Physiochemical Properties of Baobab (*Adansonia digitata* L.) Water Extract and Seed Oil

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قال تعالى:

(قُلْ إِنَّ صَلاَتِي ونُسُكِي وَمَحيَايَ وَمَمَاتِي لله رَبِّ العَالَمِينَ)

صدق الله العظيم

سورة الانعام – الآية (162)

Dedication

To my parents

To my supervisors

To my friends

To all Muslims

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My praise goes to the almighty “Allah” the most gracious and the most merciful who granted me the mind, health, strength and Patience to conduct this study successfully. I indebted to my major supervisor, Associate Prof. Elzubier Ahmed Salih for his useful guidance, cooperation, supervision and for the moral and professional support with which he provided me via the study.

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ABSTRACT

The baobab (*Adansonia digitata* L.) tree is native to Sudan in Kordofan, Darfur and Blue Nile; Sudanese people used it as beverage (dissolved in water) and sometimes use it for medicinal purposes. The aim of this study is to determine the effect of temperatures (30, 40, 50, 60 and70^{0}C) on viscosity in two types of baobab water extract (TSS 6% and 12%) and also to determine the physiochemical characteristics of baobab (fruit pulp and seed). Baobab sample was purchased from Wad Madani local market and subjected to analysis according to internationally known standard methods. The results of the analysis showed a high amount of vitamin C content, in baobab water extract (TSS 6%) was (4400 mg/kg) and in baobab concentrated water extract (TSS 12%) was (3500 mg/kg)because vitamin C is sensitive to heat, and the acidity and pH in water extract (TSS 6%) were (23 mg/g and 3.35), respectively, and the acidity and pH in concentrated water extract (TSS 12%) were (36 mg/g and 3.11) respectively, the viscosity in water extract (TSS 6%) showed at temperatures (30 ,40 , 50 , 60 and 70^{o}C) were (3.1565 x 10^{-3}, 2.7445 x 10^{-3}, 2.3755 x 10^{-3}, 2.1964 x 10^{-3} and 2.0080 X 10^{-3}Pa.s), respectively, and the density at same temperatures were (1.0005, 0.9932, 0.9911, 0.9849 and 0.9818 g/ml), respectively, and the viscosity in water extract concentrated (TSS 12%) at (30, 40, 50, 60 and70^{0}C) were (9.8288 x 10^{-3}, 10.5803 x 10^{-3}, 11.3543 x 10^{-3}, 12.4483 x 10^{-3} and 13.4472 x 10^{-3}), respectively, and the density at same temperatures were (1.0132, 1.0134, 1.0136, 1.0138 and 1.0141 g/ml), respectively. The results of chemical composition of fruit pulp showed that the moisture was (8.15%), the protein was (2.90%), the oil content was (0.29%), the fiber was (8.11%), the ash was (5.02%) and the carbohydrates (75.53%), and the solubility of baobab fruit pulp was (78.84%). The results of the analysis of baobab oil showed that the moisture of the seed was (5.34%) and the moisture of the oil was (1.90%) and the refractive index was (1.4703) and the free fatty acids were (0.6%) and the peroxide value was (1.92 meq of O_2/kg) and the oil content was (13.40%) and the saponification value was (206 mg KOH/g) and the iodine value was (84.50g/100g of oil) these values are in agreement with the CODEX for vegetable oil. This study showed that both of the concentrates (TSS 6% and 12%) can be used for further dilution with water with the addition of sugar to consumer taste. However further study on the stability of the concentrates is to be carried out, it is also recommended that the baobab fruit pulp can be used as a good source of vitamin C, and also recommended that the baobab seed oil is to be investigated for suitability for use for edible purposes and it can be used for production of soap and other products.

الخصائص الفيزيائية والكيميائية لمستخلص لب التبلدي وزيت بذرته

محمد حامد المبارك عبدالله

ماجستير في هندسة وتكنولوجيا الاغذية (مايو, 2015م)

قسم هندسة وتكنولوجيا الاغذية

كلية الهندسة والتكنولوجيا

جامعة الجزيرة

ملخص الدراسة

موطن شجرة التبلدى في السودان في كل من كردفان ودارفور والنيل الأزرق.فالسودانيون يستعملونه كعصير(يذاب في الماء) وفى بعض الأحيان يستعملونه في أغراض طبيه. الهدف من هذه الدراسة هو تحديد تأثير درجات الحرارة (30, 40, 50, 60 و 70م0) على اللزوجة في نوعين من مستخلص التبلدى(6% و 12% مواد صلبة كلية) وأيضا"تحديد الخصائص الفيزيوكيميائيه لثمرة التبلدى(لب الثمره والبذرة). تم شراء عينات ثمرة التبلدى من سوق ود مدنى المحلى ثم خضعت للتحاليل حسب الطرق القياسية العالمية المعروفة حيث أظهرت نتائج التحليل بأن بها كمية كبيرة من فيتامين ج , فمستخلص التبلدي (6% مواد صلبة كلية) يحتوي على (4400 مليجرام/كجم), أما في مستخلص التبلدي المركز (12%مواد صلبة كلية) يحتوي على (3500 مليجرام/كجم) لأن فيتامين ج يتأثر بالحرارة. أما الحمضية والأس الهايدروجينى في مستخلص التبلدي (23ميلجرام/جرام و 3.35) بالترتيب , أما الحمضية والأس الهايدروجينى في مستخلص التبلدي المركز (36مليجرام/جرام و 3.11) بالترتيب. نسبة اللزوجة لمستخلص التبلدي في درجات الحرارة التالية (30, 40, 50 ,60 و 70م0) هي كمايلى (3.1565×10^{-3} و 2.7445×10^{-3} و 2.3755×10^{-3} و 2.1964 $\times 10^{-3}$ و 2.0080×10^{-3} باسكال.ثانية) بالترتيب. اما الكثافة في نفس درجات الحرارة السابقة فهي (0.9818 1.0005 , 0.9932 , 0.9911 ,0.9849 , جرام/ملليتر) بالترتيب. أما اللزوجة في المستخلص المركز في درجات الحرارة التالية (30, 40, 50 ,60 و 70م0) هي كمايلى (9.8288×10^{-3} , 10.5803×10^{-3} 11.3543×10^{-3}, 12.4483×10^{-3} , 13.4472×10^{-3} باسكال.ثانية) بالترتيب. أما الكثافة في نفس درجات الحرارة السابقة فهي (1.0132 , 1.0134 , 1.0136 , 1.0138, 1.0141 جرام/ملليتر) بالترتيب. نتائج التحليل الكيميائي للب ثمرة التبلدي توضح بأن نسبة الرطوبة (8.15%) , نسبة البروتين (2.90%), محتوى الزيت (0.29 %), نسبة الالياف (8.11%), نسبة الرماد (5.02%) و نسبة الكاربوهيدريتات (75.53%). أما الذوبانية فهى (78.84%). نتائج تحليل زيت بذرة التبلدي يوضح بأن نسبة رطوبة البذرة (5.34%) ونسبة رطوبة الزيت (1.90%) معامل الإنكسار (1.4703) ونسبة الاحماض الدهنية الحرة (0.6%) و رقم البيروكسيد (1.92 ملجرام مكافئ/كجم) أما محتوى الزيت (13.40%) ورقم التصبن (206 ملجرام KOH/جرام) والرقم اليودى (84.50جم/100جم) هذه القيم متوافقة مع ما ورد فى (CODEX) للزيوت النباتية.هذه الدراسة توصي بأن كل من المستخلصان(6% و12% مواد صلبة كلية) علاوة"على التخفيف بالماء أيضا" يمكن اضافة السكر لهما حسب مذاق المستهلك كما توصى أيضاً بأنه يجب الأخذ في الاعتبار مدى قوة وتماسك كل من المستخلصان(6% و12% مواد صلبة كلية).كما توصى الدراسة بأن لب ثمرة التبلدي يمكن الاستفادة منه كمصدر جيد لفيتامين ج. كما توصي الدراسه أيضا" بأنه يجب التحقق من مدى قابلية زيت بذرة التبلدي لاستخدامه في أغراض الاكل.كما توصى أيضا" بأنه يمكن استعمال زيت بذرة التبلدى في الصناعات لإنتاج الصابون ومنتجات اخرى.

