بسم الله الرحمن الرحيم

Shendi University

Faculty of Graduate Studies and Scientific Research

Production of particle Boards Using Adhesives and Cellulosic Materials Of The Degree of MSC. In Chemistry

By

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Feb 2018

الآية القرآنية :

بسم الله الرحمن الرحيم

﴿وَهُوَ الَّذِي أَنْزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجْنَا بِهِ نَبَاتَ كُلِّ شَيْءٍ
فَأَخْرَجْنَا مِنْهُ خَضِراً نُخْرِجُ مِنْهُ حَبّاً مُتَرَاكِباً وَمِنَ النَّخْلِ مِنْ طَلْعِهَا
قِنْوَانٌ دَانِيَةٌ وَجَنَّاتٍ مِنْ أَعْنَابٍ وَالزَّيْتُونَ وَالرُّمَّانَ مُشْتَبِهاً وَغَيْرَ
مُتَشَابِهٍ انْظُرُوا إِلَى ثَمَرِهِ إِذَا أَثْمَرَ وَيَنْعِهِ إِنَّ فِي ذَلِكُمْ لَآيَاتٍ لِقَوْمٍ
يُؤْمِنُونَ﴾

[سورة الأنعام الآية ٩٩]

Dedication

To my parent’s

Acknowledgment

I would like to Thanks God for giving me the strength determination and health to accomplish this research.

I would like to express my deep appreciation to my supervisor Dr. Ibrahim Mohammed Ahmed for his patience guidance, encouragement and valuable and constructive suggest during the planning and development of this search. His kindness and generous attitudes has been very much appreciated.

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Abstract:

The aim if this study is the Production of new types of cellulosic adhesives used in partition, office furniture and household utensils.

The research employs the cellulose from cellulosic plant and use unemployed plants like mesquite.

The binding for cellulose materials investigated comprised, Gum Arabic, Guar, Nocrine and other polymer formulations.

The research used ordinary glassware, balance and iron and wood moulds to give the desired shapes.

The products were tested using hardness tester for the adhesion strength and moisture absorption for the efficiency, The Result obtained were as follows:

Mesquite + gum Arabic =54.9 N, (N for Newton)

Mesquite + Guar =43.2 N

Mesquite +Musk wood by Gum Arabic = 43.00 N

Okra + Gum Arabic =44.6 N

Mesquite +Okra by Gum Arabic = 42.2 N

For humidity and moisture contents the following result were obtained:

Okra +Gum Arabic:

Okra by Gum Arabic the original weight was (8g) , after one hour gave (9.7g), and after two hours (12.9g) then after 3 hours (12.1g) the sample was swelling by water.

Mesquite +Gum Arabic:

Mesquite by Gum Arabic the original weight was (17.4g), after an hour gave (29.2g), after 2 hours (30.4g) then after 3 hours the increased of water content great (30.9g) which indicate the capacity of water regain.

Mesquite +Musk wood and Gum Arabic:

(4.9g) of Gum Arabic by mesquite and musk wood was weight, after hour gave (4.9g), after 2 hours gave (5g) then after 3 hours gave (4.2g)

Mesquite +Okra and Gum Arabic:

Okra and mesquite by Gum Arabic the original weight was (5.2g), then after an hour gave (5.3g), after 2 hours (8.7g) then after 3 hours (6.9g) as increased by water absorption.

Mesquite + Guar:

Weight was (11.3g), and then after one hour gave (19.2g), after 2 hours (16.6g) then after 3 hours (9.6g) the increased of water contain followed decrease of water contain indicate the disintegrated of the sample by water.

المستخلص

الهدف من هذا البحث هو إنتاج أنواع جديدة من الخشب مثل الخشب القوي الذي يستخدم في الفواصل ، الأثاث والخشب الضعيف الذي يستخدم في المكاتب والمنازل.

إستخدم البحث أنواعا من المواد السليلوزية المستخدمه والتى ترمى أعقابها مثل الخضره والبامية والإستفادة من النباتات الغير مستخدمه مثل المسكيت .

معرفة جودة اللواصق الطبيعيه والصناعيه وأيها الأفضل أستخداما مع الخشب مثل الصمغ العربي والقوار والنوكرين والبوليمرات الاخرى.

أستخدم البحث الأدوات الزجاجية العادية في المختبر.

