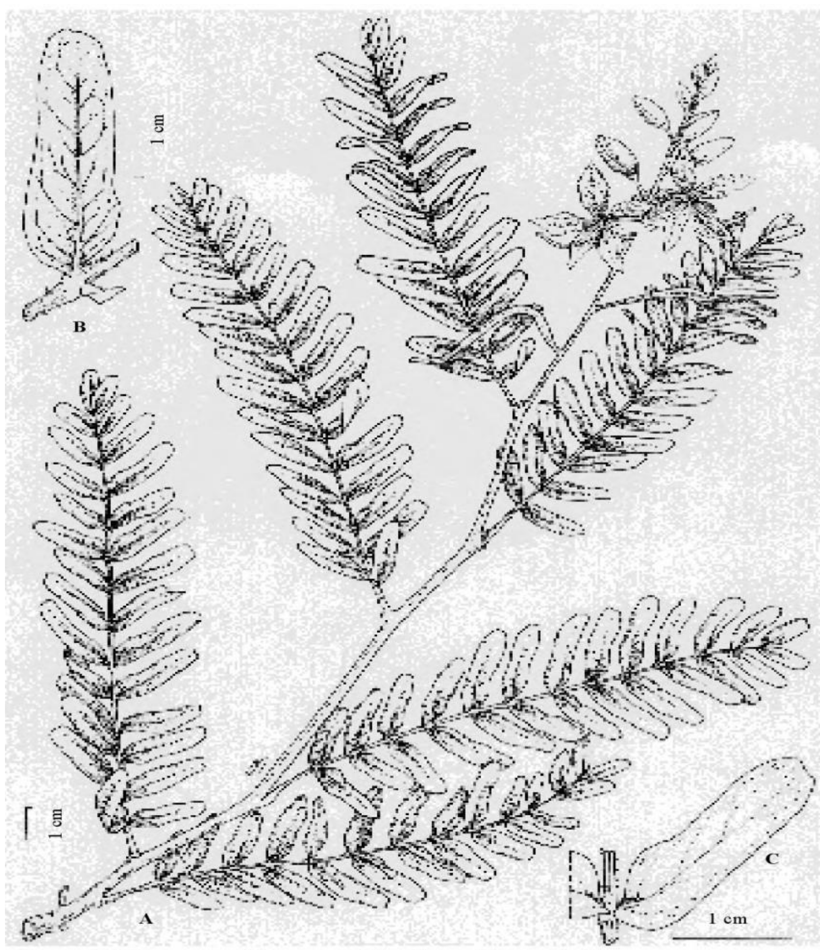


Figure 1.1 Compound leaves and leaflets of tamarind (El-Siddeg, et al., 2006) .

Flowers are borne in lax racemes which are few to several flowered (up to 18), borne at the ends of branches and are shorter than the leaves, the lateral flowers are drooping (El-Siddeg, et al., 2006).

Flower buds red ,4 sepals , 8-12 mm long ,pale yellow inside reddish outside. petals 3, yellow streaked with red or orange pods pale brown curved or sometimes straight sausage like , 3-14cm long ,2-3cm diameter, up to use at base and apex, sometimes irregularly constricted closely covered outside with brown scurf and a brittle shell containing 1-10 seeds joined one to another by tough fibres running through the sticky pulp. flowering May-July; fruiting Aug-March. (Elamin, 1990)

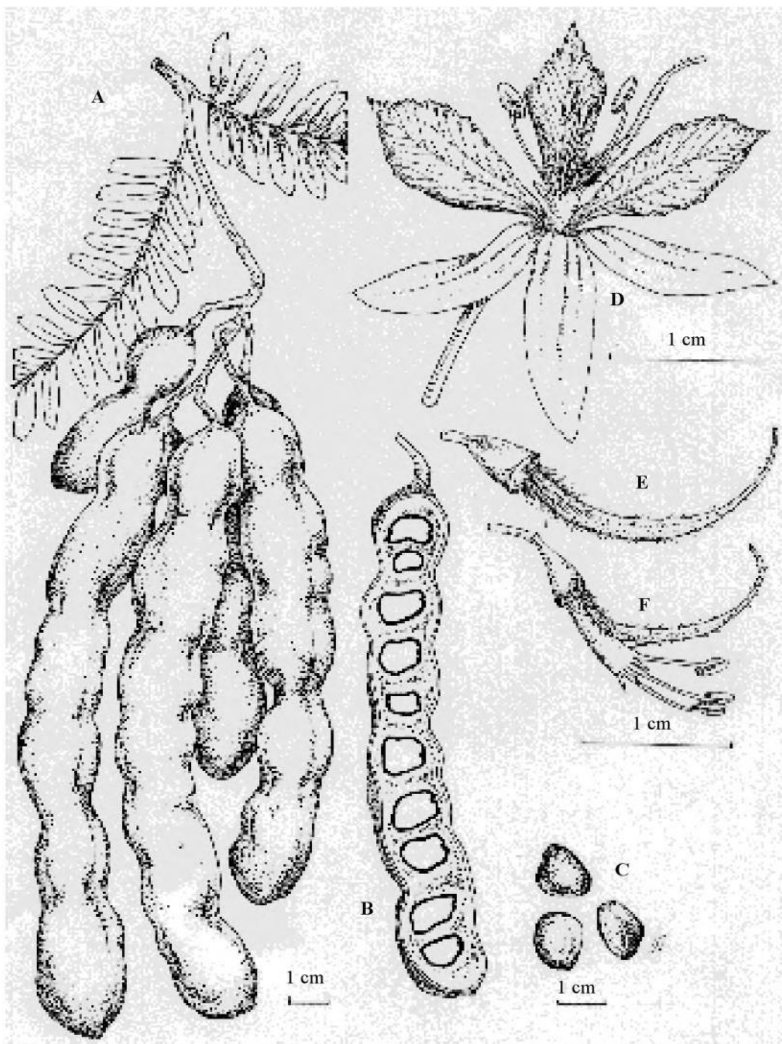


Figure 1.2 Flower and pods of tamarind showing the pistil, stamens and Seed (El-Siddeg, et al., 2006) .