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CHAPTER ONE

Introduction

1.1 Background:

Baobab (*Adansonia digitata* L.) is a tree native to certain tropical regions in Africa including South Africa, Botswana, Mozambique and west of Sudan. Baobab trees produce fruit with powdery pulp; this fruit pulp is an important foodstuff. It is dry and mealy and it is used in cool and hot drinks. Pulp can be dissolved in water or milk and the liquid is used as drink (beverages) or as a sauce for food or as fermenting agent in local brewing. Baobab fruit is sometimes used for medicinal purposes (Becker, 1983).

Knowledge of physical properties of fluid foods and their variation with temperature and concentration have been globally important for industrialization of food products with good quality, understanding the texture, process engineering application, correlation with sensory evaluation, designing of transport system, equipment design (heat exchanger and evaporator), deciding pump capacity and power requirement of mixing (Scott, 1985).

One of important properties is viscosity. Viscosity means the measure of the internal friction in a liquid or the resistance to a flow and related to other properties by many equations to obtain one of them and that combined to give good idea and uses that in design and other purposes (Sherman, 1970).

Concentration of fruit juices not only provides microbiological stability, but also leads to economical packaging, transportation and distribution of final products (Belibagli and Dalgic., 2007). In concentration processes, the solids content is increased up to 65% to 75% so that the final product is still in liquid form (Remteke *et. al*., 1993).

1.2 Objectives:

The objectives of the present study include:

1- To determine some physical properties of baobab water extract (TSS 6%) and baobab concentrated water extract (TSS 12%).
2- To determine the effect of temperature and concentration on the viscosity of baobab water extract (TSS 6%) and concentrated water extract (TSS 12%).
3- To determine the chemical composition of baobab fruit pulp.
4- To determine the characteristics of baobab seed oil.

CHAPTER TWO

Literature Review

2.1 Baobab tree:

The African baobab and its related species belong to the family *Bombacaceae* and the genus *Adansonia digitata. Adonasonia* is a member of the tribe *Adansonieae* or *Bombaceae*, depending on taxonomic treatment, it is found in savannas of Africa, India, mostly around the equator and tropical America (Von Maydell, 1990).

2.1.1 The leaves:

Young leaves are widely used, cooked as spinach and frequently dried, often powdered and used for sauces over porridges or boiled rice.

Table (2.1) chemical composition of baobab leaves (Dry weight)

Constituent	Values
Protein	13-15%
Fat	4-10%
Fibre	11%
Ash	16%
Carbohydrate	60-70%
Energy value	1180-1900 kJ/100g

Source: Becker, (1983); yazzie *et al.*, (1994); Nordeide, (1996) and Glew *et al.*, (1997).

2.1.2 Fruit pulp:

The fruit pulp is dry and mealy and is used in cool and hot drinks; pulp can be dissolved in water or milk and the liquid is used as drink, as sauce for food or as a fermenting agent in local brewing. The energy value of pulp is similar to that of baobab leaves (Becker, 1983). Pulp sweetness is provided by fructose, sucrose and glucose contents. Fruit pulp is also acidic and this is due to the presence of organic acids including citric, tartaric, malic, succinic as well as ascorbic acid (Airan and Desai., 1984). Fruit pulp is rich in pectin, tartarate and free tartaric acids. When eaten raw, the pulp is a rich source of calcium and vitamins B and C (Burkill, 1985) it contains sugars but no starch, the fruit pulp has a very high vitamin C content, almost ten times that of oranges (Sidibe *et al.*, 1996).

The fruit pulp contains high amount of carbohydrate, low protein and extremely low fat (Osman, 2004).

Table (2.2): Chemical composition of baobab fruit pulp

Constituent	Mean %	SD
Total soluble solids	79.3	1.2
Total sugars	23.2	0.2
Total pectin	56.2	0.9
Total starch	0.0	0.0
Protein	2.6	0.3
Fat	0.2	0.01
Fibre	5.7	0.2
Ash	5.3	0.02

Source: Material from Khartoum market, Sudan. Data from Nour *et al*., (1980).

Table (2.3): Chemical composition of baobab fruit pulp

Constituent	Fruit pulp
Moisture %	10.4 ± 0.4
Protein %	3.2 ± 0.1
Fat %	0.3 ± 0.0
Ash %	4.5 ± 0.2
Fibre %	5.4 ± 0.3
Carbohydrate %	76.2 ± 1.0
Energy kcal/100gm	320.3 ± 4.4
Vitamin C mg/kg	1623-4991
Ph	3.3

Source: Osman., (2004); Sidibe *et al*., (1996); Nour *et al*., (1980).

2.1.3 The seeds:

Baobab seeds can be eaten fresh, or they may be dried and ground into flour which can be either added to soups and stews as a thickener, or roasted and ground into a paste, or boiled for a long time, fermented and then dried for use (Sidibe *et al*., 1996; FAO.,1988).

Table (2.4): Chemical composition of Baobab seeds

Constituent	Seed
Moisture%	4.3 ± 0.1
Protein%	18.4 ± 0.5
Fat%	12.2 ± 0.1
Ash%	3.8 ± 0.1
Fibre%	16.2 ± 0.9
Carbohydrate%	45.1 ± 1.7
Energy kcal/100g	363.8 ± 9.7

Source: Osman., (2004).

The seeds produce oil whose major fatty acid is oleic 35.8% followed by linoleic 30.7% and palmitic 24.2% (Osman, 2004).

Table (2.5): Characteristics of the seed oil of baobab

Constituent	Baobab oil
Refractive index	1.4596 – 1.4633
Moisture %	2.08
Iodine value	55 – 96
Saponification value (mg KOH/g)	133 – 195
Peroxide value	1.86

Source: Essien and Fetuga., (1989).

Table (2.6): Physiochemical characteristics of baobab seed oil

Constituent	Baobab oil
Refractive index	1.5 $\pm$ 0.0
Iodine value	88.0 $\pm$ 4.1
Saponification number	210.0 $\pm$ 0.09

Source: Osman., (2004).

2.2 Domestic food uses and local processing:

2.2.1 Leaves:

Young fresh leaves are cut into pieces and cooked in a sauce. Sometimes they are dried and powdered and used for cooking.