تم إلصاق جميع العينات باللواصق المختلفه بإستخدام أدوات معينه مثل الساق الزجاجيه ، والميزان الحساس والقالب الذي يبني شكل العجينه. وأجريت عليها الإختبارات الآتية:

1.جهاز الإصطدام (الطق والكسر):

في هذا الجهاز توجد طاوله الصلابه التى يجرى عليها الاختبار حيث سحب العينة ويتم كسرها بالضغط على مكعب العينة ميكانيكيا بإستقامة على الطاولة.

وكانت النتيجة هي:

مسكيت+ضمغ عربي = ٥٤,٩ ن (ن = نيوتن).

قوار مسكيت + قوار = ٤٣,٢ ن

مسكيت+خشب الموسك+صمغ عربي43.00ن

بامية+صمغ عربي=44.6ن

مسكيت+بامية +صمغ عربي= 42.2 ن

٢.إختبار الإمتصاص والرطوبة:

أخذ وزن العينه أولا وتسجل ثم توضع في كأس ممتلئ بحيث تحاط بكل الجهات بالماء وتأخذ القراءات في ثلاثة أوقات مختلفه (أي ٣ ساعات) .

بامية+صمغ عربي:

وزن العينه الجاف ٨جرام بعد ساعه أصبح وزنها ٩,٧ جرام وبعد ساعتين ١٢,٩= جرام أما بعد ثلاث ساعات=١٢,١جرام

مسكيت+صمغ عربي:

وزن العينه الجاف ١٧,٤ جرام بعد ساعه أصبح وزنها = ١٧,٤ جرام وبعد ساعتين= ٣٠,٤ جرام أما بعد ثلاث ساعات= ٣٠,٩ جرام وهذا يعني أن العينه قد إمتلئت بالماء.

مسكيت+خشب الموسك +صمغ عربي:

وزن العينه الجاف=٤,٩ جرام بعد ساعه أصبح وزنها =٤,٩ جرام وبعد ساعتين= ٥ جرام أما بعد ثلاث ساعات= ٤,٢ جرام هذا يعني أن العينه ثابته ولاتمتص الماء إلا بكميات لاتذكر.

مسكيت+بامية+صمغ عربي:

وزن العينه الجاف ٥,٢جرام بعد ساعه أصبح وزنها=٥,٣ جرام وبعد ساعتين ٨,٧ جرام أما بعد ثلاث ساعات =٦,٩ جرام.

مسكيت +قوار:

وزن العينه الجاف=١١,٣ جرام وزن العينه بعد ساعه من وضعها في الماء=١٩,٢ جرام وبعد ساعتين ١٦,٦جرام أما بعد ثلاث ساعات =٩,٦ جرام هنا يعني أن العينه قد تفتت ونقص وزنها.

Chapter One:

Introduction

Introduction:

1.1 Cellulose:

Cellulose is the most abundant renewable organic resource on Earth and is widespread in higher plants, bacteria, marine algae, and other biomass. The total annual amount of cellulose is several billion tons, revealing the huge economic value of it.

Cellulose is the main component of the plant cell. Although some animals (such as tunicates) and some bacteria contain cellulose, the content of cellulose in these species is negligible when compared with plants. Cellulose was first separated by Anselme[1] from timber that was alternately treated with nitric acid and sodium hydroxide solution. It is a β-1,4-linked linear polymer of glucose units and is insoluble in water, dilute acidic solutions, and dilute alkaline solutions at normal temperatures.

Although the structure and composition of the cell walls of plants vary widely, the cellulose content usually accounts for 35–50 % of dry weight and, peculiarly, almost 100 % for cotton. Study of the supra molecular structure of natural cellulose showed that the crystalline and non crystalline phases intertwine to form the cellulose. The non crystalline phase assumes an amorphous state when tested by X-ray diffraction because most hydroxyl groups on glucose are amorphous However, large amounts of hydroxyl groups in the crystalline.

