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Chemical and Nutritive Content of Tamarind Fruits from Ukambani, Kenya

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LAP LAMBERT Academic Publishing

Impressum/Imprint (nur für Deutschland/only for Germany)
Bibliografische Information der Deutschen Nationalbibliothek: Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

Coverbild: www.ingimage.com

Verlag: LAP LAMBERT Academic Publishing GmbH & Co. KG
Heinrich-Böcking-Str. 6-8, 66121 Saarbrücken, Deutschland
Telefon +49 681 3720-310, Telefax +49 681 3720-3109
Email: info@lap-publishing.com

Approved by: Eldoret, Moi University, 2004

Herstellung in Deutschland:
Schaltungsdienst Lange o.H.G., Berlin
Books on Demand GmbH, Norderstedt
Reha GmbH, Saarbrücken
Amazon Distribution GmbH, Leipzig
ISBN: 978-3-8473-2164-4

Imprint (only for USA, GB)
Bibliographic information published by the Deutsche Nationalbibliothek: The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Cover image: www.ingimage.com

Publisher: LAP LAMBERT Academic Publishing GmbH & Co. KG
Heinrich-Böcking-Str. 6-8, 66121 Saarbrücken, Germany
Phone +49 681 3720-310, Fax +49 681 3720-3109
Email: info@lap-publishing.com

Printed in the U.S.A.
Printed in the U.K. by (see last page)
ISBN: 978-3-8473-2164-4

CHEMICAL AND NUTRITIVE CONTENT OF *TAMARINDUS INDICA* FRUIT PULP FROM UKAMBANI DISTRICTS IN KENYA

BY

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This work was presented to the faculty of Science in partial fulfillment of requirements for the award of the degree of Science at Moi University, Eldoret, Kenya.

JULY, 2004

DEDICATION

MY FAMILY

THANK YOU FOR BEING THERE FOR ME

ACKNOWLEDGEMENT

First and foremost to my God who gave me the chance to come this far.

To the Director Kenya Forestry Research Institute (KEFRI), Dr. Paul Konuche, for allocating me the funds used to collect and analyse the fruits.

The National Program Co-coordinator (NPC) Dry lands Program, (KEFRI), Dr. Ben Chikamai for facilitating the funds through his program.

To Stephen Karanja (KEFRI – Kitui), T.k. Mutisya (DFO's Office Mwingi); and Eliud Munde (KEFRI – Kibwezi) for their great assistance in site location and collection of fruits.

Most sincere gratitude to my supervisor, Dr. L.Kituyi for his willingness to support, guide and supervise my WORK thus making it a success. The entire Chemistry Department especially Ms. Julia, Mr. Karanja for the part they played in ensuring chemicals were available and successful use of Atomic absorption Spectrometer.

My fellow students Amina and Linus for availing their computer for typing the project.

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LIST OF ABBREVIATIONS

KV1.....Kavisuni
MK1.....Makindu
MB2.....Mbitini
KT3.....Katse
KY.....Kyanundu
TR3.....TARDA

CHAPTER ONE

1.0 INTRODUCTION

1.1 General

Since time immemorial human beings have used natural vegetation as a source of food. Trees provide fruit which cuts across the whole spectrum of society with the degree of reliance being reflected more in the low income group and communities living in marginal areas. Traditionally people ate fruit from the wild trees between meals while herding or working in the fields. This is still the case today.

Kenya has a variety of indigenous food plants that are under exploited and are now also in danger of disappearing. Although indigenous fruits have always played an important role in the diet of many communities, most of them grow in the wilderness and now domestication is being done (Imbabi *et al.*, 1992).

With increasing population in Kenya, and need for agricultural land many of these indigenous fruit trees are being cleared as land is opened for cultivation. There is pressure on land which has led to deforestation and environmental degradation (Ondachi, 1999).

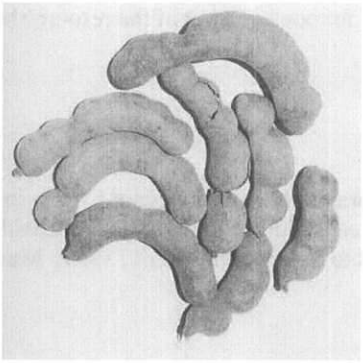
Modern times have also brought new food habits and several new crops and the

plants from which traditional foods were obtained are now facing double tragedy i.e. genetic erosion and loss of traditional knowledge on how to grow and use them. Little has been done to conserve the germplasm of these important species and also very little is known about their chemical composition (Muok, 2001).

Tamarindus indica found in the Caesalpiniadae family of the Fabaceae species, is an evergreen savannah tree indigenous to tropical Africa and is widely cultivated and used in the Sahel, South East Asia, the Carribean and Central America. It measures 4 – 15m with thick bole and spreading crown (Beentje, 1994). The bark is rough grey – brown. It is semi – domesticated food resource picked from the wild but often planted on a small scale in crop land a near homesteads.

The fruit is a sausage shaped pod to 10cm or more. Young fruits are greenish brown turning rusty brown at maturity. Dry fruit coat is brittle while pulp is reddish brown. The seeds are dark red.

The fruits appear as seen in the picture below;



In Kenya, the tree is found in lowlands, 0 – 1600m, usually 0 – 1300m. It is very common in the drier parts of the coast and along rivers and streams in the humid semi – arid areas. Rainfall ranges between 250 – 1200mm. The plant is not restricted to riverine environments.

In the past, there has been little emphasis on growing of indigenous tree in the farms. Efforts have been laid mainly on the cultivation of exotic fruit tree species, since the agronomic and market information is available on the exotic species. The only attempt that has been made is to leave out some important trees standing when clearing bushes for agricultural practices. Due to changing feeding habits, the indigenous fruit tree species have been largely ignored. The utilization of indigenous fruit tree species, therefore depend mainly on the supply from natural woodlands and forests. Considering the rate at which the natural woodlands are

disappearing, there is no doubt that this utilization strategy is not sustainable and has very little provision for conservation of the resource base.

1.2 Uses

It is one of the most commonly sold indigenous fruits in Baringo, Siaya, Lodwar, West Pokot and Coastal towns (Maundu *et al.,* 1999; Muok & Kariuki, 2001).

1.2.1 Food

The pulp which has an acid taste is dissolved in water and used in porridge. The solution may also be added to vegetable stews or as a flavouring for tea, rice or with dried termites as used by the Turkana people. Young leaves are also chewed as "khat' (miraa) or cooked as vegetables. The seeds are fried and eaten while the fruit pulp is used in beer preparation by the Turkanas. In some countries the pulp is used for the preparation of jams, juices and sweets.