The fruits are pods 5-10(-16) cm long × 2 cm broad, oblong, curved or straight, with rounded ends, somewhat compressed and indehiscent althoughbrittle The pod has an outer epicarp which is light grey or brown and scaly. Within is the firm but soft pulp which is thick and blackish brown. The pulp is traversed by formed seed cavities, which contain the seeds. The outer surface of the pulp has three tough branched fibres from the base to the apex

. Each pod contains 1-12 seeds which are flattened, glossy, orbicular to rhomboid, each 3-10 × 1.3 cm and the center of each flat side of the seed marked with a large central depression. Seed size is very variable and there are (320-)700(-1000) per kilo .Pods ripen about 10 months after flowering and can remain on the tree until next flowering period, unless harvested (El- Siddeg, et al., 2006).

Fig 1.3 (A) Fruits, (B) Leaves, (C) Flowers, (D) Stem bark of T. indica (Zohrameena,et al., 2017) .

1.4 Distribution:

Various geographical areas have been proposed for the origin of tamarind: India or the Far East or Africa but the consensus is that it is Africa. (Troup, 1921) placed it in Ethiopia, but others considered it indigenous to the drier savannahs of tropical Africa, from Sudan, Ethiopia, Kenya and Tanzania, westward through sub-Sahelian Africa to Senegal . Figure 1.4 shows the indigenous distribution. Around homesteads in Africa it is still wild or protected (El-Siddeg, et al., 2006). in southern parts of central Sudan from east to west and continuing southwards to S. Region also found in all parts of tropical Africa (Elamin, 1990).

Figure 1.4 The shaded area represents the approximate indigenous range of tamarind in Africa (El-Siddeg, et al., 2006) .

1.5 Chemical constituents of *Tamarindus -indica*:

The most valuable and commonly used part of tamarind tree is the fruit . Nutritional composition of tamarind fruit varies considerably depending on the climatic conditions of its growth , variation in genetic strains and different stages of maturity. A typical fruit contains 40% pulp ,34% seeds and 11 % shell (pod) and fibers (Balasubramanian, et al., 2018).
Phytochemical investigation carried out on *T. indica* revealed the presence of many active constituents, such as phenolic compounds, cardiac glycosides, l-(-)mallic acid, tartaric acid, the mucilage and pectin, arabinose, xylose, galactose, glucose, and uronic acid (Bhadoriya, et al., 2011).

Table 1.1 Mean composition of tamarind fruit (El-Siddeg, et al., 2006).

Constituents	Amount (per 100 gm)
Water	17.8-35.8 g
Protein	2-3 g
Fat	0.6 g
Carbohydrates	41.1-61.4 g
Fibre	2.9 g
Ash	2.6-3.9 g
Calcium	34-94 mg
Phosphorous	34-78 mg
Iron	0.2-0.9 mg
Thiamine	0.33 mg
Riboflavin	0.1 mg
Niacin	1.0g
Vitamin C	44 mg

1.5.1 *Tamarindus –indica* pulp:

Tamarind pulp contains different organic acids like : tartaric acid , acetic acid , citric acid , formic acid , malic acid and succinic acid . Pulp is a good source of the B vitamins (thiamin , niacin and riboflavin) 4.79 mg/100 g , vitaminE 93.16 mg/100 g (Balasubramanian, et al., 2018) .

The major volatile constituents of tamarind pulp include furan derivatives (44.4%) and carboxylic acids (38.2%), the components of which are furfural (38.2%), palmitic acid (14.8%), oleic acid (8.1%) and phenyl acetaldehyde (7.5%) . According to Lee, et al., (1975) , the most abundant volatile constituent of tamarind pulp is 2-acetyl-furan, coupled with traces of furfural and 5-methylfurfural, which form the total aroma of tamarind.

The total content of volatile compounds in fruit pulps can be around 3 mg/kg. Apart from the major volatile components listed above there may be up to 81 different volatile substances (El-Siddeg, et al., 2006).

The dried tamarind pulp of commerce contains (8–18 %) tartaric acid (2, 3-dihydroxy butanedioic acid–$C_4H_6O_6$, a dihydroxy carboxylic acid) and (25–45 %) reducing sugars, of which 70 % is glucose and 30 % fructose (Sulieman, et al., 2015).

Lewis and Neelakantan (1964), reported that one half of the tartaric acid was present as potassium bitartrate (cream of tartar) and to a lesser extent as calcium tartrate. The tender fruits contain most of the tartaric acid in free form (up to 16%), which can be easily extracted with hot water. (Lewis, et al., 1961) also reported that tartaric acid is present at all stages of fruit development as an optically active (+) isomer (El-Siddeg, et al., 2006).

The ascorbic acid content in tamarind is very small and varies from 2-20 mg/100g (Lewis and Neelakantan, 1964). The tamarind pulp does not contain any detectable amounts of phytic acid, but the trypsin activity is higher than in the seed

Tamarind fruit pulp has a sweet acidic taste, due to a combination of high contents of tartaric acid and reducing sugar (Balasubramanian, et al., 2018). The dry pulp also consists of about (4 %) protein and (1%) fat (Balasubramanian, et al., 2018). The pulp contains oil , which is greenish in colour and liquid at room temperature .the saponification value of the oil is high but the iodine value is low . Some physicochemical properties of the pulp and seed are shown by (table 1.2).

table 1.2 Physicochemical properties of lipid extracted from the pulp and seed of tamarindus fruit (El-Siddeg, et al., 2006).

Physicochemical property	pulp	seed
Saponification value (mg KOH g-1)	301.3	266.6
Iodine value	120.6	78.1
Acid value (g kg-1)	896.0	292.6
Free fatty acid (g kg-1)	448.0	46.3

According to Rao, et al., (1954) about 55% of the total nitrogen in the tamarind pulp was non-protein N or soluble in 10% trichloroacetic acid, and 70% is free amino acids. The following free amino acids were identified in the tamarind pulp: proline, serine, beta-alanine, phenylalanine and leucine. These amino acids were present in higher quantities in the ripe fruits than in immature fruits, indicating the accumulation of free amino acids during the maturation and ripening of tamarind.