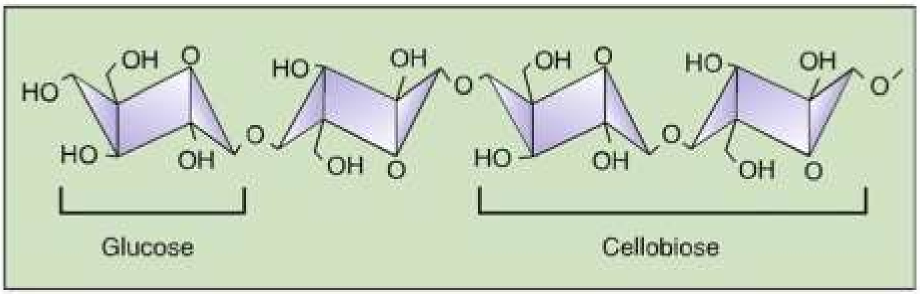

Fig (1.1) Molecular chain structure of cellulose [1]

form many hydrogen bonds, and these hydrogen bonds construct a huge network that directly contributes the compact crystal structure[2]. In most conditions, the cellulose is wrapped by hemicellulose (dry matter accounting for 20–35 %) and lignin (dry matter accounting for 5–30 %). Cellulose has become an important raw material for the pulp and paper, textile, and fibrous chemical industries. Predictably, bioenergy generated from lignocellulosic materials will become clean energy in the future.

Chemical Structure of Cellulose:

Cellulose is a linear homopolymer composed of D-glucopyranose units linked byβ-1,4-glycosidic bonds . It mainly contains carbon (44.44 %), hydrogen (6.17 %), and oxygen (49.39 %). The chemical formula of cellulose is $(C_6H_{10}O_5)n$; n, called the degree of polymerization (DP), represents the number of glucose groups, ranging from hundreds to thousands or even tens of thousands. In the twentieth century, it was proved that cellulose consists of pure dehydrated repeating units of D-glucoses (as shown in Fig. 1.1), and the repeating unit of the cellulose is called cellobiose. Sodium hydroxide solution at different concentrations and different temperatures could dissolve cellulose with different DP. According to different solubilities under specific conditions, cellulose can be divided into three types:

① **α**-cellulose, which is dissolved in 16.5 % NaOH at 20 °C.

② β-cellulose, which is deposition extracted after neutralizing the acid solution and the remaining alkaline solution.

③ γ- cellulose, which is the soluble remainder in the neutralized solution.
Staudinger used a viscosity method to measure the DP of these three celluloses.
The results indicated that the DPs of α-cellulose, β-cellulose, and γ-cellulose were more than 200, between 10 and 200, and less than 10, respectively. In industry, α-cellulose usually is used to express the purity of cellulose. Traditionally, β-cellulose and γ- cellulose are together called industrial hemicellulose.
Holocellulose refers to all the carbohydrates in natural cellulose material, which also is the sum of cellulose and hemicelluloses[3].

Physical Structure of Cellulose:

The physical structure of cellulose refers to the spatial arrangement of different scale structural units, including the chain structure and aggregation structure of the polymer. The chain structure also known as the primary structure, shows the geometric arrangement of the atoms or groups in the molecular chain.

The short range structure is the first-level structure and refers to the chemical structure or stereo chemical structure of one or several structural units in a single-molecule polymer. Remote structure is the second-level structure and refers to the size of a single-molecule polymer and a special structure. The aggregation structure, also called the secondary structure, refers to the inner structure of the whole polymer, including the crystal structure, non crystal structure, orientational structure, and liquid crystal structure.

The third-level structure term is used to describe how molecules in a polymeric aggregate accumulate each other, such as tangly clew structure and crystal structure formed with ordered folding chains.

The chain structure of the polymer is the main structural hierarchy that reflects many characteristics of a polymer, such as melting point, density, solubility, viscosity, adhesion, and so on. The aggregation structure of a polymer is the major factor that determines the service performance of macromolecular compound products [4].

Filament Structure:

Structure of some natural and synthetic fiber materials (such as textile fibers, timbers, or fibrous protein); A fibril is a small, stretching unit; these unit in one direction. aggregate and then they constitute and also make long molecular chains gathered into bundles Because the inequality in size of febrile aggregation, current terminologies include elementary fibril, microfilament 10,000 glucose units, and the fibril[5] contains approximately 60–80 cellulose molecules.Hydrogen bonds are formed between adjacent molecules.

In a certain range of space, hydrogen bonding can be ment,macrofilament (also called a microfilament bundle) . Natural cellulose has shown in the X-ray pattern when it reaches a certain number. This space is called the crystalline region, and the rest is called the amorphous region.