1.2.2 Medicinal

Leaves are pounded in a mortar or boiled, then sieved and the solution taken as a drink or applied to cure measles or chicken pox by the Akambas. Leaves and fruits are widely used as a laxative. Infusion is made from other plants in use for the

treatment of gonorrhea by the Tharaka. Leaf extract is applied to inflamed eyes by the Giriamas.

1.2.3 Others

Fuel wood, charcoal, fodder for camels in northern Kenya, branches used for water purification

Indigenous fruits e.g. *Tamarindus indica* may supply micronutrients that are important for the healthy growth of children but may be deficient in the bulky cereal based diet in the home. There is, therefore, need to establish the nutritional composition of this fruit and in order to enhance conservation both *in situ* by not clearing this tree species and *ex-situ* by domestication. This project therefore seeks to establish nutritional composition of the fruit pulp from three districts in Ukambani Kenya.

1.3 Domestication problems of indigenous fruit trees

Even though indigenous fruit trees are cheap sources of food, medicine, fodder and cash, their domestication is still hampered by number of factors (Muok & Auka, 2001):

a) They are perceived as growing slower and taking longer to produce fruits as compared to exotic species

b) They have low ratio of edible to non – edible parts as seen in Table:1

c) Lack of appropriate technologies for domestication of indigenous trees in general

d) They are perceived as having low market value

e) Little demand and low prices coupled with a poor marketing infrastructure for indigenous fruits which are also easily processed and preserved

f) Lack of tree planting culture, especially of indigenous trees, among majority of farmers in Kenya

g) Seasonal availability discourages would – be investors, although this factor is important for domestication.

1.4 Analytical methods

Several analytical methods are used to determine the chemical composition (Ranganna, 1978) and nutritive content of the fruit pulp and these include both physical and chemical methods (Aurand, 1987).

1.4.1 Physical methods

1.4.1. Oven drying

This method consists of measuring the weight lose foods due to the evaporation of water. However the weight loss may be due to:

a) loss of volatile matter

b) evaporation of 'free water' contained by protein foods. This is generally referred to as bound water.

Hence there is need to compare results obtained using the same conditions

1.4.1.2 Sulphated ash

This involves moistening the ash with concentrated sulphuric acid and igniting gently to constant weight. The sulphated ash gives more reliable ash figure for samples containing varying amounts of volatile inorganic substances that may be lost according to ignition temperature used.

Ash is the organic residue from incineration of organic matter. The amount and composition of ash in food product depend on the nature of food ignited and on the method of ashing. The residue consists of oxides and salts containing anions such as phosphates, chlorides, sulphates and other halides and cations such as sodium, potassium, calcium, magnesium, Iron and manganese.

Ash content of foodstuff, therefore, represents inorganic residue remaining after destruction of organic matter. It may not be exactly equivalent to the mineral matter as some losses may occur due to volatilization, or some cases be suggestive of the presence of adulterants.

1.4.2 Chemical methods

1.4.2.1 Elemental analysis

The elements to be analysed include; potassium, calcium, sodium. magnesium as major elements and Iron, manganese, copper and zinc as trace elements. The fruit pulp is analysed using a CTA 2000 Atomic Absorption Spectrophotometer. The ash from the sulphated ash is used to carry out analysis for the mineral elements.

Fruits and their products like any other foods, contain organic matter which must be destroyed prior to estimation of minerals. Dry ashing is applicable to most common minerals with the exception of mercury and Arsenic. It requires less attention, and large amounts of material can be handled more conveniently than by wet digestion. A temperature of 450°C should not be exceeded if zinc is to be analysed and 480 °C should not be exceeded for potassium.

1.4.2.2 Vitamin C

The ascorbic acid content of the fruits is determined by macerating the sample with

a stabilizing agent, i.e., metaphosphoric acid, and titrating the decanted extract with 2, 6-dichlorophenolindophenol.

1.4.2.3 Crude protein

Nitrogen content is estimated by kjedahl method, which is based on the determination of the amount of reduced nitrogen (NH_2 and NH) present in the sample. In the kjedahl procedure, the nitrogen in an organic compound is converted to ammonia salts, from which the ammonia is liberated by adding non – volatile alkali. The various nitrogenous compounds are converted into ammonium sulphate, by boiling with concentrated sulphuric acid. The ammonia liberated is absorbed in excess boric acid solution and titrated. Adding sodium or potassium sulphate, to raise the boiling point accelerates the digestion reaction and catalysts contain usually copper, mercury or selenium. The hydrogen peroxide oxidizes the organic matter, while the selenium compounds act as catalysts for the process, and the sulphuric completes the digestion at elevated temperatures.

For most routine purposes the "crude protein" in the sample is then calculated by multiplying the total nitrogen by an empirical factor.

1.4.2.4 Crude fibre

This is the organic residue which remains after food has been treated under standardized conditions with petroleum spirit, boiling sulphuric acid, boiling dilute sodium hydroxide solution, dilute hydrochloric acid, alcohol and ether. The crude fibre consists largely of cellulose together with lignin. As the recovery of cellulose using the specified procedure seldom exceeds four – fifths of that actually present, the crude content does not represent a measure of a specific group of substances. Also, as the amount obtained tends to vary with the conditions employed, it is important to adopt a standardized procedure in order to obtain consistent results.

1.4.2.5 Crude fat

The fatty constituents of foods consist of a number of lipid substances. The 'fat' content (sometimes called the ether extract, neutral fat or crude fat), may be considered as consisting of petroleum fractions and diethyl ether, whereas the 'bound' lipid constituents require more polar solvents such as alcohols for their extraction. The bound lipids can be broken down by hydrolysis or other chemical treatments to yield free lipid. Hence, the amount of extracted lipid found in a foodstuff will depend on the method of analysis used.

1.4.2.6 Carbohydrates

This is determined by the difference from the other determinations i.e.

100% - (percentage moisture content, protein, fibre, fat and ash)

1.4.2.7 Energy values

This determination is done by use of a bomb calorimeter. Yoshida seisakusho model 1013 – B. Generally the term calorimetry refers to enthalpy change, ΔH, or energy change, ΔE accompanying a given isothermal change in a state of a system in which the reaction occurs. In a bomb calorimeter the reaction takes place between a compound usually organic and oxygen at high pressure and the reaction is supposed to give well defined products ,i.e., carbon dioxide gas and water.

CHAPTER 2.0

JUSTIFICATION

In Kenya the Tamarind fruits are not fully utilized despite their abundance in Nyanza, Rift valley, Coast and Eastern Provinces. Most of them go to waste. This project, therefore, intends to determine the composition of the fruit pulp which is the edible part; from Mwingi, Kitui and Makueni districts in Ukambani, Eastern province and this will enhance their utilization .

Knowing the nutritive value, this fruit could assume greater commercial importance as the respective communities will be advised on how to use supplement foods in cases where there is nutrient deficiency; and how to regulate the amounts where there is sufficiency (Ondachi, 2001 & 2003)). Its utilization as food sources in arid and semi – arid regions could, therefore, be based on a more sound scientific information.