Tamarind pulp is rich in minerals: potassium (62-570 mg/100g);phosphorus (86-190 mg/100 g); and calcium (81-466 mg/100g), and a fair source of iron (1.3-10.9 mg/100g).

El-Siddeg, et al.,(2006) reported magnesium (25.6-30.2 mg/100g) , sodium (23.8- 28.9mg/100g) , copper (0.8- 1.2 mg/100g) and zinc (0.8-0.9mg/100g) .

1.5.2 *Tamarindus –indica* seeds :

The seed comprises the seed coat or testa (20-30%) and the kernel or endosperm (70-75%) . Tamarind seed is the raw material used in the manufacture of tamarind seed kernel powder (TKP), polysaccharide (jellose), adhesive and tannin.

The whole tamarind seed and kernels are rich in protein (13-20%), and the seed coat is rich in fibre (20%) and tannins (20%) . (Panigrahi, et al., 1989) reported that whole tamarind seed contains (131.3 g/kg) crude protein, 67.1g/kg crude fibre, (48.2 g/kg) crude fat, (56.2 g/kg) tannins and trypsin inhibitor activity (TIA) of (10.8), with most carbohydrate in the form of sugars and(14-18%) albuminoid tannins located in the testa.

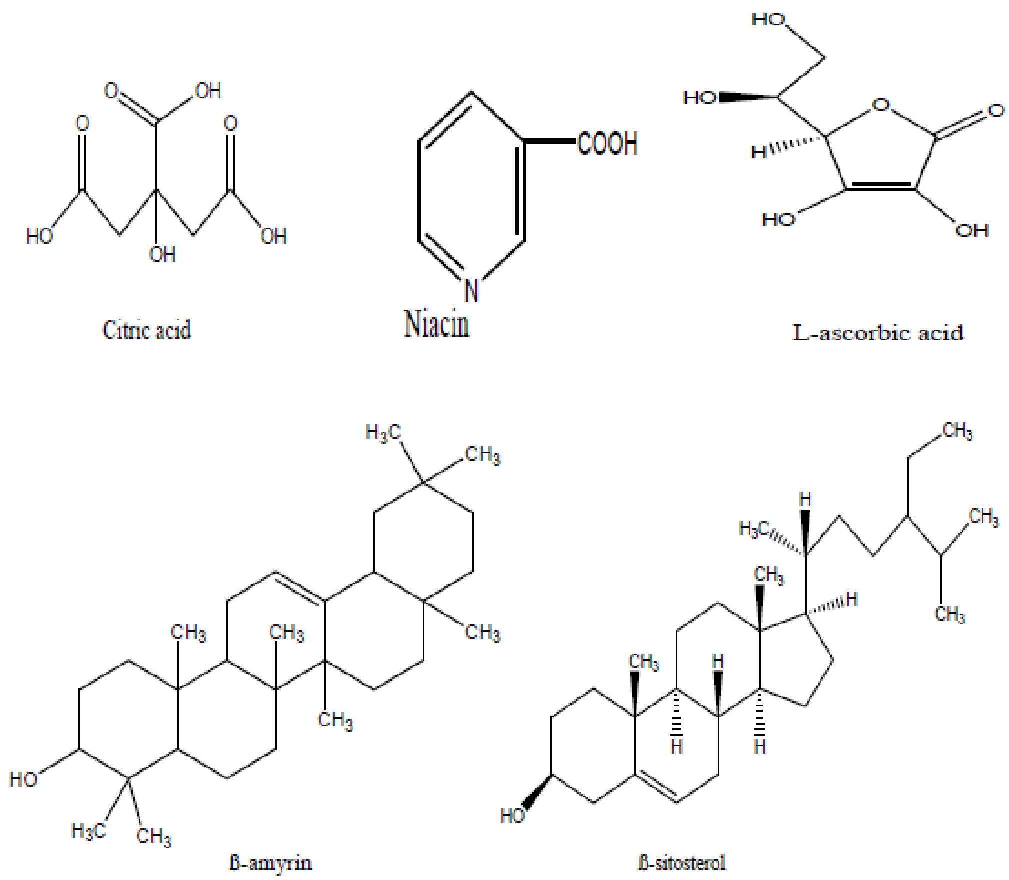
According to Purseglove, (1987), the seeds contain (63%) starch and (4.5-6.5%) of semi drying oil (El-Siddeg, et al., 2006).

The seed kernel oil is golden yellow , semi drying oil , the major fatty acid in it were palmitic , oleic , linoleic and eicosanoic . The seed kernel is rich in phosphorus , potassium and magnesium . The macronutrients, calcium, magnesium, potassium and phosphorus, however, were low in comparison with other cultivated legume (El-Siddeg, et al., 2006). Tamarind seeds comprised procyanidins , represented mainly by oligomeric procyanidin (Balasubramanian, et al., 2018).

1.5.3 Leaves and flowers :

Tamarind leaves contain (4.0-5.8%) proteins while the flowers contain only (2-3%). The leaves are fair source of vitamin C and beta – carotene and themineral content is high , particularly in Potassium , Phosphorous , Calciumand Magnesium.

Leaves contain tartaric acid and maleic acid ,the latter is found in excessand increases with the age of the leaves. Oxalic acid (196 mg/100g) is also present and the tender leaves show a good calcium/ oxalate ratio of 1:1 at pH 4.5. This indicates that the leaves are a good source of calcium, however, the presence of oxalic acid may effect the nutritive value (El-Siddeg, et al., 2006).



Figures: 1.5. Chemical structure of some phytoconstituents from *Tamarindus- indica*. (Zohrameena, et al., 2017) .