In Mali, use of the leaves in sauce is usually in association with seeds of onion, okra, pepper, ginger, sometimes meat, but more often fish. The sauce is used with a thick porridge made from millet, sorghum or maize, but also for rice (Nordeide 1996). In other areas leaves are used for soup e.g. in northern Nigeria and ground leaves are boiled in salt water (Yazzie *et al*., 1994). In Malawi they are boiled with potash (Williamson, 1975).

2.2.2 Fruit pulp:

The dry pulp is either eaten fresh or used to add to gruels on cooling after cooking.

It can also be ground to make a refreshing drink with a pleasing wine-gum flavour. In Tanzania it is added to aid fermentation of sugar cane for bear making (Fleuret, 1980).

When the fruit is ripe, the pulp is removed from the fibres and seeds by kneading in cold water, the resulting emulsion is sieved, and then added to thick grain

preparations to make thinner gruels. In Nigeria the fruit pulp is used as sweetener for many local foods and as curding agent for milk.

Pulp can be stored for fairly long periods for use in soft drink production but it needs airtight containers. Storage is improved by using of sodium metabisulphate (Ibiyemi *et al*.,1988). It can also be frozen if ground to a powder (Obizoba and Amaechi., 1993).

2.2.3 Seeds:

In general, seeds are used as a thickening agent in soups, but they can be fermented and used as a flavouring agent, or roasted and eaten as snacks (Palmer and Pitman., 1972; Addy *et al.*, 1995). When roasted, they are sometimes used as a substitute for coffee. Frequently, baobab seeds are ground with peanuts and water and sugar, added to make a sauce used with porridge (Pele and Berre., 1967).

2.3 Domestic non-food uses:

2.3.1 Fibre:

The fibre is used for making rope, basket nets, fishing lines and weaving.

2.3.2 Dye:

In East Africa roots are used to make a soluble red dye. The green bark is also used as a dye and for decoration (Dovie *et al*., 2001).

2.3.3 Seed shell:

The hard fruit shells are used in the manufacture of pots for food and drink (Dovie *et al.*, 2001).

2.3.4 Fuel:

The wood is a poor source of fuel; however, fruit shells are used as fuel in Tanzania and they are used as water dippers (Nkana and Iddi., 1991).

2.4 Medicinal uses:

2.4.1 Traditional use:

Baobab is used in folk medicine to overcome fevers. Both leaves and fruit pulp are used for this purpose. Fruit pulp and powdered seeds are used in cases of dysentery and to promote perspiration. Powdered leaves are used to treat fatigue and for insect bites and internal pains, and to treat dysentery (Dweck, 1997).

In India pulp is used internally with buttermilk in cases of diarrhea and dysentery.

In Sudan, especially the west, people traditionally depended on the pulp of *Adansonia digitata* for treatment of dysentery, diarrhea, gastro-enteritis and colics (Fleuret, 1980).

In Srilanka, young leaves crushed into a poultice and used externally for painful swellings (Jayaweera, 1981).

2.4.2 Use in cosmetic treatment:

An infusion of roots is used in Zimbabwe to bathe babies to promote smooth skin (Wickens, 1982). Since seed oil is used to treat skin complaints, to a degree it is used cosmetically.

2.5 Physical properties:

Physical properties of foodstuffs play a significant role in modlling of heat and mass transfer in basic food processing operations such as drying, thermal processing and freezing. The engineering design of food processes and equipment requires the knowledge of basic physiochemical and engineering properties of food materials. Due to the complex physical and chemical structure of food, theoretical prediction is not always possible. There is need for more reliable data on the engineering properties of foods in design and simulation of food processes (Sherman, 1970).

2.5.1 Density:

Density is defined as the mass per unit volume of a substance, and it is a physical property of matter. A physical property can be measured without changing the chemical identity of the substance. Since pure substances have unique density values, measuring the density of a substance can help identify that substance. Density is determined by dividing the mass of a substance by its volume:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

The units of density are commonly expressed as g/cm^3 for solids, g/ml for liquids and g/l for gases (Sherman, 1970).

2.5.2 Viscosity:

Viscosity is an important characteristic of liquid foods in many areas of food processing, for example the characteristic mouth feel of food products such as tomato, ketchup, cream, syrup and yoghurt is dependent on their consistency or viscosity. The viscosity of many liquids changes during heating, cooling, concentration, etc, and this has important effects on, for example, the power needed to pump these products (Sherman, 1970).

2.5.2.1 Dynamic viscosity (μ):

Viscosity describes a fluid resistance to flow. Dynamic viscosity (Absolute viscosity) is obtained by dividing the shear stress by the rate of shear strain.

The units of dynamic viscosity are:

$$\frac{\text{Force} \times \text{time}}{\text{Area}}$$

[μ] = Pa.s

1.00 Pa.s = 10 poise = 1000 centipoise.

2.5.2.2 Kinematic viscosity (V):

Sometimes viscosity is measured by timing the flow of a known volume of fluid from a viscosity measuring cup. The timings can be used along with a formula to estimate the kinematic viscosity value of the fluid in centistokes (cSt).

The motive force driving the fluid out of the cup is the head of fluid. This fluid head is also part of the equation that makes up the volume of the fluid. Rationalizing the equations the fluid head term is eliminated leaving the units of kinematic viscosity as:

$$\frac{\text{Area}}{\text{time}}$$

$$[V] = \frac{m^2}{S}$$

1.0 m^2/s = 10000 stokes = 1000000 centistokes.

$$\text{Kinematic viscosity} = \frac{\text{Dynamic viscosity}}{\text{Density}}$$

2.5.3 Effect of temperature:

During manufacture, storage, transport, sale and consumption, fluid foods are subjected to continuous variations of temperature. For this reason, it is important to know the physical properties of the products as a function of temperature (Scott, 1985).

2.5.4 Vitamin C (Ascorbic acid):

Vitamin C is water soluble, meaning that the body doesn't store it. We have to get what we need from food, including citrus fruits, broccoli and tomatoes. Vitamin C is needed for growth and repair of tissues in all parts of the body. It helps the body make collagen, an important protein used to make skin, cartilage, tendons, ligaments and blood vessels.

Vitamin C is needed for healing wounds and repairing and maintaining bones and teeth. Vitamin C is an antioxidant, which block some of the damage caused by free radicals, substances that damage DNA.

Vitamin C helps to regulate blood pressure, contributes to reduce cholesterol levels and aids in the removal of cholesterol deposits from arterial walls, thus preventing arteriosclerosis. The easily destroyed nutrient also protects us from the revenges of free radicals, dangerous unpaired oxygen fragment that are produced in huge number as a normal bi-product of human metabolic processes.

So vitamin C plays a role in protecting against heart disease, high blood pressure, common cold and cancer.

The best way to take vitamin C supplements is 2-3 times per day with meals depending on the dosage. Some studies suggest that adults should take 250-500mg twice a day for any benefit (Daniel, 2000).

When there is insufficient vitamin C in the diet, humans suffer from the potentially lethal deficiency diseases scurvy. Humans and primates lack the terminal enzyme in the biosynthetic pathway of ascorbic acid, L-gulonolactone oxidase, because the gene encoding for the enzyme has undergone substantial mutation so that no protein is produced (Chapman, 1982).