2.1 Objectives

2.1.1 Broad objective

To verify whether *Tamarindus indica* fruit pulp from three districts in Ukambani

vary in both chemical and nutritive composition.

2.1.2 Specific objectives

- To determine the physical properties such as moisture content, ash content, cations and energy values of the *Tamarindus indica* fruit pulp from Mwingi, Kitui and Makueni districts.

- To determine the chemical properties that is proteins, carbohydrates, fats, fibre and vitamins in the fruit pulp.

2.3.1 Hypothesis

H_o There exists variations in the physical composition of edible fruit pulp of *Tamarindus indica* from the three districts in Ukambani.

H_1 There are variations in the chemical composition between the fruits from the three districts.

CHAPTER 3.0

LITERATURE REVIEW

3.1 General composition of fruits

In a survey of fruit trees carried out since 1987, over 200 indigenous plant species with edible fruits were identified (Gilbert, 1989). Some of these especially *Tamarindus indica* (Tamarind) are used as regular items of local diet, in the regions where they grow.

The major part of the edible portion of fresh fruits consists of water (75.95%) for most types. Fruits are poor sources of proteins (0.2 – 1.3%) as N X 6.25 and oil. The main exceptions to this are the olive and also avocado which may contain as much as 40% oil (Pearson, 1976).

Most fruits contain reasonable amounts of carbohydrates. The latter may include varying proportions (according to fruit, maturity etc.) of dextrose, fructose, sucrose and possibly starch. The principal acids present in fruits are citric, tartaric and malic acids. The total acidity falls after picking. Other constituents include cellulose and woody fibres, mineral salts, pectin, gums, tannins, colouring matter and volatile oils. Certain fruits have higher content of vitamin C than others. See table 1.

Table 1: Composition of commonly known/domesticated fruits/100g of sample. [Source: Kirk, R and Sawyer, R. (1991) Pearson's composition and analysis of Foods. 9th edition]

Fruit	Inedible Matter %	Ener. KJ	Prot. G	Fat g	CHO g	Water g	Ca mg	Iron mg	Vit. C mg
Apple	20	196	0.3	0	11.9	84	4	0.3	5
Avocado	29	922	4.2	22.2	1.8	69	15	1.5	15
Mango	34	253	0.5	0	15.3	83	10	0.5	30
Orange	25	150	0.8	0	8.5	86	41	0.3	57
Pears	28	175	0.3	0	10.6	83	8	0.2	3
Pineapple (canned in juice)	0	194	0.5	0	11.6	77	12	0.4	20-40
Strawberries	0	109	0.6	0	6.2	89	22	0.7	59
Plums	8	137	0.6	0	7.9	85	12	0.3	3
Beans	1	83	1.9	0.2	-	-	22	0.7	-
Eggs–boiled	12	612	12.3	10.9	0	-	52	2.0	-
Eggs -fried	0	961	14.1	19.5	0	-	64	2.5	-

3.2 Potential of indigenous Fruit species as Nutrition Supplement

With the increased climatic instability causing frequent agricultural crop failure, the role of indigenous food tree species in providing nutritional supplement to people in dry lands areas is being recognized (Maghembe, 1991). A study by Mwanjumwa, 1982) to investigate the potential of using local fruits to meet the requirements of the limiting micronutrients, Vitamin A, C and calcium in the diet of the rural Kenyan Populations revealed that wild fruit species were high in dry matter, fibre and minerals.

Tamarind fruit has a potential for utilization as human food and oil extraction (Tyozabura, (1976) and it is one of the most important plant resource used as food material (Tsuda *et al.*1994). Its pulp is used in spices and seasoning; and it is accepted as a herbal medicine (Anani *et al.*2000). The flower and leaf are eaten as vegetables. The germ obtained from seeds is used for manufacturing Tamarind gum and it has been demonstrated that its seed has natural anti - oxidant components with potential for use in the food industry (Tsuda *et al.* 1994). This is particularly important as most artificial antioxidants have been found to be carcinogenic (Hirose *et al.* 1994)

Tamarind fruit is often eaten in pressed form with seeds, or used in drinks, preservatives, curries, jellies, syrups and sauces. In Africa, the seeds are fermented into "dawa dawa" a seasoning for native dishes. They are also used in chutneys. Seeds alone are eaten after roasting or used as a source of edible oil. Flowers, leaves, young ponds and sprouts are also edible (Tyozabura, 1976).

3.3 Distribution of Tamarindus indica in Kenya

The full distribution picture for *Tamarindus indica* trees (Appendix 2) illustrates well the four basic geographical regions of Kenya as Nyanza region around lake Victoria, Rift valley, Eastern and coastal regions. See Appendix 1.

CHAPTER 4.0

MATERIALS AND METHODS

4.1 MATERIALS

- *Tamarindus indica* ripe fruits from the 3 districts in Ukambani

- Atomic Absorption Spectrophotometer , AAS (Shimadzu, AA – 630 – R)

- Kjedahl auto analyzer (Hitechhood, Fs – 182)

- steam bath, bomb calorimeter, oven, muffle furnace, hot plate, dessicator, crucibles with lids, beakers, labels, khaki paper bags, ignition wire, tissue paper, digestion tubes, thimbles, burette, cotton wool volumetric flask , sox let apparatus, pipette, ashles filter paper, buchner funnel, suction pump and weighing balance.

4.2 REAGENTS

- Concentrated sulphuric acid

- Petroleum ether

- Sodium sulphate, copper suphate, selenium catalyst

- Industrial methylated spirit, alcohol

- Hydrochloric acid, light petroleum ether, boiling point (40 – 60° C)

- 0.313M sodium hydroxide, pure ascorbic, 40% w/v sodium hydroxide

- 2% boric acid, bromophenol indicator, metaphosphoric acid

- 2,6 dichlorophenolindophenol

- Benzoic acid

- Salicyclic acid, 30% hydrogen peroxide
- Sulphuric acid and selenium powder mixture
- Digestive mixture

4.3 METHODOLOGY

Ripe fruits were collected from around Mwingi, Makueni and Kitui districts in Ukambani. Choice of fruits was based on the ripe ones during the period of July – September. The fruits were peeled and the edible part removed. Analyses of triplicate samples of the edible portion was carried out as follows:

4.3.1 Physical methods

4.3.1.1 Moisture content

A thin layer of finely divided asbestos was spread in a flat bottomed metallic dish. This was dried at 110°C for 1 hour, dish covered, cooled and weighed. 20g of fruit pulp was uniformly spread over the asbestos layer. Weighing was done as quickly as possible to avoid loss of moisture. The cover was removed and drying done in a hot air oven at atmospheric pressure. A temperature of 70°C was maintained for between 16 – 18 hours. After drying, the lid was replaced and sample cooled in a desiccator and reweighed. Sample was reheated to obtain constant weight.(variation not more than 3 – 5mg). The sample was dried in a silica dish

without any filter (asbestos) aid, to be used for ashing and mineral estimation. This procedure was done in triplicates.