1.6 *Tamarindus-indica* polysaccharides :

Polysaccharides are long chains of monosaccharides which are storage house of energy. There are different sources for polysaccharides which , include plant seeds, plant cell wall, seaweed extracts, bacterial cell wall, plantroots tubers, etc (Joseph, et al., 2012).

It was well known that the molecular properties (*e.g.*, molecular weight, monosaccharide composition and spectroscopic characteristics), conformational behavior (*e.g.*, radius of gyration, hydrodynamic radius and their ratio) and structural attributes (*e.g.*, linkage, sequence and modelling of glycosidic bonds) of polysaccharides could be closely correlated to various biological activities, as well as physicochemical, functional and technological properties .

It is assumed that the molecular and structural characteristics of polysaccharides from tamarind pulp could be essential for elucidating its technological and medical functions (Guo, et al., 2020).

Gas chromatography analysis allowed identification of the sugar components and types of linkages of the polysaccharide from tamarind pulp in the hydrolyzed sample of partially purified polysaccharide: glucose: xylose: galactose at a molar relation of (3.3:1.5:0.5); fructose residues (2.91%) and arabinose (3.59%), as well as rhamnose (3.41%). The signals characterizing the β-D-glucan were confirmed in (32.45%) (Izquierdo, et al., 2007).

According to Guo, et al., (2020), monosaccharide composition, macromolecular properties, spectroscopic patterns and structural characteristics were investigated in terms of polysaccharides extracted from tamarind pulp via ultrasound. the crude polysaccharide from tamarind pulp (CPTP) was extracted using 200 W ultrasonic extraction at 50 C for 40 min with a solid-liquid ratio of 1:30 g/mL, and its maximum yield was (31.94 ± 0.70 w/w) , based on pulp powder mass.

Table 1.3 Chemical and monosaccharide compositions of the crude polysaccharidefrom tamarind pulp CPTP.

Chemical compositions	**W/W %**
Moisture content	9.32 ± 0.44
Total sugar	66.21 ± 3.58
Protein	3.39 ±0.99
Uronic acid	8.02 ± 2.43
Monosaccharide compositions	**mol %**
Fucose	1.76
Rhamnose	8.32
Arabinose	57.49
Galactose	-
Glucose	21.28
Galacturonic acid	9.03
Glucuronic acid	2.12
Total uronic acid	11.15

Tamarind seed polysaccharide (TSP) , known as tamarind gum , acts as a cell wall storage unit in seed and can be extracted from the tamarind kernel powder obtained from tamarind seeds (Izquierdo, et al., 2007) . TSP has an average molecular weight of (52,350 Dalton) and it is called as a galactoxyloglucan. TSP contains monomers of glucose, galactose and xylose sugars present in a molar ratio of (3:1:2) , which constitutes about 65% of the seed components.Various studies identified it as a non-ionic, neutral, hydrophilic,mucoadhesive, highly branched polysaccharide consisting of a cellulose-likebackbone that carries xylose and galactoxylose substitution at the glucan chain (nearly 80%), chemical residues similar to those of membrane spanningmucin (Joseph, et al., 2012) . According to Shao, H., et al, (2019), a polysaccharide that extracted from tamarind (Tamarindus indica L.) seed (TSP) by acidic hot water extraction and ethanol precipitation was composed of 86.2% neutral polysaccharide, 5.4% uronic acid and 1.3% protein.

According to Izquierdo, et al., (2007), polysaccharide (amyloid) has been isolated from the cellular walls of the cotyledons of the *T. indica*. seeds . Polyglucose has been identified as a xyloglucan (XG) and a main chain with β-(1→4) linkages to glucose residues, with a double helix conformation, and substitution patterns with lateral chains .

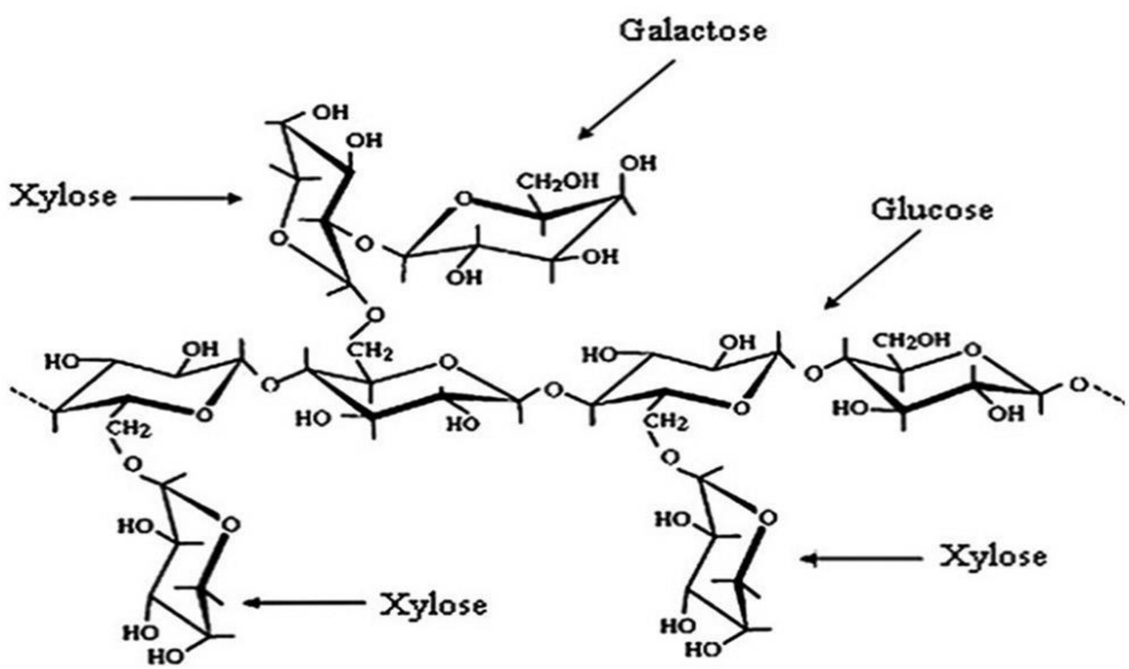


Figure 1.6: Structure of tamarind seed polysaccharide (Izquierdo, et al., 2007).