2.5.5 Solubility:

Solubility is defined as the amount of substance that passes into solution to achieve a saturated solution at constant temperature and pressure. Solubility is expressed in terms of maximum volume or mass of the solute that dissolve in a given volume or mass of a solvent (Jasper Larsson, 2009).

CHAPTER THREE

Material and Methods

3.1 Material:

Baobab (Raw material):

In this study baobab was purchased from the local market of Wad Madani - Gezira state - Sudan.

3.2 Equipment and Reagents:

3.2.1 Equipment:

Vacuum evaporator.

Centrifuge filter.

U- Tube viscometer.

Oven.

Magnetic stirrer.

Hot water bath.

Muffle furnace.

Sensitive balance.

Soxhlet Extraction Unit.

Refractometer.

pH –meter.

Thermometer.

Heater.

Condenser.

Small screw presser.

Pycnometer.

Mantle.

Mortar.

Pestle.

Filter paper.

Cotton.

Funnel.

Soft tissue paper.

Dropper.

Flat bottom flask.

Round bottom flask.

Mesh.

Beaker.

Burette.

Pipette.

Conical flask.

Measuring cylinder.

Dessicator.

Crucible.

3.2.2 Reagents:

Water (tap water).

Distilled water.

Sodium Hydroxide (NaOH 0.1N) (Analytical Reagent).

Sodium Hydroxide (NaOH 1.25%) (Analytical Reagent).

Sodium hydroxide (NaOH 40%) (Analytical Reagent).

Phenolphthalein solution (Analytical Reagent).

Iodine (1.0N) (Analytical Reagent).

Starch solution (Analytical Reagent).

Ethanol (Boiling point 78.3 ^{o} C -78.8^{o} C) (Analytical Reagent).

Acetic acid (CH_3COOH) (Analytical Reagent).

Chloroform ($CHCL_3$) (Analytical Reagent).

Acetone (Analytical Reagent).

Carbon tetrachloride ($CHCl_4$) (Analytical Reagent).

Sodium thiosulphate ($Na_2S_2O_3$ 0.1N) (Analytical Reagent).

Hexane (Boiling point 65 ^{o} C) (Analytical Reagent).

Ethanolic potassium hydroxide (KOH 0.5N) (Analytical Reagent).

Potassium Iodide (KI 10%) (Analytical Reagent).

Saturated potassium iodide (KI) (Analytical Reagent).

Hydrochloric acid (HCl 0.5N) (Analytical Reagent).

Hydrochloric acid (HCl 0.1N) (Analytical Reagent).

Iodine mono chloride (ICl) (Analytical Reagent).

Concentrated sulphuric acid (H_2SO_4) (Analytical Reagent).

Sulphuric acid (H_2SO_4 1.25N) (Analytical Reagent).

Boric acid (2%) (Analytical Reagent).

3.3 Methods:

3.3.1 Samples preparation:

3.3.1.1 Raw material:

An amount of 2000 g of baobab (raw material) was used, 33% fruit pulp (660g), 1.5% fibre (30g) and 65.5% seeds (1310g).

3.3.1.2 Baobab water extract sample (TSS 6%):

About 2000 g of whole baobab (fruit pulp, fibre and seeds) were soaked in 8 liters of water as ratio (1:4) for four hours at room temperature 28^{o} C.

Then the seeds (1310g) and the fibre (30g) were removed with plastic mesh as prefiltration operation, then the cake was separated from water extract with centrifuge filter (Tripod suspended separator), with 1385 rpm in 20 min.

Baobab water extract = 7.66L.

Cake = 1000g.

Seeds = 1310g.

Fibres = 30g.

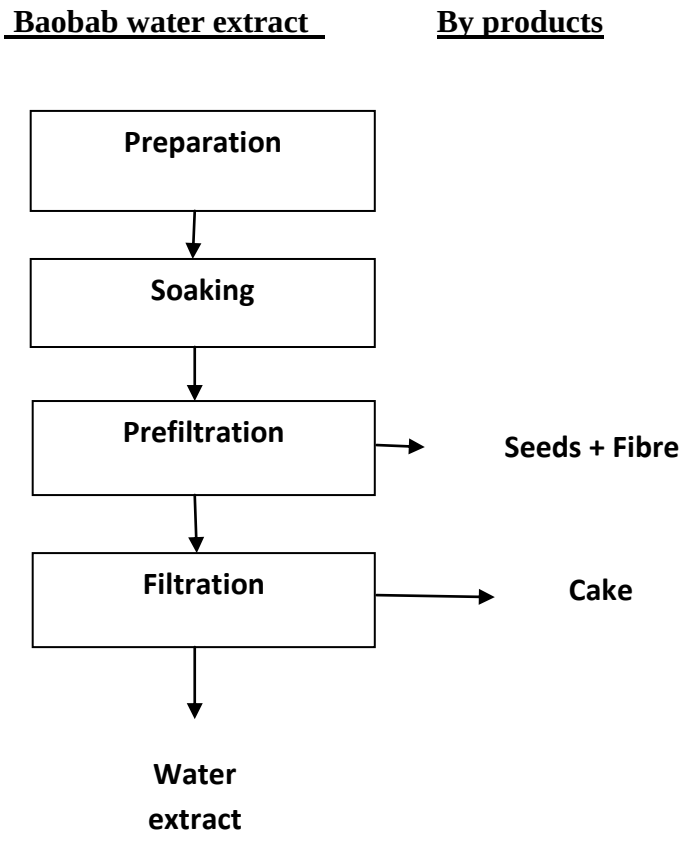

Fig. (3.1): Baobab water extract flow chart

3.3.1.3 Baobab concentrated water extract sample (TSS 12%):

Vacuum evaporator (Flash evaporator, TOKYO RIKA-KIKAI CO.LTD) was used to concentrate the baobab water extract(TTS 6%), the vacuum evaporator contains a water bath (100^{o}C) and two coolers, one for cooling motor and the other for condenser, the evaporator was started at vacuum (- 60kg/cm^{2}), the baobab concentrated water extract (TSS 12%) leave the evaporator at temperature 48^{o}C.