Crucible (C) (Air dry) + Sample (S) – C + S (Oven) = % Moisture Content

4.3.1.2 Sulphated ash

The dried samples from 4.3.1 above were transferred to 50 – 100ml platinum dishes and sufficient dilute sulfuric acid added to moisten the entire sample. This was heated gently using a hot plate until the samples were dry and charred, heating was continued until all the samples had completely volatized or nearly all of the carbon had been oxidized. They were then cooled. The residue was then moistened using 0.5ml of concentrated sulphuric acid and heated in the same manner until the remainder of the samples and any excess sulphuric acid had been volatized. Finally the samples were ignited in a muffle furnace at 800°C +/- 0.25°C for a minimum of 15 minutes. Samples were cooled in a desiccator and weighed.

4.3.2 Chemical methods

4.3.2.1 Crude Protein

Oven dried ground samples were placed in clean dried digestion tubes. 4.4ml of digestion mixture added, and digestion done at 110°C for 1 hour. This temperature was then increased to 330°C and heating continued until the solution became colourless. The contents were then allowed to cool.

The solution was allowed to cool and 25ml distilled water, contents mixed well and solution made up to 50ml.

Acid digestion of the fruit was followed by distillation – titration.

Standardisation was done by titrating 25ml of sodium bicarbonate N/70 with N/70 HCl using methyl orange indicator until colour changed from pink to magenta endpoint.

$$\% N = \frac{(a - b)0.2 \times 100}{1000 \times 0.3 \times 5}$$

Where a = Volume of HCl for the blank

b = Volume of the titre HCl for the sample

w= weight of the sample taken

al = aliquot of the solution taken for analysis.

Protein (%) = Nitrogen % x Protein factor of 6.25

4.3.2.2 Elemental analysis

From the 50ml solution of digest from crude protein analysis, Na, Ca, Mg, K, Fe, Mn, Zn and Cu were analysed using the CTA 2000 Atomic Absorption Spectrometer.

4.3.2.3 Vitamin C

4.3.2.3.1 Standard indophenol solution

This was prepared by dissolving 0.05g of 2,6 – dichlorophenolindophenol (sodium salt) in water, diluted to 100ml and filtered. To standardize the indophenol, 0.05g of pure ascorbic acid was dissolved in 60ml of 20% metaphosphoric acid and diluted with water to exactly 250ml. From this 10ml were pipetted into a small flask and titrated with indophenol until a faint pink colour persisted for more than 15 seconds. The concentration was expressed as mg ascorbic acid equivalent to 1 ml of the dichlorophenolindophenol.

4.3.2.3.2 Determination of vitamin C

50 ml of the un concentrated juice (or the equivalent of concentrated juice) were pippetted into a 100ml flask, 25ml of 20% metaphosphoric acid as stabilizing agent added and solution made up to the mark with water. 10ml of this solution was pippeted into a small flask, 2.5ml acetone added and this titrated with indophenol solution until a faint pink colour persisted for about 15 seconds. The vitamin C content was calculated as mg per 100 ml (or 100g).

4.3.2.4 Crude fibre

2g of sample was digested using 1.25% sulphuric acid, followed by filtering the

digest and washing with boiling water until free from acid. Boling was done again in 1.25% sodium hydroxide, followed by washing with 1% Hcl, and then washed in boiling water until free from alkali. Washing was done twice with alcohol and thrice with ether, before drying in an oven at 100°C for I hour. The sample was then cooled in a desiccator and weighed. Incineration was done in a muffle furnace at 500°C for I hour followed by cooling in a desiccator and then weighed. The crude fibre content was then calculated as follows:

$$\text{Crude fibre \%} = \frac{\text{Weight before incineration} - \text{Weight after incineration}}{\text{Weight of sample taken}}$$

4.3.2.5 Crude Fat

The dried samples from moisture content determination were put in thimbles and the top of the thimble plugged with a wad of fat free cotton. The thimble was then dropped into a fat extraction tube of a sox let apparatus and the bottom of this tube attached to the sox let flask. About 150ml of petroleum ether was poured through the sample in the tube into the flask. The top of the extraction tube was then attached to the condenser and the sample extracted on a water bath set at 60 °C for 16 hours.

At the end of the extraction period, the thimble was removed and most of the

petroleum ether distilled off into the empty sox let tube. The remaining small volume of ether was emptied into a pre – weighed beaker that was then put in the water bath to evaporate off all the ether and leave the fat extract. The difference in weight gave the fat – soluble material in the sample.

4.3.2.6 Carbohydrates

This was determined by the difference from the other determinations i.e.

100 – (%Moisture content, % Protein, % Fibre, % Fat and %Ash)

4.3.2.7 Energy value

The calorific value of 0.9942g of benzoic acid was first determined as the standard. 0.5g of the sample was then weighed for the analysis. The weight of the tissue paper (used to wrap the sample) and the ignition wire were also noted. The sample was wrapped in the tissue paper and tied with the ignition wire. This was placed in the sample pan and the two ends tied to the terminals. The bomb was then tightly closed and oxygen pumped in until the pressure gauge indicated 30. The inner cylinder of the calorimeter was then filled with 2100ml of water and Beckmann's thermometer for outer tank inserted. The bomb was then gently placed on the base of the inner cylinder. The covers were put in place and the stirrer and Beckmann's thermometer of the inner cylinder. The temperature of the outer tank was adjusted with hot or cold water so that the water temperature of the inner cylinder remained

within the range of 0.1 °C. This was stirred for about 10 minutes after which the sample was fired.

As the temperature of the Beckmann's thermometer of inner cylinder started to rise immediately after combustion of the sample the readings were noted. The temperatures for the outer cylinder were also noted and hot water was continually added so that the range of 0.3°C was maintained. This was done to ensure accuracy so that the highest temperature of inner cylinder is not interfered with by loss of heat to the outer cylinder. The highest temperature recorded for the inner cylinder was then recorded and used for calculations.

Calorific value

$$= \frac{H_20 \text{ equivalent} = (H_20 \text{ quantity x temp. rise of inner cylinder}) - \text{Calory collection}}{\text{Quantity of sample}}$$

Where: (i) Water equivalent

$$\frac{\text{C.v of benzoic acid x wgt of benzoic acid}}{\text{Rise in temp. of benzoic acid}} - \text{Weight quantity of inner cylinder}$$

(ii) Calory collection

= (Wgt of tissue x its calorific value) + Wgt of ignition wire x its calorific value

Calorific Values of the tissue paper and the ignition wire shall be determined.