Microfilament is composed of elementary fibrils and is fixed in size. Macrofilament has more than one microfilament, and its size varies with the sources or processing conditions of raw materials. The structural model proposed by Fegnel for all the cell wall of timber is the representative model for the microfilament structure of each layer of the cell wall.

He reported that the elementary fibril with a diameter of 3 nm is the most basic structure unit; 16 (4 x 4) elementary fibrils form a fibril with a diameter of 12 nm, then 4 fibrils form a relatively thick microfibril with a diameter of 25 nm, and more than one microfibril form macrofilament. Hemicellulose is filled between the adjacent elementary fibrils; the microfilaments are wrapped with lignin and A multilayer of several hemicelluloses is filled between fibrils 12 nm in diameter; the monolayer of hemicelluloses is filled between 3-nm elementary fibrils. Because the microfilament is formed before the lignification of the cell wall, lignin is surrounded by only microfilament with a diameter of 25 nm[5],

It is generally thought that the movement of the liquid in the cell wall occurs mainly at the elementary fibril level of hemicellulose; usually, contraction and swelling processes also mainly occur at this level. In recent years, elementary fibrils with a diameter of 1.7 nm have been found with high-resolution electron microscopy. Because the fibrils are surrounded by hemicellulose and the microfilaments are surrounded by a large amount of lignin, the microfilament can be observed after delignification, and the elementary fibril can be found only after the hydrolysis of hemicellulose.

The measurement results for elementary fibrils according to most investigators indicated that the diameter of elementary fibrils is between 30 and 35 Å, and an elementary fibril is composed of 40 cellulose macromolecular chains. The ordered region of cellulose macromolecules is the crystalline region; irregular regions form an incomplete crystalline structure. When the crystal diameter is about 3 nm, a monolayer of hemicellulose would exist around the crystal, and several cellulose crystals combine to form the cellulose crystal beam called the nanofiber. The diameter of a nanofiber is about 2–3 nm, and hemicellulose and lignin are around it. In summary, the fiber cell walls are composed of many fibers, and larger micro fibrils always consist of smaller elementary fibrils.

Aggregation Structure:

The aggregation state of cellulose, also called the supra molecular structure of cellulose, mainly refers to how cellulose molecules arrange to form crystal and amorphous structure , then elementary fibril and micro fibril structures.

X-ray diffraction studies showed that, in the aggregates of cellulose macromolecules, molecules in crystal structure arrange regularly and display a clear X-ray pattern, so the density of cellulose in the crystalline region is high (1.588 g/cm3). Molecular chains in the amorphous region arrange irregularly and loosely, so the distance between molecules is large. The density of cellulose in the amorphous region is low, 1.500 g/cm3. However, the molecule chain is almost parallel with the main spindle of cellulose. The cellulose crystallinity, generally between 30 and 80 %, refers to the percentage of all the cellulose occupied in the crystalline region [9].The crystallization of cellulose shows pleomorphism. There are five kinds of crystal modification in solid cellulose, whose characteristics can be reflected by characteristics of their unit cells. Under certain conditions, cellulose crystals can be converted into many crystal variants.

Type I is the crystal form of the natural cellulose. Types II, III, IV, and X are those crystal forms of “artificial” cellulose under artificial processing. Now, the commonly accepted cell structure of type I is the monoclinic unit cell model introduced [4].Extensive chemical treatment and heat treatment will change the crystal form; for example, ball milling can destroy crystal lattice completely. There is no distinct boundary from the crystalline region to the amorphous region. Each crystalline. region is called a microcrystal (also called a micel or micella). Since free hydroxyls at position 2, 3, and 6 of glucosyl in cellulose microcrystal regions have formed hydrogen bonds, only amorphous regions contain some free hydroxyls.