1.7 Physicochemical properties of *Tamarindus- indica*:

The knowledge about physical and chemical properties like size, weight, moisture content, protein content, carbohydrate content *etc.* of any biomaterial is essential to designing its equipment for processing , storage , transportationand for the value addition. (Sinha, et al., 2012)

1.7.1 Moisture content :

The moisture content is weight lost due to the evaporation of water (Person, 1970). normally fruits are left to ripen on the tree so that about 20% moisture content is reduced before harvesting (Naeem, et al., 2017). Physical properties of Tamarind fruit like size, length, breadth, thickness and weight of fruit (pulp weight, seed weight, shell weight etc) followed a declining trend with decrease in moisture content of the tamarind fruit. The chemical properties like total soluble solids, protein content, carbohydrate content, fat and ash content followed an increasing trend but the titratable acidity is decrease with decreasing the moisture content of the fruits (Sinha, et al., 2012).According to (Sulieman, et al., 2015). The moisture content of tamarind pulp from El-Gedaref was found to be 15.20 % , while moisture content of tamarind from El-Damazin and El-Obeid was found to be (5.8% , 7.9%) .

1.7.2 Colour :

The unripe fruit pulp is green in color, while the ripe pulp is light brownish red. (Obulesu, M. and Bhattacharya, S., 2011)
The fruit contains a variety of pigments. The red colour is due to water soluble red-rose anthocyanin pigment, while in the common types of pulp leuco-cyanidin is present (El-Siddeg, et al., 2006).
Colour parameters of tamarind pulp according to Obulesu, M. and Bhattacharya, S., (2011)**:**
Green tamarind pulp (L, a, b) : 60.0, −2.8, 19.8
Ripe tamarind pulp (L, a, b) : 30.6, 8.7, 15.5
(L, a , b) color parameters . The values of L denote brightness.
a indicates redness or greenness with positive and negative values
b means yellowness or blueness with positive and negative values.

During storage ,The brownish-red color of the tamarind pulp turns darker and within one year, it becomes almost black. (Obulesu, M. and Bhattacharya, S., 2011)
The darkening of tamarind pulp or the color changes during developmental stage of tamarind fruit as well as during storage of tamarind pulp is due to non-enzymatic browning Maillard reaction , Reaction of sugars with amino acids through Maillard reaction is responsible for the non-enzymatic browning in food and agricultural products . Lysine is the major amino acid that contributes to this type of reaction as it has a free ε-amino group that can readily react with reducing sugars (Obulesu, M. and Bhattacharya, S., 2011).

1.7.3 pH value :

Acids present in foods are not only improve the palatability of many fruit products but also influence their nutritive value by playing significant role in the maintenance of acid-base balance of the body. The acids influence the flavor, brightness of color, stability, consistency and keeping quality of the product (Girma, 2014) .

The titratable acidity of tamarind pulp from Gedaref, Damazin and El-Obeid were (30%, 38.5% and 28.7%), respectively , as tartaric acid which is relatively lower than (43.4%) documented by (Sulieman, et al., 2015). During room temperature storage, it was found that the titratable acidity, moisture contents and reducing sugars increased , while pH value decreased (Naeem, et al., 2017) The reduction of pH leads to inhibition of food spoilage , microorganisms growth, hence extending the shelf life of tamarind and its products like juice, vinegar and pickles (Sulieman, et al., 2015) . According to Sulieman, et al., (2015) the pH of tamarind from El-Gedaref was found to be 3.4, which was higher than those obtained by Duke who reported a pH of 3.15, while the pH of tamarind from El-Damazin and El-Obeid were found to be (3.1 and 2.9), respectively.

1.7.4 Solubility :

Tamarind- indica is soluble in water , alcohol , ether , chloroform (Panda, 2010). Tamarind pulp powder is highly soluble in water (Sharangi & Datta, 2015).

1.7.5 Ash content :

The percentage ash content of the sample gives an idea about the inorganic content of the samples from where the mineral content could be obtained. Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements, which are expected to speed up metabolic processes and improve growth and development. (Girma, 2014) According to Sulieman, et al.,(2015). tamarind fruit pulp from Obeid was found to be 3.9% while the ash content of tamarind from El-Damazin and El-Gedaref were found to be 5% and 3.95%, which is higher than those documented by (Morton, 1987) who reported a range of 2.6% - 3.9% . The variation in ash content could be attributed to the difference in environmental factors (Sulieman, et al., 2015).

1.7.6 Specific rotation:

A polarized light when passed through an optically active substance , each molecule of it encountered by the light beam rotates the plane of polarization by a constant amount characteristic of the substance (Kar, 2005).The optical activity of organic molecules (saccharides and carbohydrates) is related to their structure and a characteristic property of the substance. (Stevens *et al.*, 1987). Specific rotation is a characteristic property of a certain substance and it is standard measurement for optical rotation for that substance. Lewis, et al., (1961) reported that tartaric acid is present at all stages of fruit development as an optically active (+) isomer. The most commonly found isomer in fruit is malic acid; about 1.37 mg/l existed as the (-) form in tamarind fruits.

1.8 Uses of various parts of *T-indica* :

Tamarind pulp is used as a raw material for the manufacture of several industrial products, such as tamarind juice concentrate (TJC), tamarind pulp powder (TPP), tartaric acid, tamarind kernel powder (TKP) (El-Siddeg,et al., 2006).

The sweet fruit pulp is eaten and made into a cooling drink (Elamin, 1990) . In India, TKP is used as a source of carbohydrate for the adhesive or binding agent in paper and textile sizing, and weaving and jute products , The sizing property of (TKP) is due to the presence of up to (60%) of the polysaccharide (El-Siddeg, et al., 2006). The oil from the seeds can be made into a varnish (Elamin, 1990)

The seed testa contains (23%) tannin, which when suitably blended is used for tanning leather and imparting colour-fast shades to wool. In leather tanning tests, tamarind tannin gives a harsh and highly coloured leather that could be used for heavy soles, suitcases etc. (El-Siddeg, et al., 2006).