CHAPTER 5.0

RESULTS AND DISCUSSION

Table 2: Moisture content/ Dry matter

DISTRICT	DIVISION	SAMPLE	Wt of Crucible C (g)	C+S (g)	Oven Wt (g)	% MC	Dry matter	Av dry matter
KITUI	KAVISUNI	1	18.7756	20.7778	20.4134	18.20	81.80	81.70
		2	22.2516	24.2525	23.8823	18.50	81.50	
	MBITINI	1	17.2894	20.2894	19.4995	26.33	73.67	73.90
		2	36.7851	38.7852	38.2678	25.87	74.13	
MWINGI	MUI (KATSE)	1	13.6449	15.6407	15.2755	18.30	81.70	81.80
		2	13.6449	15.6401	15.2770	18.20	81.80	
	KYANUNDU	1	16.4716	18.4788	17.9017	28.75	71.30	71.70
		2	21.6460	23.0885	23.0885	27.93	72.07	
MAKUENI	KAMBU (TARDA)	1	18.8631	21.8610	21.1403	24.04	78.96	77.50
		2	20.2629	22.2678	21.7878	23.94	76.06	
	MAKINDU	1	22.2117	24.2133	23.5598	32.65	67.35	67.40
		2	22.2074	24.2009	23.5530	32.50	67.50	

Samples obtained near the town centers had a lot of moisture and most were not yet ripe. This is due to the cold climate that was observed around the town centers leading to late ripening; as opposed to the outskirts which had their fruits ripe at

the same period. This explains the difference in Mbitini and Kavisuni samples from Kitui districts; 26% and 18% respectively. This gave dry matter content of 81.7% and 73.9% respectively.

Samples from Tana and Athi river Development Authority (TARDA) area in Kambu Division of Makueni district had a lower moisture content of 24% as opposed to that from Makindu town center which had unripe fruits, with the highest moisture content of 32%. Thus the dry matter was 81.7% 71.7% respectively, not different from Kitui district.

From Mwingi division of Mwingi district a planted sample at Kyanundu shopping center gave a high moisture content of 28%, since it's near the town center, followed by 24% from Mui division which is further away from Mwingi town. Katse in Mumoni division which is about 59km from Mwingi town gave the lowest moisture content of 18%.

Table 3: Sulphated ash determination

DISTRICT	DIVISION	SAMPLE (S)	Wt of crucible C (g)	Wt of C+S (g)	Wt of ash + C (g)	Wt of ash (g)	Av % ash
KITUI	KAVISUNI	1	18.7699	20.7700	18.8610	4.55	4.53
		2	22.2436	24.2425	22.2436	4.50	
	MBITINI	1	22.2024	24.2024	22.3102	5.39	5.41
		2	36.7855	38.7855	38.6771	5.42	
MWINGI	MUI (KATSE)	1	17.2850	19.2840	17.3886	5.20	5.15
		2	15.8314	17.8319	17.7299	5.10	
	KYANUNDU	1	23.1409	25.1411	25.0490	4.60	4.59
		2	16.4710	18.4711	18.3795	4.58	
MAKUENI	KAMBU (TARDA)	1	21.6413	23.6410	21.7997	7.92	7.91
		2	18.8246	20.8246	20.6667	7.90	
	MAKINDU	1	20.2588	21.3646	20.3286	6.31	6.31
		2	48.7564	50.7564	50.6304	6.30	

From the above table, sulphated ash for Kitui and Mwingi districts ranged between4 – 5% while the difference Makueni, TARDA had 7.91% which is the highest could be as a result of high composition of organic residue since the fruits were for the previous season and most were decomposing.

Makindu with 6.31% on the other hand showed second highest from TARDA since the fruits were still ripening and probably contained more cations like magnesium

and Iron; and anions such as chlorides and phosphates as inorganic residue. This was an indication that the fruit had not reached maturity.

TABLE 4: Concentration of mineral elements

			Mg/100g sample							
DISTRICT	**DIVISION**	**SAMPLE**	**Na**	**K**	**Mg**	**Ca**	**Fe**	**Mn**	**Zn**	**Cu**
KITUI	**KAVISUNI**	**KV1**	0.38	243	45.2	21.7	1.84	0.08	0.01	0.09
	MBITINI	**MB2**	0.64	ND	ND	ND	ND	ND	ND	ND
MWINGI	**MUI(KATSE)**	**KT3**	0.52	717	29.1	26.1	1.17	0.07	0	0.08
	KYANUNDU	**KY**	0.48	581	10.5	25.1	1.09	0.08	0.27	0.13
MAKUENI	**KAMBU (TARDA)**	**TR3**	0.80	1050	43.1	25.8	0.89	0.09	0.07	0.07
	MAKINDU	**MK1**	0.42	634	75.2	29.1	2.21	0.07	0.12	0.07

ND – Not done

The Mn concentration (Appendix 3) is almost the same in all districts. It is a trace element whose function in mammals is unknown but in plants it is part of a redox catalyst in photo system 2 in which water is oxidized.

KY had the highest value for Zn and , Cu ,i.e., 0.27 & 0.13 respectively. This is a planted species. Zinc deficiency may contribute to a rare form of dwarfing found in the near east. Zinc is also essential in pregnant women as it is necessary for foetal development (Keen and Zindenberg – Cherr 1994)

Makueni district had the lowest values in Cu while it had the highest Na values with TR3 having 0.80 mg/100g sample. Copper in plants functions as electron transfer agents.

MK1 had 2.21 value for Iron which was the highest while KY registered 1.09 as the lowest. This lower value may be as a result of the fact that KY is a planted species which may be classified as domesticated. Table 1 shows lower values of

Iron content for domesticated fruits. Iron is the metallic center of activity in hemoglobin which carries oxygen from lungs to the rest of the body parts and carbon dioxide from the body parts to the lungs. Iron deficiency in the human body causes anemia, a problem most common with women than men. *Tamarindus indica* fruits could come in hardy to alleviate this problem.

Calcium levels in *Tamarindus* fruits are highest for MK1 having a value of 29.1 mg/100g of sample, and lowest for KV1 with 21.7 mg/100g of sample. These values are very much higher than those of domesticated fruits in Table1. This element is found entirely in the bones(98%) but also plays the roles of muscle contraction, neural activity, part of biological membranes and active sites of enzymes e.g. micrococcal nuclease. It is also known to stabilize conformation of proteins and trigger hormone release.

Presence of magnesium as a cation in the fruits indicates it was unripe. That is why MK1 gave 75.2 which was highest and TR3 gave 43.1mg/100g of sample which was the lowest since the latter was an old sample from the previous season. magnesium in plants is important for photosynthetic activity because it makes up part of the chlorophyll structure.