Physicochemical Properties of Cellulose:

Chemical Properties of Cellulose:

Every glucosyl ring of cellulose has three active hydroxyls: one primary hydroxyl group and two secondary hydroxyl groups. Thus, cellulose may have a series of chemical reactions related to hydroxyl. However, these hydroxyl groups also can form hydrogen bonds between molecules, which has a profound influence on the morphology and reactivity of cellulose chains, especially the intermolecular hydrogen bond formed by oxhydryl at C_3 and oxygen at an adjacent molecule ring ,These hydrogen bonds not only can enforce the linear integrity and rigidity of the cellulose molecule but also can make molecule chains range closely to form a highly ordered crystalline region[5] .The accessibility of cellulose refers to the difficulty reagents have in arriving at the cellulose hydroxyl. In heterogeneous reactions, the accessibility is mainly affected by the ratio of the cellulose crystalline regions to the amorphous regions. The reactivity of cellulose is the reactive capability of the primary hydroxyl and the secondary hydroxyl at the cellulose ring. Generally, because of the smallest steric hindrance, the reactivity of the primary hydroxyl groups is higher than for the secondary hydroxyl groups, so the reactivity of hydroxyl at C_6 with a bulky substituting group is higher. For example, esterification of toluenesulfonyl chloride chiefly occurs in the primary hydroxyl.

The reversible reaction occurs mainly in the hydroxyl group at C_6, and an irreversible reaction always occurs in the hydroxyl group at C_2. Thus, for the esterification of the cellulose the reactivity of the hydroxyl group at C_6 is the highest, but for the etherification, C_2 is the highest [5].

The degradation of cellulose is an important reaction that can be used to produce cellulose products. Acid degradation, microbial degradation, and alkaline degradation are mainly to break the glycosidic bonds between two adjacent glucose molecules; an alkali peeling reaction and oxidation-reduction reaction of cellulose usually act on reducing ends of celluloses, and the oxidative degradation of the cellulose occurs mainly in dissociating hydroxyls at C_2, C_3, and C6 of the glucosyl ring.

Cellulose molecule chains will form carbonyls at C_2 when oxidized to some degree and then be degraded in the following alkali treatment process by the elimination reaction of “-alkoxy. After disconnecting the glycosidic bond, the reaction product is formed and then degraded to a series of organic acids [4].Esterification and etherification reactions of cellulose act on three alcoholic hydroxyls of cellulose molecule monomer.

They can greatly change the properties of cellulose, thereby producing many valuable derivatives of cellulose, such as sulfonic ester, cellulose acetate, cellulose nitrate, and cellulose ether, carboxyl methyl cellulose, methyl cellulose, ethyl cellulose). To enhance the reactivity of ester and the ether bond of cellulose in multiphase medium and improve the quality of cellulose ester and ether, some pretreatments need to be performed.

The main methods:

① Pres welling treatment of celluloses can weaken the hydroxyl-binding forces between cellulose molecules to increase the reagents diffusion velocity in cellulose, such as being immersed in concentrated caustic solution , activated by glacial acetic acid, and so on.

② The elimination of crystallinity by the ethamine can only change the DP by 20 % (usually, the concentration is higher than 1 %) when the concentration of ethamine is more than 71 %. Therefore, it was analyzed that ethylamine only enters into the microfilaments, only makes the amorphous region swell, and does not greatly change crystallization regions.
③ Cellulose derivatives with a high degree of substitution and many hydroxyl groups are substituted substantially, so the total free hydroxy declines and water absorbability decreases. So, actually some cellulose derivatives with a low degree of substitution have higher water absorbability, such as methyl, ethyl, hydroxyethyl, hydroxymethyl cellulose ether, and so on. These groups lead to the swelling of the cellulose structure and binding force decrease in macromolecules. They further result in the increase of water absorbability, degree of hydrolysis, and wrinkle resistance. The improvement of wrinkle-resistant property can be used to enhance the stiffness and moisture resistance of cardboard; also, it can improve the burst strength and the dimensional stability of paper [4].

Physical Properties of Cellulose:

Free hydroxyls of cellulose have a strong attraction to many solvents and solutions but adsorbed water only exists in the amorphous region, not the crystalline region in the moisture sorption process, the hydrogen bonds of the amorphous region in the dry cellulose constantly could be broken; the hydrogen bonds in the cellulose molecules are replaced by the hydrogen bonds between cellulose molecules and water molecules, even forming new hydrogen bonds, and some hydrogen bonds in cellulose molecules remain.