Sap wood is yellowish white , sometimes with red streaks ,the heart wood in dark brown mottled with black in old trees , hard , heavy , difficult to work , polishes well and resists insect attacks . the wood is used for house utensils , furniture cabinet work , pestles and morters , tool handles , constructional work ,house posts , boat building ,carts and oil mills. the roots are used for chest complaint (Elamin, 1990).

The tree is a host of silk worm and the silk is made into fabrics .The tree is planted in gardens and avenues as a good shade tree , it also produces good firewood and charcoal (Elamin, 1990).

1.8.1 Medicinal Uses:

1.8.1.1 Pulp :

Tamarind pulp has long been used for many medicinal purposes and continues to be used by many people in Africa, Asia and America. In former times, the fruit pulp was used as a gentle laxative .Tamarind pulp alone or in combination with lime juice, honey, milk, dates, spices or camphor is used as a digestive and a carminative, even for elephants, and as a remedy for biliousness and bile disorders and febrile conditions. It isused as a gargle for sore throats and dressing of wounds. (El-Siddeg, et al., 2006)

The fruits are reported to have anti-fungal and anti-bacterial properties . This activity is believed to be due to the presence of saponins in the fruit. And phenolics (including flavonoids such as orientin and vitexin as well as to lupeol (Ravindran, 2017).

Fruit extracts have been shown to enhance the bioavailability of ibuprofen in humans . Frequent research on aqueous extracts of seeds has shown a strong anti-diabetic effect in rats. (El-Siddeg, et al., 2006)

Tamarind pulp has laxative properties , the laxative property is due to the presence of its high acid content such as malic acid and tartaric acid and high potassium content.

Tamarind fruit extract showed weight reduction and hypolipidaemic properties , it is thought that tamarind shows this effect with increasing dopaminergic transmission , regulating lipid metabolism and decreasing plasma leptin level (Ravindran, 2017). It is available commercially in tablet form in Thailand for the reduction of excess weight. (El-Siddeg, et al., 2006).

Tamarind pulp extract significantly reduced plasma fluoride concentration and ameliorates fluoride- induced liver and kidney damage , moreover tamarind seed shell powder impregnated with iron oxide is capable of removing fluoride and other heavy metal ions (like arsenic from drinking water. (Ravindran, 2017).

1.8.1.2 Seed :

The seed is usually powdered and is often made into a paste for the treatment of most external ailments. In Cambodia and India , it has been reported that powdered seeds have been used to treat boils and dysentery , it has also been externally applied on eye diseases , ulcers, chronic diarrhea and jaundice. It is found that an ethanol extract prepared from the seed coat exhibited anti-oxidative activity ,this suggests that tamarind seed coat , a by-product of the tamarind gum industry , could be used as a safe and low-cost source of antioxidant (El-Siddeg, et al., 2006).

tamarind seed has a significant and dose- dependentprotective effect on peptic ulcer induced by ibuprofen , alcohol and pyloric ligation in animal models . the protective effect is attributed mainly to the procyanidin epicatechin and polymeric tannin .these compounds are well known for their anti-oxidant effects and they offer protection against free radicals. Tannins also prevent ulcer development by causing protein accumulation and vasoconstriction (Ravindran, 2017).

1.8.1.3 Leaves :

Tamarind leaves are usually ground into powder and used in lotions or infusions ,the leaves , mixed with salt and water , are used to treat throat infections , coughs , fever , intestinal worms and liver ailments . leaf extracts also exhibit anti-oxidant activity in the liver. young leaves are reported to cure other eye infections , sprains and wounds (El-Siddeg, et al., 2006) .

1.8.2 *Tamarindus- indica* as Anti-acids :

Acidity is a frequently occurring gastrointestinal disorder that can occur due to diverse reasons which is related to heartburn and gas formation in stomach. In acidity, gastro esophageal reflux disease, there is a movement of gastric acid from the stomach into the lower esophagus. (Pawar , et al., 2018).

Gastric acid is a digestive fluid formed in the stomach having a pH of 1 to 2. It is a mixture of hydrochloric acid, large quantities of potassium chloride and sodium chloride. Herbal remedies are complex chemical combinations prepared from plants that are extensively used in health management (Pawar , et al., 2018) .Antacids efficacy is based on their inherent ability to react with and neutralize gastric acid . (Ebadi, 2006).

Antacids herbs are recommended for their ability to soothe inflamed tissues of the esophagus , and reduce excess stomach acid . (Milunovich, 2014)

The ash of tarmarind showed moderate acid neutralizing capacity (17.25±3.97) mEq. HCl (Nahar, et al., 2007)

1.9 The objectives of this study were are :

- To study of physicochemical properties of tamarind pulp.
- To prepare an anti-acid from tamarind pulp.
- To characterize the anti-acid product.

Chapter Two
Materials and Methods

2. Materials and Methods

2.1 Collection of samples :

Samples of a Aradeib fruit were collected from tamarind tree.

2.2 Chemicals :

- Sulfuric (98% v/v).
- Nitric acid conc
- Barium chloride.
- Sodium bicarbonate.
- Amberlite cation exchange resin.

2.3 Instruments:

- Refractometer
- Halogen Moisture Analyzer
- Visual Colorimeter
- Digital Viscometer
- Polarimeter
- Hot air Oven.
- Sensitive Balance.
- Ion meter.
- Furnace.

2.4 Preparation of Tamarind Sample

Tamarindus- indica fruits sample were obtained from Western Sudan (El-Obeid).

The tamarind samples were then cleaned from foreign materials and the seeds were removed from the pulp .

25g of the pulps were soaked in 500 ml deionized water for 24 hours, then the sample was filtered .