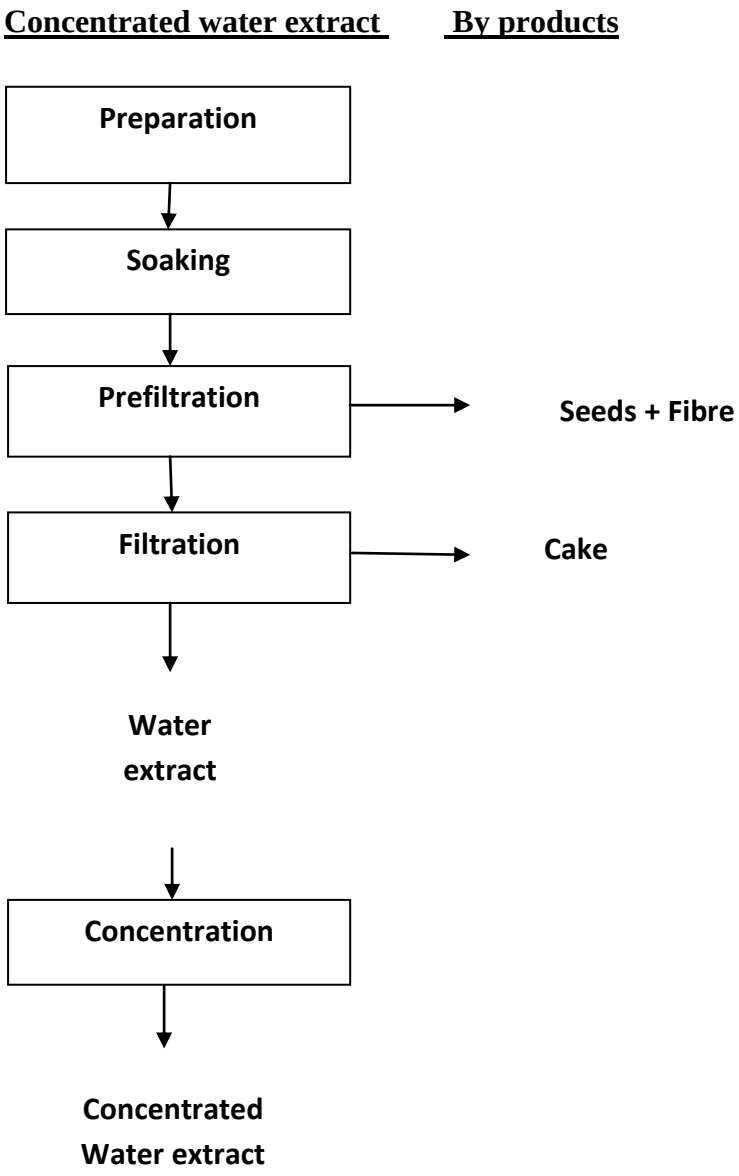

Fig. (3.2): Baobab concentrated water extract flow chart

It was noticed that the concentrates showed a settlement of the solid phase, leaving a clear solution on top. This can possibly be remedied by the addition of binding agents (gum Arabic or corn flour or CMC).

3.3.1.4 Baobab seed oil sample:

Baobab seeds were dried, crushed, pressed and filtered.

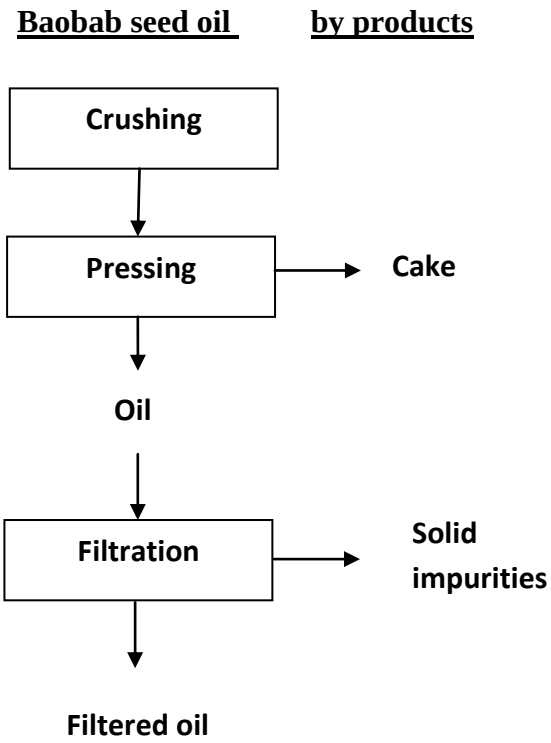

Fig. (3.3): Baobab seed oil flow chart.

3.3.2 Temperature:

The temperature was raised from 30^0C to 70^0C using a water bath (OSK 6361 Electric Water Bath), the temperature was measured by thermometer, which was inserted into the bottle of the sample.

3.3.3 pH:

The pH was measured by using pH-meter, (model PHSJ-4A PH METER), the PH-meter electrode was inserted into the beaker, pH was recorded directly from the screen of pH-meter.

3.3.4 Concentration:

The refractometer, (model 60/70 ABBE) was used to determine the concentration.

3.3.5 Vitamin C:

Vitamin C was determined according to the method of AOAC (1990), 10 ml of sample were taken into a conical flask, and then dissolved in 90 ml of distilled water, then 5 drops of starch solution were added as indicator with dropper then the mixture was titrated with iodine I.0N, then the consumed volume of iodine was recorded.

$$\text{Vitamin C\%} = \frac{\text{ml of iodine} \times 0.088 \times 100}{\text{volume of sample}}$$

3.3.6 Acidity:

The Acidity was determined according to the method of AOAC (1990), 5g of sample was taken into a conical flask then dissolved in 30 ml of ethanol, then 5 drops of phenolphthalein were added as indicator, after that the mixture was titrated with sodium hydroxide NaOH 0.1N, the consumed volume of NaOH was recorded.

The Acidity was calculated as follows:

$$\text{Acidity as citric acid\%} = \frac{V*N*Meq}{W} *100$$

Where:

V ≡ Volume (in ml) of NaOH used.

N ≡Normality of NaOH.

Meq ≡Milliequivalent weight of citric acid.

W≡ Weight of sample.

3.3.7 Density:

The density was measured according to the method of AOAC (1990) by using pycnometer (100 ml).

The density was calculated as follows:

$$\text{The density} = \frac{W_1 - W_2}{V}$$

Where:

W_1≡ The weight of the liquid + the weight of the empty pycnometer

$W_2 \equiv$ The weight of empty pycnometer.

V $\equiv$ Volume of the liquid (100ml).

3.3.8 Viscosity:

The viscosity was measured according to the method of AOAC (1990), Ostwald viscometer (U-tube viscometer) was used to measure the viscosity, the liquid was sucked up the mark A (upper point on the arm), when the liquid was reached above the mark A, the finger was used to control the liquid's flow until reached mark A, then stop watch was used to measure the time from point A to point B (lower point on the arm), same method was used for water, then the time was then substituted in the following formula to get the viscosity of the liquid.

The viscosity was calculated as follows:

$$\mu_1 = \left(\frac{\rho 1}{\rho 2}\right)\left(\frac{t1}{t2}\right)\mu_2$$

Where:

$\mu_1 \equiv$ Liquid's viscosity

$\rho_1 \equiv$ Liquid's density

$t_1 \equiv$ The time per second of the liquid from point A to point B.

$\mu_2 \equiv$ Water's viscosity

$\rho_2 \equiv$ Water's density.

$t_2 \equiv$ The time per second of the water from point A to point B.

3.3.9 Solubility:

The solubility was measured according to Muckhtar (2001) method, accurately 1.0 g of sample was dissolved in 100 ml of distilled water (1% w/v), and the mixing was done by using magnetic stirrer (IKARCT basic) for one hour until the sample was fully dissolved. The solution was passed through a No 44 filter paper and the filter paper was dried in an oven (Electrothermal Thermostat Dryer, model G2X-DH-300 BS) for one hour.

$$\text{Insoluble matter\%} = \frac{W_1 \times 100}{W_2}$$

Where:

$W_1 \equiv$ weight of insoluble matter.

$W_2 \equiv$ weight of sample (1g).

The solubility% = 100 - insoluble matter

3.3.10 Chemical composition of fruit pulp:

3.3.10.1 Determination of moisture content:

The moisture content was measured according to the method of AOAC (1995), 5g of sample was taken into a dish then placed into an oven (Electrothermal Thermostat Dryer model G2X-DH-300 BS) for three hours at 105^{o}C after that the dish was transferred quickly into a dessicator to cool down to room temperature, and then the weight was recorded.