In the desorption process, because of the obstruction from inside, hydrogen bonds between cellulose molecules and water molecules cannot be broken completely and reversibly, resulting in hysteresis. Some water absorbed by cellulose enters into the amorphous region of cellulose and forms the water bound by hydrogen bonds, called bound water. Molecules of bound water attracted by hydroxyl of cellulose are arranged in a certain direction and have a high density, making swelling the cellulose and generating a heat effect. When the celluloses absorb water that reaches the fiber saturation point, water molecules continue to enter into the cell lumina and pores of cellulose to form a main layer adsorbed water or capillary water, which is called free water. No heat effect and swell ability of cellulose exist when absorbing free water[4] .When solids absorb liquids, the configuration homogeneity does not change, but solids become soft with the decrease of the inner cohesive force and increased volume. This phenomenon is known as the *swell ability.*

Swellability of cellulose :

is divided into swell ability in the crystalline regions and swell ability between crystalline regions. The former refers to the fact that the swelling agent can only reach the surface of crystalline and amorphous regions, and the X-ray pattern of cellulose does not change.

The latter refers to the fact that the crystallization regions of microfilaments are permeated with the swelling agent and then swell to generate new crystalline lattice and display a new X-ray pattern. Unlimited swelling of the cellulose is dissolution. The hydroxyl groups in the cellulose have polarities.

As a swelling agent, the greater polarity the liquid has, the greater degree of swelling the cellulose has. The metal ion in the alkali solution is usually in the form of aqua ions which is more favorable for entering the crystallization region. Usually, 15–20 % NaOH will cause swelling within crystalline regions. If the alkali concentration is increased, the radius of aquo ions is reduced because the ion density is too high, resulting in the drop of swell ability. Except for alkali, the swellability of other swelling agents, sorted from strong to weak, is as follows: phosphoric acid,water, polar organic solvents, and so on. Cellulose is saturated in a concentrated solution of NaOH to generate alkali cellulose. Although alkali cellulose is washed with water and dried, such changes cannot restore it to its original condition. Alkali cellulose may have a crystalline form of hydrate cellulose that is more stable than that of natural cellulose, which would increase its absorbability and makes it easy to react with a variety of reagents. Using alkali to impregnate celluloses is also called *mercerization*. In addition, alkali cellulose is the important intermediate product for the production of viscose fibers and derivatives of cellulose ether [4] .Characteristics of polymer compounds are high molecular weight and a strong cohesive force. They have movement difficulties in the system and a poor diffusion capacity, so they cannot be dispersed in a timely manner in the solvent. The solvent dissolved with celluloses is not the real cellulose solution, but the mixed product is obtained by mixing celluloses and components in liquids. The solvents of the cellulose can be divided into two categories: aqueous and non aqueous.

Aqueous solvents include the following:

① Inorganic acids, such as H_2SO_4 (65–80 %), HCl (40–42 %), H_3PO_4 (73–83 %), and HNO_3 (84 %) can lead to the homogeneous hydrolysis of cellulose. Concentrated HNO_3 (66 %) does not dissolve the cellulose but forms an addition compound with cellulose.

② Lewis acids, such as LiCl, $ZnCl_2$, $Be(ClO_4)_2$, thiocyanate, iodide, bromide, and others, could dissolve celluloses with a low DP.

③ Inorganic bases, such as NaOH, hydrazine and sodium zincate, NaOH, and others can only dissolve cellulose with a low DP.

④ Organicbases, such as quaternary ammonium bases $(CH_3)_4NOH$, amine oxides, and others are also aqueous solvents. The application of amine oxide solvent to dissolve cellulose can be used to manufacture the man-made fibers.

⑤ Complexes, such as copper oxide ammonia (cuoxam), copper ethylenediamine (cuen), cobalt hydroxide ethylenediamine (cooxen), zinc ethylenediamine (zincoxen), cadmium ethylenediamine (cadoxen), and the iron–tartaric acid–sodium complex (EWNN, an aqueous alkaline solution of iron sodium tartrate) are included as aqueous solvents [4].

Anonaqueous solvent of cellulose:

refers to a nonaqueous or less-aqueous solvent that is based on the organic solvents. It consists of activators and organic liquids. The organic solvents can be used as a component of the active agent and as a solvent of the activator, which can make the solvent have a larger polarity to dissolve cellulose. Therefore, the mechanism of cellulose dissolved in a nonaqueous solvent system cannot be easily explained by swelling theory, as in aqueous solvents.

The detailed mechanism of this process can be expressed as follows:

①An oxygen atom and a hydrogen atom of cellulose hydroxyl participate in the interaction of the EDA; the oxygen atom and the hydrogen atom act as a -electron donor and a •-electron acceptor, respectively.