2.5 Preparation of Tamarindus acid:

Ion exchange column packed with Amberlite (IR-120H+) resin was thoroughly washed with 2.M H_2SO_4 ,Then deionized water were passed until the column was Sulfate free .

tamarind pulp sample (5%) was slowly passed down the column .

2.6 Preparation of magnesium Tamarind anti-acid :

450g of Magnesium bicarbonate were weighed and then was added to 400 ml of Tamarindus acid in 500 ml beaker and then transferred in a petry dish and was dried for three days at room temperature , after that it was grinded .

2.7 Methods of Analysis :

The following analytical methods were adopted in this study:

2.7.1 Determination of moisture content*:*

Moisture content of Tamarind fruit pulp sample and the product (Tamarind anti-acid) were estimated according to AOAC (2000) using the official method 925.09. A clean crucibles were dried in an oven at 105C for 30 minutes , cooled in a desiccator and then weighed (M1). About 2 grams of sample were placed in the crucible and weighed accurately (M2). Contents were heated in an oven for 4 hours at 105C. Then it is cooled and re-weighed (M3). Loss percentage on drying was calculated as follows:

$M2 - M3/M2 - \text{M1 X 100}$

Where: The determination was conducted according to AOAC (1990).

M1: Weight of the empty crucible

M2: Weight of crucible +sample

M3: Weight of crucible +sample after drying

2.7.2 Determination of ash content :

Total ash was determined according to AOAC (1990). Crucibles were heated in an oven for 30 minutes cooled in a desiccator and then weighed (W1). About Five grams of tamarind pulps and the anti-acid were placed in the crucibles and accurately weighed (W2), then ignited at 550 C in a muffle furnace for 6 hours, Then they were cooled and weighed (W3).

Total ash% was calculated as follows:

$W3 - W1 / W2 - \mathrm{W1} \times 100$

Where:

W1: Weight of the empty crucible

W2: Weight of crucible +sample

W3: Weight of crucible +sample after drying

2.7.3 Determination of pH value:

pH values were determined according to AOAC (1984) using official method 14.022. pH was determined in 5% aqueous solutions using Ion Meter 3205 JENWAY. Two standard buffer solutions of pH 4.00 and 7.00 were used for the calibration of the pH meter. The temperature was kept at 25°C and the pH was let to stabilize for one minute and then the pH of tamarind pulp solution, the eluent and the Anti-acid were read directly. The readings were repeated three time for each formulation.

2.7.4 Determination of specific rotation:

1 g/100cm-3 aqueous solution of Tamarind pulp was prepared, the solution was filtered . Optical rotation was measured using a(2dm=20cm) tube filled with the test solution, at room temperature specific optical rotation was calculated (Omer et al., 2015).

Specific rotation = $\alpha \times 100 / C \times L$ =⋯…dm^{-1} mL g^{-1}

Where:

α = observed optical rotation

C = concentration of the solution (g/ml)

L = length of the Polarimeter tube (dm)

2.7.5 Determination of viscosity :

(25%) aqueous solution of Tamarind pulp and the final product (tamarind anti-acid) were prepared ,then the viscometer was operated and the sample was transferred into sample cup (chamber) , the viscometer spindle was inserted and centered in the test sample and the motor "on" key was pressed ,6min was allowed for the indicated reading to stabilize after that the motor "off " key was pressed and the results were recorded.

2.7.6 Determination of colour :

(25%) aqueous solution of Tamarind pulp and the final product (tamarind anti-acid) were prepared and located at the cuvette (optical glass cell) ,the colorimeter was switched on, all the racks were pushed to their extreme left position .
While looking into the eyepiece, the tabs controlling the coloured filters were slid to the right until the colour match was obtained. then the results were recorded .

2.7.7 Determination of mineral content :

The mineral elements contents of tamarind fruit pulp, the eluent and the final product (tamarind anti-acid) were determined using ICP/OES as described by the procedure of AOAC (1984). All values were expressed in mg/Kg.
Accurately 5.7411 grams of Tamarind pulp sample and 5.0265 gm of tamarind anti-acid were weighed in clean beakers , to each beaker ashless paper was added ,then the beakers were placed on hot plate and heated until the ashless paper ignited and burned off , leaving no trace of the filter paper, after that the samples were ignited to ash in a muffle furnace at 550oC for 6 hours.
After removal of organic material by dry ashing ; the residue was dissolved in 20 ml of HNO3 & H2O (1:1) and it was boiled on the hot plate until the volume was about 3 ml ,then the ash solution was cooled to room temperature and allowed to stand for 15-20 minutes and filtered through a filter paper into a 50ml volumetric flask. The beakers were washed three times with de- ionized water; the washings were filtered into the flask. Then the solutions were diluted to the mark (50ml) with de-ionized water. A blank was preparedby taking the same procedure as the samples.

Chapter Three
Results and Discussion

3. Results and Discussion :

Table 3.1 : Physicochemical Properties of Tamarind pulp

Physicochemical properties	
Moisture content %	22.54
Ash content %	3.69
pH	2.78
Viscosity (cp)	12.5
Colour	28.4
Specific Rotation dm^{-1} mL g^{-1}	+40

Table 3.1 shows the physicochemical properties of tamarind fruit pulp : The moisture content of the tamarind pulp was found to be (22.54 %) , Such result was in agreement with the reported value (17.8 – 35.8%) for moisture content of ripe tamarind fruit pulp by (K. El-Siddig, 2000) and higher than the value 7.90 ± 0.05 % reported by (Sulieman, et al.,2015) , The variation in moisture content of tamarind pulp could be due to thestorage conditions, environmental conditions, as known Sudan has a tropicalclimate which is hot most of the year.

The ash content was found to be (3.69%),The value of Ash content of tamarind pulp falls within the range of the resultsobtained by (Morton, 1987), (Coronel, 1991) and (El-Siddeg, et al., 2006), who reported a range of (2.6% - 3.9%) .