The moisture content calculated as follows:

$$\text{Moisture \%} = \frac{\text{loss in weight} \times 100}{\text{weight of sample}}$$

3.3.10.2 Determination of ash content:

The ash content was measured according to the method of AOAC (1995), 3g of sample was taken into a crucible, and then placed into a muffle furnace (model Carbolite NO. 3/78/255 Type LME1-PD) at 550^{o}C for 6 hours, after that the crucible was placed into dessicator to cool down to room temperature, then the weight was recorded.

The Ash content calculated as follows:

$$\text{Ash content\%} = \frac{\text{weight of ash} \times 100}{\text{weight of sample}}$$

3.3.10.3 Determination of protein:

The protein content was measured according to the method of AOAC (1995). One gram of sample was taken into khjeldahal flask and 1 g of catalyst was added as digestion mixture, then 25ml of concentrated sulphuric acid H_2SO_4 were added, and antipumping granule particles were added and placed in khjeldahal unit (model BUCHI, B323 Simi-micro khjeldahal) for 2 hours, the digested mixture was cooled down to room temperature and diluted to 100 ml with distilled water in volumetric flask, then 20 ml of the diluted solution were taken into the distillation unit flask, 10 ml of sodium hydroxide NaOH 40% were added, the distilled solution was received in conical flask which contained 25ml of boric acid (2%), the distillation was continued until the volume reached 50 ml and color became blue, the solution was

titrated with hydrochloric acid HCl 0.1N until color changed to red, and the volume of HCl was recorded.

The protein percentage was calculated as follows:

$$\text{Protein \%} = \frac{V*N*0.014*6.25*\text{dilution factor}}{W} \times 100$$

Where:

V≡ Consumed volume of HCl

N≡ Normality of HCl

W≡ Weight of sample

3.3.10.4 Determination of oil content:

The oil content was determined according to the AOCS Official Method Am 2- 93 revised (2000), the sample was placed into an oven for three hours at 105^{o}C to remove the moisture, then cooled down to room temperature, 10g of the sample was taken into the thimble and closed properly with cotton, the thimble and sample were placed in the soxhlet extractor, the solvent (hexane) was poured into the round bottom flask , heating mantle(model EME 6 0250/CEB-Elecromantle ME) was started to reflux the solvent, the refluxing was continued 6 hours, then the thimble was transferred into the oven to ensure complete removal of the solvent, then cooled down to room temperature , and the weight was recorded.

Oil content was calculated as follows:

$$\text{Oil content \%} = \frac{\text{weight of oil}}{\text{weight of sample}} \times 100$$

3.3.10.5 Determination of crude fibre:

The fibre content was measured according to the method of AOAC (1995), 2g of defatted sample was taken into a beaker, 200 ml of sulphuric acid H_2S0_4 1.25% were added and boiled for 30 minutes using heater, then the contents were filtered through a Buchner funnel, and the residue was transferred into the beaker, 200 ml of sodium hydroxide NaOH 1.25% were added and boiled for 30 minutes, the contents were again filtered and dried into an oven at 130^{o}C for 2hours, the contents were weighed and placed into a muffle furnace at 550^{0}C for 6 hours, and the weight was recorded.

The fibre content was calculated as follows:

$$\text{Fibre content \%} = \frac{\text{loss in weight}}{\text{weight of sample}} \times 100$$

3.3.10.6 Determination of carbohydrates:

The total carbohydrates were calculated by difference. The sum of moisture, ash, protein, fat and fibre were subtracted from 100 as it was described by West *et al*, (1988).

The total carbohydrates% = 1OO – (moisture% + ash% + protein% + fat% + fibre%)

3.3.11 Baobab seed oil:

3.3.11.1 Determination of moisture content:

The moisture content was measured according to the method of AOCS official Method Ba 2a-38 revised (2003), 5g of sample was taken into a dish then placed into an oven (Electrothermal Thermostat Dryer model G2X-DH-300 BS) for three hours at 105^{o}C after that the dish was transferred quickly into a dessicator to be cooled down to room temperature, and the weight was recorded.

The moisture content calculated as follows:

$$\text{Moisture \%} = \frac{\text{loss in weight}}{\text{weight of sample}} \times 100$$

3.3.11.2 Determination of refractive index:

The AOCS official Method Tp, La-64 revised (2003), was used to determine the refractive index at 20^{0}C using refractometer (model ATAGO Rx-7000 α).

3.3.11.3 Determination of Free Fatty Acids:

The free fatty acids were determined according to the method of AOCS official Method Ca 5a-40 reapproved (1997), 5g of sample was taken into a conical flask, then dissolved in 30 ml of ethanol, and 5 drops of phenolphthalein solution were added as indicator, then the mixture was titrated with sodium hydroxide NaOH 0.1N, then consumed volume of NaOH was recorded.

The free fatty acids as oleic acid calculated as follows:

$$\text{F.F.A\%} = \frac{V*N*Meq}{W} *100$$

Where:

F.F.A% ≡ Free fatty acids as oleic acid%.

V ≡ Consumed volume of NaOH.

N ≡ Normality of NaOH.

Meq ≡ Milliequivalent weight of oleic acid.

W≡ The weight of sample.

3.3.11.4 Determination of Peroxide value:

The peroxide value was determined according to the method of AOCS official Method Cd 8-53 revised (2003), 5g of sample was taken into a conical flask, 30 ml of mixture of acetic acid CH_3COOH and chloroform $CHCl_3$ as a ratio 3:2 were added, then 0.5 ml of saturated solution of potassium iodide KI was added, the mixture was shaked for one minute, then 30 ml of distilled water were added, and 5 drops of starch solution were added as indicator, then the mixture was titrated with sodium thiosulphate $Na_2S_2O_3$ 0.1N and the consumed volume of $Na_2S_2O_3$ was recorded, the blank experiment was carried out under same conditions, without added oil; the blank was titrated with $Na_2S_2O_3$ 0.1N, and consumed volume of $Na_2S_2O_3$ was recorded.

Peroxide value was calculated as follows:

$$P.V\ (Meq\ O_2/Kg) = \frac{(S - B) * N * 1000}{W}$$

Where:

P.V ≡ Peroxide value.

B ≡ Volume of $Na_2S_2O_3$ required to titrate blank.

S ≡ Volume of $Na_2S_2O_3$ required to titrate sample.

N≡ Normality of $Na_2S_2O_3$

W≡ Weight of sample.

3.3.11.5 Determination of Oil content:

The oil content was determined according to the method of AOCS official Method Am 2-93 revised (2000), the sample was placed into the oven for three hours at 105^oC to remove the moisture, then the sample was cooled down to room temperature into a dessicator, then 10 g of the sample was taken into the thimble and closed properly with cotton, the thimble and sample were weighed and then placed

into the soxhlet extractor , the solvent (hexane) was poured into the round bottom flask, and heating mantle (model EME 6 0250/CEB-Elecromantle ME) was started to reflux the solvent, the refluxing was continued 6 hours, the thimble was transferred into the oven to ensure complete removal of the solvent, then cooled down to room temperature into a dessicator, and the weight was recorded.