In humans, magnesium is needed for bones and other cells. had the highest value

of Potassium (1053mg/100g sample) while KV1 had the lowest value of 243. Potassium is useful in Glucose metabolism, protein synthesis and activation of some enzymes.

As problematic as it may have been, Sodium content was determined in the fruit samples and TR3 recorded the highest value of 0.80mg/100g sample whereas KV1 gave 0.38mg/100g sample. Sodium together with potassium (Appendix 4) are used to maintain osmotic pressure within cells and as a sodium pump. Together with Calcium, sodium ions are found in body fluids, outside cells.

CHARTS SHOWING CONCENTRATION OF MINERAL ELEMENTS FOR THE VARIOUS SAMPLES.

Chart 1: KV1

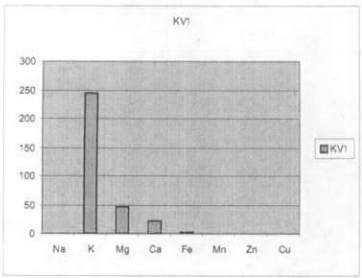


Chart 2: MB2

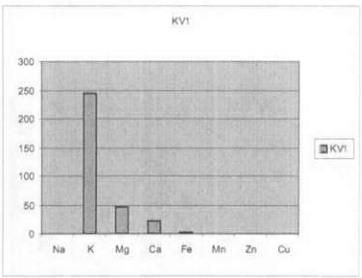


Chart 3: KT3

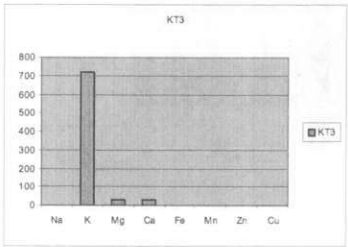


Chart 4: KY

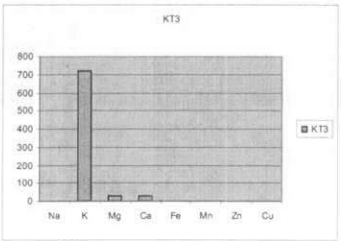


Chart 5: TR3

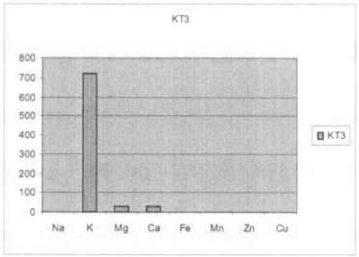


Chart 6: MK1

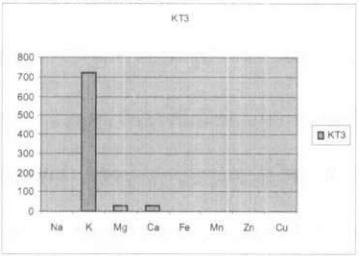


Chart 7: COMPARISON OF CONCENTRATIONS OF MINERAL ELEMENTS FOR VARIOUS SAMPLES

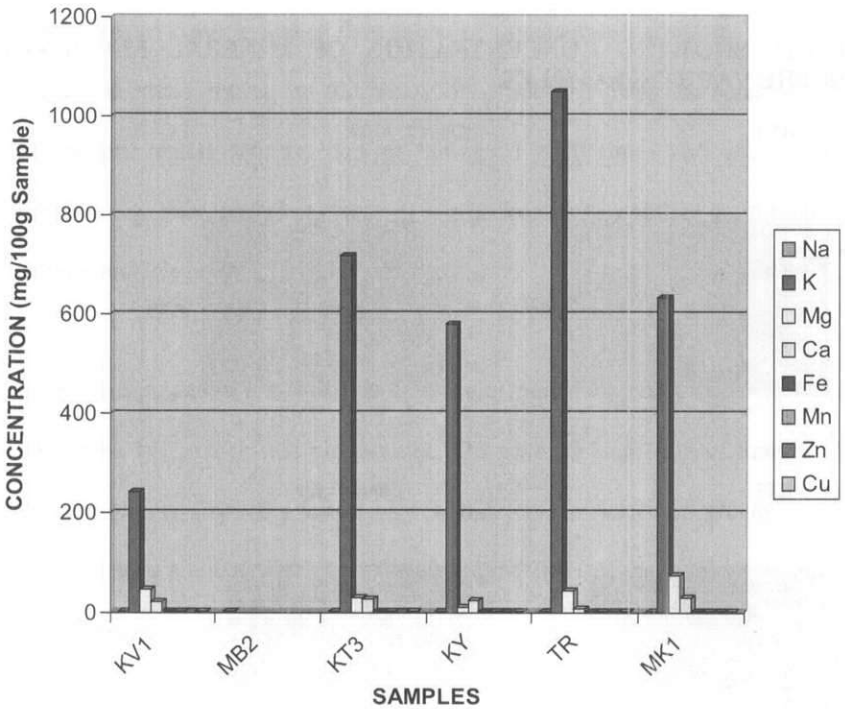


TABLE 5: ASORBIC ACID

DISTRICT	DIVISION	SAMPLE	WT (g)	TITRE (ml)	ASCORBIC ACID CONTENT mg /100g SAMPLE
KITUI	KAVISUNI	KV1	10.0075	0.1	7.994
	MBITINI	MB2	10.0015	0.1	7.999
MWINGI	MUI (KATSE)	KT3	10.0039	0.1	7.997
	KYANUNDU	KY	10.0065	0.1	7.995
MAKUENI	KAMBU (TARDA)	TR3	10.0045	0.1	7.996
	MAKUENI	MK1	10.0016	0.1	7.999

Samples from all districts had same ascorbic acid content hence topography had no effect on its content in this case. This is higher than some domesticated fruits like apples which have 5mg, pears 3mg and plums having 3mg. Table 1.

This value also compares with that obtained in Traditional Food Plants of Kenya by National Museums of Kenya. (8.13%) Deficiency in Vitamin C results in scurvy.

TABLE 6: CRUDE PROTEIN

DISTRICT	DIVISION	SAMPLE	TITRE	TOTAL N	% PROTEIN
KITUI	KAVISUNI	KV1	0.1	0.001	0.008
	MBITINI	MB2	ND	ND	ND
MWINGI	MUI (KATSE)	KT3	0.2	0.003	0.02
	KYANUNDU	KY	0.2	0.003	0.02
MAKUENI	KAMBU (TARDA)	TR3	0.2	0.003	0.02
	MAKINDU	MK1	0.2	0.001	0.008

ND – Not done

MK1 and KV1 have the lowest protein values of 0.008% they were unripe. The fruits that gave the highest protein values of 0.02% were mature. It appears that protein content has something to do with maturity period. Percent protein is the same for all the 3 districts.