② The active agent in the solvent system has an electron donor center and an electron receiving center; the spatial location of these two centers is suitable for interaction with the oxygen atom and hydrogen atom of cellulose hydroxyl.

③ There is necessarily a suitable scope for the interaction strength of the EDA, causing the centers of the donor and acceptor to interact in polar organic solvents. When the hydroxyl charge separates to some extent, the complex of cellulose molecular chains is separated and dissolved .

Several different systems of nonaqueous solvents of cellulose exist:

①Paraformaldehyde/dimethyl sulfoxide (PF/DMSO) is an excellent new solvent system that is not biodegradable. PF resolves into formaldehyde by heating,and then formaldehyde reacts with the hydroxyl group of cellulose to generate hydroxymethylcellulose, which is dissolved in DMSO.

② Dinitrogen tetroxide/dimethylformamide (N_2O_4/DMF or DMSO) is an intermediary derivative of the reaction of N_2O_4 with cellulose to generate nitrite esters; it can be dissolved in DMFor DMSO.

③ Amine oxides directly dissolve cellulose without the intermediate derivatives.

④ Liquid ammonia/ammonium thiocyanate restricts the dissolution of the cellulose; the solvent consisting of 72.1 % (w/w) NH_4SCN, 26.5 % (w/w) NH_3, and 1.4 % (w/w) H_2O has the maximum dissolving ability.

⑤ Lithium chloride/dimethylacetamide (LiCl/DMAC) also directly dissolves cellulose without the intermediate derivatives. At room temperature, the LiCl/DMAC solution is stable and can be used for reeling off raw silk and film forming. Recently, research on nonaqueous solvents of cellulose has been active; they not only can be used to produce artificial fiber and films but also can be available for processing cellulosic materials and for the use of cellulose in homogeneous conditions to produce cellulose derivatives.

The problems of cellulose solvents are the low solubility of cellulose, high price and low recovery of solvents, and environmental pollution.Thermal decomposition of cellulose is in the narrow temperature range of 300–375$^{\mathrm{O}}$ ıC. Different products depend on different temperatures. Heated at a low temperature (200–280$^{\mathrm{O}}$ ıC), cellulose mainly dehydrates into dewatering cellulose and then forms charcoal and gas products. Heated at higher temperatures, cellulose separates into flammable volatile products (tar). The most important intermediate product of cellulose high-temperature thermal degradation is laevoglucose, which can be further degraded into low molecular products and tar-like products.

Tarlike products can be polymerized into an aromatic ring structure similar to graphite structure at high temperature (400$^{\mathrm{O}}$ ıC or higher). Mechanical degradation of the cellulose occurs because cellulose in the mechanical process can effectively absorb.

mechanical energy, causing changes of morphology and microstructure; these changes are shown as decreased DP and crystallinity and significantly increased accessibility [5].

Biosynthesis of Cellulose:

Cellulose Synthesizing Site:

Some research has already forecast that assembling of cellulose microfilaments is finished in the enzyme complex located in the extending top of the cellulose.

Then,scientists hypothesized that a cellulose synthase complex was made up of many subunits, and each subunit synthesized single-chain glucose, then polymerized it to the ordered particles of cellulose. But, until 1976, through the freeze-etching technique, the complex located in the end of the cellulose microfilament was first observed in green algae.

This verified the hypothesis that assembling of cellulose microfilaments is finished in the enzyme complex located in the extending top of the cellulose. The subunits of the complex are arranged linearly in three lines and form the linear enzyme complex where cellulose is synthesized [6]. The alternating self-aggregation and dispersion of the complex determine that the microfilament arrangement direction changes periodically, resulting in different levels of microfilaments arranged perpendicular to each other. Later, similar terminal complexes were observed in bacteria, mosses, ferns, green algae, and microtubule plants, but in corns, spherical complexes were found [7]. A terminal complex like a rosette has been observed in higher plants and concentrates in the cellulose gathering place. Each six cellulose synthase subunits of rosette synthesizes 6 glucose chains and then forms microfilaments with 36 chains.

The microfilament directions are mutually different in the different levels of the cell wall, which makes the cell wall in any direction have high mechanical strength [1] .The rosette complex not only has the function of synthase but also can bring glucose chains to the surface of cytoplasm. A complete rosette complex is essential for the synthesis of crystalline cellulose.The terminal complex would disappear or be changed when EDTA (ethylenediaminetetraacetic acid) is used to handle oysters or Congo red is used to handle banana cells, further causing the interruption or disturbance of cellulose biosynthesis.