Oil content was calculated as follows:

$$\text{Oil content \%} = \frac{\text{weight of oil} \times 100}{\text{weight of sample}}$$

3.3.11.6 Determination of saponification value:

The saponification value was determined according to the method of AOCS official Method Cd 3-25 revised (2003), 5g of the sample was taken into a clean dry round bottom flask, 50 ml of ethanolic potassium hydroxide KOH 0.5N were added, and the mixture was placed into water bath for one hour, then the mixture was cooled to room temperature, 5 drops of phenolphthalein were added as indicator, and the mixture was titrated with hydrochloric acid HCl 0.5N. The consumed volume of HCl was recorded, the blank experiment was carried out under same conditions without added oil; the blank was titrated with HCl 0.5N and consumed volume of HCl was recorded.

Saponification value was calculated as follows:

$$\text{Saponification value (mg KOH/g)} = \frac{(B - S) * N * 56.1}{W}$$

B ≡ Volume of HCl required to titrate blank.

S ≡ Volume of HCl required to titrate sample.

N ≡ Normality of HCl.

W ≡ Weight of sample.

3.3.11.7 Determination of iodine value:

The iodine value was determined according to the method of AOCS official Method Cd 1-25 revised (2003), 0.3g of the sample was taken into a conical flask then it was dissolved in 10 ml of carbon tetrachloride and 25ml of wijs solution (Iodine mono chloride ICl) were added and the mixture was placed in dark for 30 minutes, after that 10 ml of potassium iodide solution KI 10% were added, 100 ml of distilled water were added, and 5 drops of starch solution were also added as indicator, and the mixture was titrated with sodium thiosulphate $Na_2S_2O_3$ 0.1N, and the consumed

volume of $Na_2S_2O_3$ was recorded, the blank experiment was carried out under same conditions (without added oil); the blank was titrated with $Na_2S_2O_3$, and consumed volume of $Na_2S_2O_3$ was recorded.

The iodine value was calculated as follows:

$$\text{Iodine value (g/100g)} = \frac{(B - S) * N * 12.7}{W}$$

Where:

B ≡ Volume of $Na_2S_2O_3$ required to titrate blank.

S ≡Volume of $Na_2S_2O_3$ required to titrate sample.

N ≡ Normality of $Na_2S_2O_3$

W ≡ Weight of sample

CHAPTER FOUR

Results and Discussion

4.1 Viscosity and density of baobab water extract (TSS 6%):

The effect of temperature on viscosity and density of baobab water extract (TSS 6%) are shown in Table (4.1), Figure (4.1) and Figure (4.3), the viscosity and density decreased with the increase in temperature.

Table (4.1): The effect of temperature on viscosity and density of baobab water extract (TSS 6%):

Temperature (^{o}C)	Density (g/ml)	Viscosity(Pa.s)
30^{o}C	1.0005	3.1565 x 10^{-3}
40^{o}C	0.9932	2.7445 x 10^{-3}
50^{o}C	0.9911	2.3755 x 10^{-3}
60^{o}C	0.9849	2.1964 x 10^{-3}
70^{o}C	0.9818	2.0080 x 10^{-3}

4.2 Viscosity and density of baobab concentrated water extract (TSS 12%):

The effect of temperature on viscosity and density of baobab concentrated water extract (TSS 12%) are shown in Table (4.2), Figure (4.2) and Figure (4.4), the viscosity and density increased with the increase in temperature. This information has not previously been reported. It is useful for designing, processing, handling and sensory evaluation of food product.

Table (4.2): The effect of temperature on viscosity and density of baobab concentrated water extract (TSS 12%):

Temperature (^{o}C)	Density (g/ml)	Viscosity(Pa.s)
30^{o}C	1.0132	9.8288 x 10^{-3}
40^{o}C	1.0134	10.5803 x 10^{-3}
50^{o}C	1.0136	11.3543 x 10^{-3}
60^{o}C	1.0138	12.4483 x 10^{-3}
70^{o}C	1.0141	13.4472 x 10^{-3}

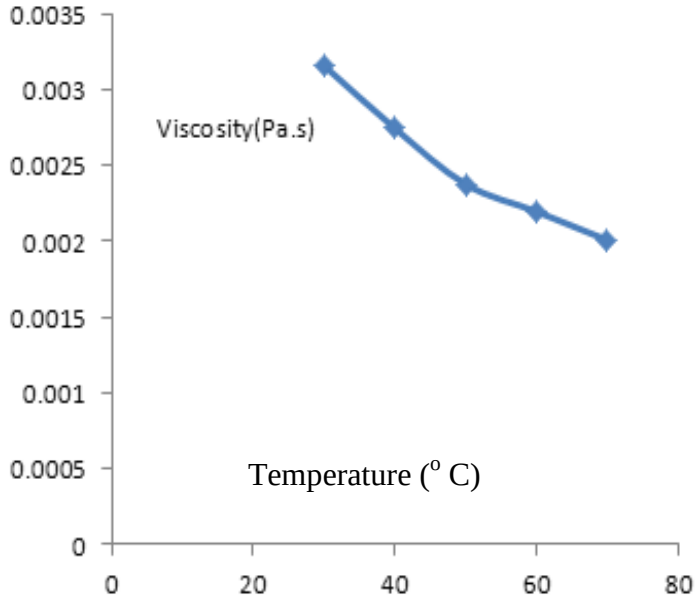

Fig. (4.1): The effect of temperature on viscosity of (TSS 6%)

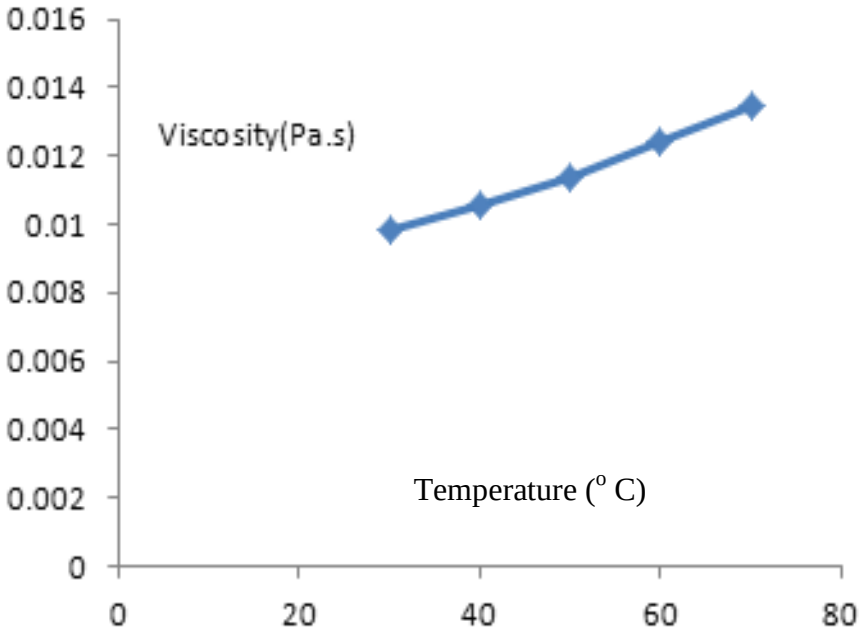

Fig. (4.2): The effect of temperature on viscosity of (TSS 12%)