TABLE 7: CRUDE FIBRE

DISTRICT	DIVISION	SAMPLE CODE	WT OF SAMPLE (g)	FINAL WT (g)	% CRUDE FIBRE
KITUI	KAVISUNI	KV1	2.0046	0.1063	5.30
	MBITINI	MB2	2.0069	0.1049	5.23
MWINGI	MUI (KATSE)	KT3	2.0069	0.1355	6.75
	KYANUNDU	KY	2.0014	0.0660	3.30
MAKUENI	KAMBU (TARDA)	TR3	2.0011	0.1012	5.06
	MAKINDU	MK1	2.0050	0.1102	5.50

The fibre content ranges around 5% apart from KT3 which had 6.75%. This is because it 's a riverine sample causing it to have less minerals as most are soluble in the large volume of water taken up by the plant. The less the mineral quantity, the larger the fibre content and vice versa. KY has the lowest crude fibre content of 3.30. It's a planted sample with less minerals and more fibre content.

Fibre contributes to food bulkiness, thus contributing to low calorie intakes. It also plays an important role in digestion, hence preventing constipation and possibly colon cancer. It is also documented to have an effect on blood cholesterol, although

the mechanism involved is not clearly understood. However fibre has been observed to result in lower levels of low – density lipoprotein in the blood, and the latter has been associated with coronary heart disease (Latham, 1979).

TABLE 8: INTERNAL ENERGY

DISTRICT	DIVISION	SAMPLE CODE	WT OF PAPER (g)	WT OF PAPER + SAMPLE g)	WT OF WIRE (g)	I_O	I_1	RISE IN TEMP/^OC	WATER EQUIV-ALENT	CALORY COLLECTI-ON	C.V KCAL g^{-1}
KITUI	KAVISUNI	KV1	0.0601	0.5602	0.0078	0.21	0.90	0.69	465.62	2395.59	2.85
	MBITINI	MB2	0.0592	0.592	0.0078	0.62	1.31	0.69	465,62	2365.76	2.94
MWINGI	MUI (KATSE)	KT3	0.0595	0.5597	0.0076	0.72	1.41	0.69	465.62	2377.56	2.90
	KYANUNDU	KY	0.0600	0.5601	0.0057	0.59	1.28	0.69	465.62	2396.02	2.86
MAKUENI	KAMBU (TARDA)	TR3	0.0605	0.5607	0.0077	0.77	1.46	0.69	465.62	2417.50	2.82
	MAKINDU	MK1	0.0601	0.5601	0.0077	0.56	1.25	0.69	465.62	2401.55	2.85
		Benzoic tablet	0.0576	1.0024	0.0077	0.83	3.15	2.32	465.62	235.90	6.42

All samples have same internal energy hence difference in localities does not affect internal energy or the amount of calories in the fruits

TABLE 9: CRUDE FAT

DISTRICT	DIVISION	SAMPLE CODE	WT OF SAMPLE (g)	WT OF S+FLASK (g)	WT AFTER EXTRACTION (g)	% CRUDE FAT
KITUI	KAVISUNI	KV1	10.0015	114.4600	114.4422	0.17
	MBITINI	MB2	10.0097	127.7421	127.7313	0.11
MWINGI	MUI (KATSE)	KT3	10.0084	68.5038	68.4596	0.44
	KYANUNDU	KY	10.0005	162.1369	162.0949	0.42
MAKUENI	KAMBU (TARDA)	TR3	10.0056	117.7792	117.7750	0.04
	MAKINDU	MK1	10.0000	68.7118	68.7118	0.042

Makueni has low crude fat content probably due to the fact that the fruits were slightly green. Mwingi on the other hand had very ripe fruits and hence the high fat content since most were over ripe.

CONCLUSION

From this study, it was found that *Tamarindus indica* fruit ('Ukwaju" – Kiswahili) which is an indigenous fruit is chemically and nutritionally, fairly rich, hence important in contributing to the diets of the communities. The fruit has appreciable levels of macro and micro – elements which are essential in the human diets "Ukwaju" can be taken as a supplement for Vitamin C, Iron, Calcium, Na , K, Mg and crude fibre. It also has minimal levels of proteins, fats, Cu, Zn and Mn.

The fruit has high energy values making it an important energy source in the communities where it is found.

RECOMMENDATIONS

- Potential markets should be developed to enable indigenous fruits compete with commercial fruits in the market

- The industrial sector should develop appropriate processing techniques and develop the market infrastructure

- The communities should be educated on harvesting techniques to avoid destruction of the rest of the plant

- Further study using molecular techniques may give insight on the fact that morphological characteristics cannot be associated with species region (provenance)

- Chemical analysis of the seeds from the same region could be determined in order to advice the community on which part of the fruit is more nutritious.

- This fruits are found in dry areas and are a major supplement to the nutrition of these communities. While a lot has been done in west, Central and South Africa little has been done in east Africa. These is therefore need for research in this

area that would lead to domestication and hence conservation.

- There is also need to compare effects of locality, time of harvesting storage, type of soil, climatic conditions. on nutritional composition of the fruit.

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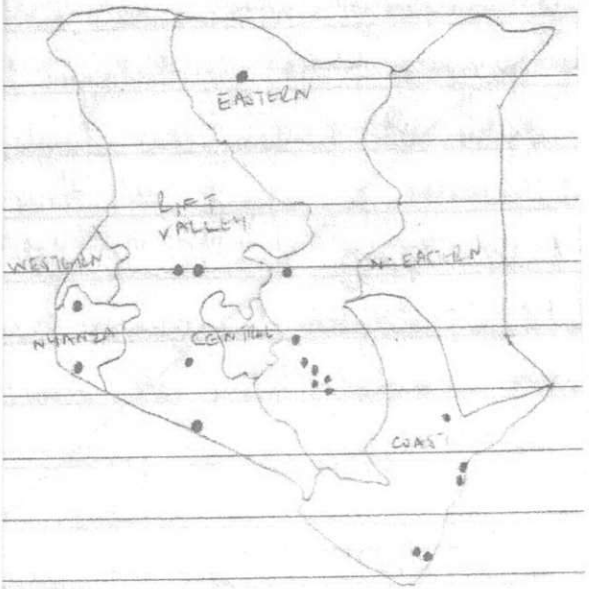
APPENDICES