The pH of tamarind pulp was found to be (2.78), which was lower than those obtained by (Sulieman, et al., 2015) who reported a pH of 2.95 ± 0.26 ,The result indicated that the pulp was fairly acidic. It might be due to the organic acids such as citric and tartaric acids existing in the tamarind.
The colour component of tamarind fruit pulp was found to be (28).
The viscosity of tamarind fruit pulp solutionwas found to be (12.50) cP .

Table 3.2 : Physicochemical Properties of Tamarind Anti-acid

Physicochemical properties	
Moisture content %	22.34
Ash content %	48.38
PH	6.19
Viscosity (cp)	7.50
Colour	5
Specific Rotation dm^{-1} mL g^{-1}	+0.5

Table 3.2 shows the physicochemical properties of Tamarind Anti-acid :
The moisture content of Tamarind Anti-acid was found to be (22.34 %) .

The ash content was found to be (48.38 %). The percentage ash content of the sample gives an idea about the inorganic content of the samples . Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements. Therefore , the higher value of ash content in the final product (Tamarind anti-acid) over the ash content of tamarind pulp indicates a high level of inorganic component .

The pH of the eluent (tamarindus acid) was found to be (2.09) while the pH of the final product (tamarind anti-acid) showed in table 3.2 was foundto be (6.19) .
Decreasing of pH value of the eluent (2.09) compared to the pulp solution (2.78) indicates and confirms that the positive ions were present in the pulp solution have been exchanged for Hydrogen ions ($\mathbf{H^+}$) during the ion-exchange process .
The increasing of pH of the final product (tamarind anti-acid) (6.19) compared to the eluent (2.09) indicates that the hydrogen ions have been substituted for base cations (Magnesium Ions).
The colour component of tamarind anti-acid was found to be (5).
The viscosity of tamarind anti-acid was foundto be (7.5) cP .

Table 3.3 : Mineral content of Tamarind pulp , the Eluent and tamarind Anti-acid ppm (mg/kg) .

Sample	Na	Mg	Ca	V	Fe
Tamarind pulp	83.905	828.588	489.36	1.15	42.428
Eluent	14.146	1.087	1.865	0.099	0.284
Tamarind anti-acid	15712	16.431	55.386	1.093	51.44

The concentration of Sodium presentin tamarind pulp Sample was (83.905 ppm) , Magnesium (828.588 ppm) , calcium (489.36) , Vanadium (1.15 ppm) and Iron was (42.428 ppm).
The eluent mineral composition was Sodium (14.146 ppm) , Magnesium (1.087 ppm) , calcium (1.865) , Vanadium (0.099 ppm) and Iron was (0.284 ppm).
The final product (tamarind anti-acid) mineral composition was Sodium (15712 ppm) , Magnesium (16.431 ppm) , calcium (55.386) , Vanadium (1.093 ppm) and Iron was (51.44 ppm).

The concentration of sodium present in tamarind pulp (83.905) was lower than the value (211.5 ppm) recorded by (Sulieman, et al., 2015) for the tamarind fruit pulp from El-obied (kordofan state).
Sodium and potassium are the chief cations in the extracellular fluid and help to maintain osmotic pressure of body fluid, which protects the body from excessive fluid loss. Their deficiency in the body leads to heart fatigue, muscular weakness, drowsiness and mental confusion (Manay & Shadaksharaswamy, 2001) .
The concentration of Sodium in the eluent sample (tamarindus acid) was found to be (14.146 ppm) , which was less than the estimated value in tamarind pulp sample (83.905 ppm) , this indicates that these ions were replaced during Ion Exchange process.

The concentration of Sodium in the final product (tamarind anti-acid) was found to be (15712 ppm) ,which confirms that the hydrogen ions that present in the eluent have been substituted by Sodium ions present in bicarbonate salt , therefore the final product is Sodium Tamarind anti-acid.
The concentration of magnesium in tamarind pulp was 828.588 ppm . This value was in close agreement with the reported value (849 ppm) by (Okello, et al., 2017) .
Magnesium is needed for more than 300 biochemical reaction in the body , it helps to maintain normal nerve and muscle function , supports a healthy immune system and it helps adjust glucose levels.
The concentration of Calcium in tamarind pulp was 489.36 ppm . This value was in close agreement with the reported value (340-948 ppm) by Coronel, (1991) and (El-Siddeg, et al., 2006) and lower than the value (1390 ± 10 ppm) recorded by (Sulieman, et al., 2015) for the tamarind fruit pulp from obied (kordofan state). Calcium help in regulation of muscle contractions, transmit nerve impulses and help in bone formation (Girma, 2014) .The recommended dietary allowance (RDA) for calcium is 800 mg/day. This shows that these fruit parts could be a good source of calcium (Girma, 2014).
The concentration of Iron in tamarind pulp was 42.428 ppm . This value was in an agreement with the reported value (13-109 ppm) by (Parvez, et al., 2003) , (El-Siddeg, et al., 2006) .
Iron main purpose is to carry oxygen in the hemoglobin of red blood cells throughout the body so cells can produce energy.

Conclusion :

This study gives an information about some of physicochemical properties of Tamarind .

- In conclusion it can be state that tamarindus indica fruit pulp from kordofan state (El-obeid) – Sudan can be characterized by the presence oflow amount of water and low pH value .
- The fruit pulp samples were rich in Iron , Magnesium and Calcium as well as high sugar concentration .
- Tamarind fruit pulp can be used in pharmaceutical industries for the formation of anti-acid active ingredient for producing anti-acid tablets.
- It is predicted from the study that anti-acid active ingredient "magnesium tamarindus acid " can be prepared from tamarind pulp and magnesium bicarbonate using the same procedure of preparation of sodium tamarindus anti-acid.

Recommendation :

- For antacid tablet formation , magnesium tamarindus anti-acid is recommended to be used preferably as active ingredient .
- Further research on functional efficiency of Sodium tamarindus anti-acid and magnesium tamarindus anti-acid in vivo may be needed in the future.
- Further work on other physicochemical and functional properties of tamarind fruit pulp may be needed to test its potential use in more applications.

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