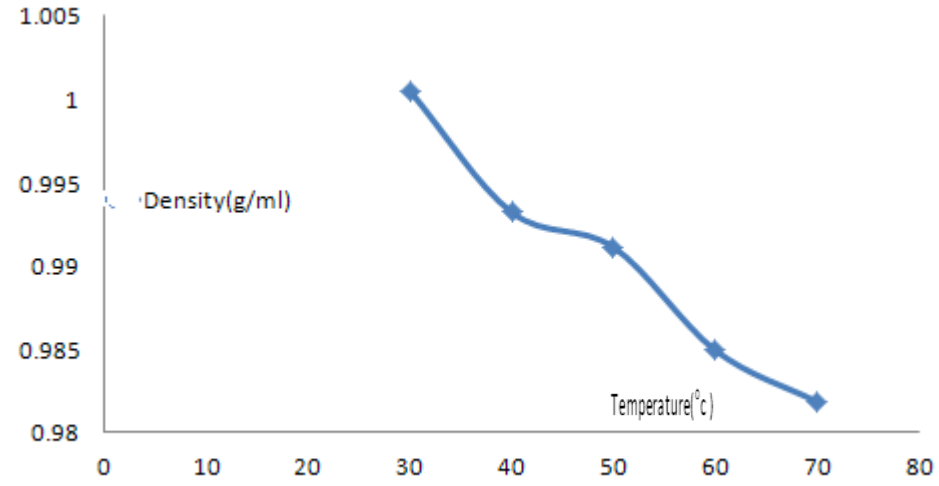

Fig. (4.3): The effect of temperature on density of (TSS 6%)

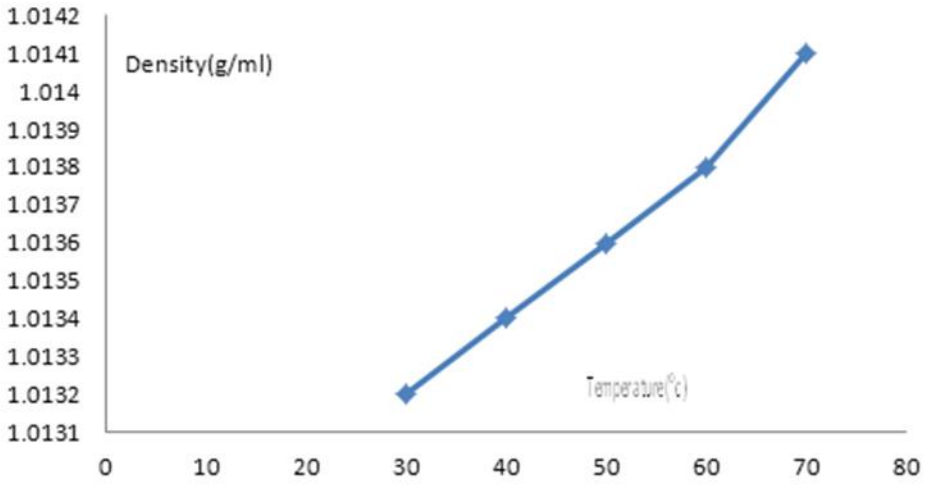

Fig. (4.4): The effect of temperature on density of (TSS 12%)

4.3 pH, vitamin C and acidity of baobab water extract (TSS % and 12%):

The pH, vitamin C and acidity of baobab water extract (TSS 6%) and concentrated water extract (TSS 12%) are shown in table (4.3), the pH of baobab water extract was (3.35) which is higher than in baobab concentrated water extract (3.11) because the acidity was increased with the decrease in pH (the acidity in baobab water extract was (23mg/g) and in concentrated water extract was (36mg/g)). Vitamin C content in baobab water extract was (4400 mg/kg) which is almost ten times the vitamin C in orange (vitamin C in orange 48.45 mg/100g as reported by (Alanowd and Soheer., 2005)), and vitamin C in concentrated water extract was (3500 mg/kg) it is less than in water extract, because vitamin C is sensitive to heat, and these results agreed with that reported by Nour *et al*., (1980).

Table (4.3): pH, Vitamin C and Acidity of baobab water extract (TSS 6% and 12%):

Parameter	Baobab water extract (TSS 6%)	Baobab concentrated water extract (TSS12%)
pH	3.35	3.11
Vitamin C(mg/kg)	4400	3500
Acidity(mg/g)	23	36

4.4 Chemical composition of baobab fruit pulp:

The chemical composition of baobab fruit pulp is shown in Table (4.4). Fruit pulp contains a high amount of carbohydrates (75.53%), low protein (2.90%) and extremely low oil (0.29%). The chemical composition of the fruit pulp is similar to that reported by Nour *et al*., (1980).The solubility was found to be (78.84%).

Table (4.4): Chemical composition of baobab fruit pulp:

Constituent	Percentage
Moisture	8.15
Protein	2.90
Oil	0.29
Fibre	8.11
Ash	5.02
Carbohydrate	75.53
Solubility	78.84

4.5 Characteristics of baobab seed oil:

The seed of baobab is generally underutilized. However, in order to make a more efficient use of baobab, the seed as a source of oil should be investigated. The baobab seed oil characteristics are shown in Table (4.5). The seed contains (13.40%) oil and (5.34%) moisture. The moisture content in the oil is low (1.90%). The free fatty acids (FFA) and peroxide value (PV) are important parameters in evaluating the quality of the oil with respect to rancidity and oxidation; the FFA obtained in this study (0.6%) is within the acceptable level recommended by CODEX for vegetable oils, the level of FFA is a good indicator to investigate the oil's suitability for edible purposes. The PV was (1.92 meq of O_2/kg of oil); this value is in agreement with the maximum codex standard peroxide value (10 meq of O_2 /kg of oil) for vegetable oil deterioration. The low level of FFA and PV obtained suggest that the oil can be stored for a long time without spoilage. The iodine value (84.5g/100g of oil) signifies a high degree of saturation and the lesser the liability of the oil to become rancid by oxidation, the baobab seed oil can be classified as a non-drying oil. The high value of saponification (206 mg KOH/g) indicates that the baobab seed oil is a good source for soap production. Similar results were reported by Osman (2004).The oil refractive index (1.4703) is similar to that reported by Affo and Akande (2011).

Table (4.5): The characteristics of baobab seed oil:

Characteristic	Value
Refractive index	1.4703
Free fatty Acids%	0.60
Peroxide value (meq O_2/kg)	1.92
Oil content%	13.40
Saponification value (mg KOH/g)	206
Iodine value (g/100g)	84.50
Oil moisture%	1.90
Seed moisture%	5.34

CHAPTER FIVE

Conclusions and Recommendations

5.1 Conclusions:

1- In this study the viscosity of the total soluble solids (6%) decreased with the increase in temperature, and the viscosity of the total soluble solids (12%) increased with the increase in temperature. This information is reported here for the first time.
2- Fruit pulp is a good source of vitamin C, carbohydrates and fibre.
3- The physiochemical properties showed that the baobab seed oil is a non-drying and stable that can be used in food and other industries.

5.2 Recommendations:

1- Both of the concentrates (TSS 6% and 12%) can be used for further dilution with water with the addition of sugar to consumer taste. However further study on the stability of the concentrates is to be carried out.
2- More research is needed for the baobab tree to be used for different purposes.

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