APPENDICES

APPENDIX 1: Distribution of Tamarindus indica in Kenya



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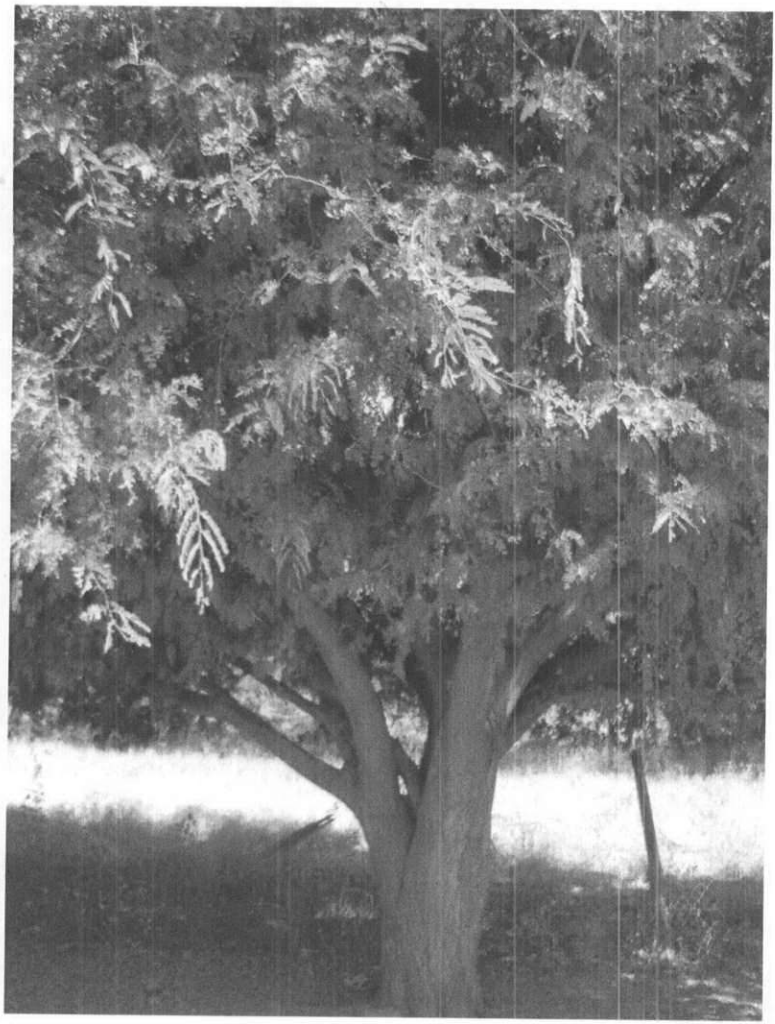
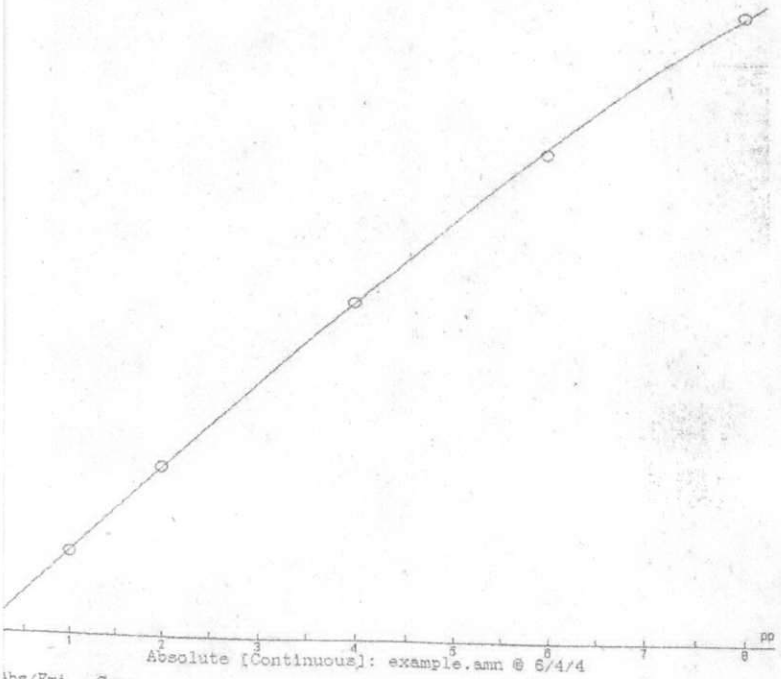
APPENDIX 2 ***Tamarindus indica*** **tree.**



APPENDIX 3: STANDARD CONCETRATION CURVE FOR Mn

STD6	Mn	example.amn	Abs= 0.528	0.000ppm @	6/4/4 4:42 PM
STD 1	Mn	example.amn	Abs= 0.069	1.049ppm @	6/4/4 4:43 PM
STD 2	Mn	example.amn	Abs= 0.143	2.152ppm @	6/4/4 4:43 PM
STD 4	Mn	example.amn	Abs= 0.282	4.183ppm @	6/4/4 4:44 PM
STD 6	Mn	example.amn	Abs= 0.408	5.989ppm @	6/4/4 4:45 PM

Fit Error 0.4%
Reslope x 1.00



Abs/Emi	Conc
0.528	6.000
0.069	1.000
0.143	2.000
0.282	4.000
0.408	6.000

APPENDIX 4: STANDARD CONCETRATION CURVE FOR K

```
STD 6          K    example.ak Abs= 0.680  0.000ppm @ 6/11/4 12:07 PM
STD 3.7        K    example.ak Abs= 0.425  3.751ppm @ 6/11/4 12:08 PM
STD 1.3        K    example.ak Abs= 0.157  1.376ppm @ 6/11/4 12:08 PM
STD 5.17       K    example.ak Abs= 0.594  5.171ppm @ 6/11/4 12:11 PM
 Fit Error 0.6%
 Reslope = 1.00
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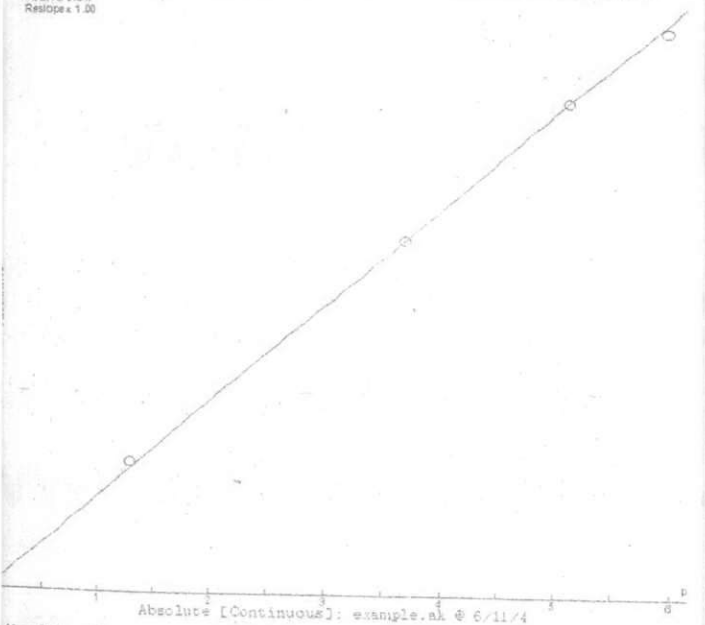

Abs/Emi	Conc
0.680	5.000
0.425	3.700
0.157	1.300
0.594	5.170

41