Once the cellulose synthesis recovers, the terminal complex reappears. The mutation of the *Ces*AI gene in *Arabidopsis* heat-sensitive mutants (RSWL) will lead to the reduction of the cellulose content, the content of antacid “-glucan, and the number of rosette complexes in the cell membrane, perhaps because the mutation of this enzyme disrupts the structure of the rosette complex.This indicates that the RSW1 (a radial swelling phenotype) maybe one component constituting the rosette complex [8] ,[9]. used the polyclonal antibody technique on the central area in cotton *CesA* protein to verify that the plasma membrane has a rose-like structure, which was the complex of cellulose synthase, and was *Ces*A protein located in rosettes. This finding demonstrated that the *Ces*A gene has an important role in cellulose synthesis and provided direct evidence for the hypothesis that cellulose biosynthesis takes place in the terminal complex of the rosette[6] It is uncertain whether the rosette complex is composed of identical subunits or different subunits.

Key information on assembly also still cannot be clarified. The bacteria linear terminal complex goes through the cell membrane and lipopolysaccharide layer and mainly synthesizes the 1α types of cellulose I, which is the metastable monoclinic system. But, the rosette terminal complex in plants is part of the cell membrane, which mainly synthesizes the 1β type of cellulose I, which is a stable monoclinic form. Therefore, it is generally believed that cellulose synthesis in cotton also occurs in the cellulose synthase complex connected with the plasma membrane. In the process of cellulose biosynthesis, in addition to the terminal complex,another polypeptide with a molecular mass of 18 kDa also plays an important role.This polypeptide does not exist in the plasma membrane but is loosely connected with the plasma membrane. So, it is unlikely to be the component with catalytic activity in the cellulose synthase complexes.

However, it may have regulating effect because it can combine with 2,6-dichloro-phenyl nitrile, which is the inhibitor of cellulose synthesis.

Substrate for Cellulose Synthesis:

Identifying the substrate of cellulose synthesis has been difficult. Previous studies reported that callosum generated in the translating period was the substrate of cellulose synthesis.

This result was derived from the fact that, within vivo conditions, the speed of synthesizing callosum from the substrate that can supply a radioactive label is higher than the predictable accumulation level, and the conversion of callose radioactivity is consistent with the change of cellulose. The conversion may occur because of the transglycosylation of β-l,3-glucose polymerase; the discovery that the cell wall had the activity of β-l,3-glucose polymerase also supports the hypothesis mentioned.

Callose is a homopolymer of β-1, 3-linked glucoses. It plays an important role in the regulation of vital processes, such as metabolism of the sieve tube, the development of the gametophyte, and so on.

The composition and resolution of callose are directly related to the normal growth of plant metabolic processes [10]. The precursor for the biosynthesis of cellulose is uridinediphosphate-D-glucose (UDPG). However, in the past, UDPG was thought to be obtained by the catalysis of UDPG pyrophosphorylase. Now, with research on cotton fiber development, it has been found that the catalytic reaction by the sucrose synthase could also provide UDPG.

In the formation stage of the secondary wall of the cotton fibers, sucrose synthase is connected with cellulose synthase, which may be used as carbon path. Two sets of evidence support this view. It has been proved that in vitro biosynthesis of cellulose takes cellulose synthase from the cell membrane of cotton fiber as the enzyme source and UDPG as a substrate. The products are always β-1,3-glucan Biosynthetic pathway of plant cellulose fig (1.2) [11],[12]"-1,4-glucan, a few calloses, and a small amount of cellulose. When taking sucrose as a substrate, the synthetic rate of cellulose is equal to the synthetic rate of callose, and sometimes is more than the synthetic rate of callose; the absence of Ca^{2+} is more conducive to cellulose synthesis. This shows that cellulose synthase can only use the UDGP directly from the catalytic reaction by sucrose synthase, but callose synthase can directly use the free UDPG.

The other evidence is that, in the mutant of cotton without fibers, there is no gene expression of sucrose synthase in the ovule epidermal cell, but there is large gene expression of sucrose synthase in wild-type fiber cells; this shows that sucrose synthase has a close relation to the development of cotton fiber [13].

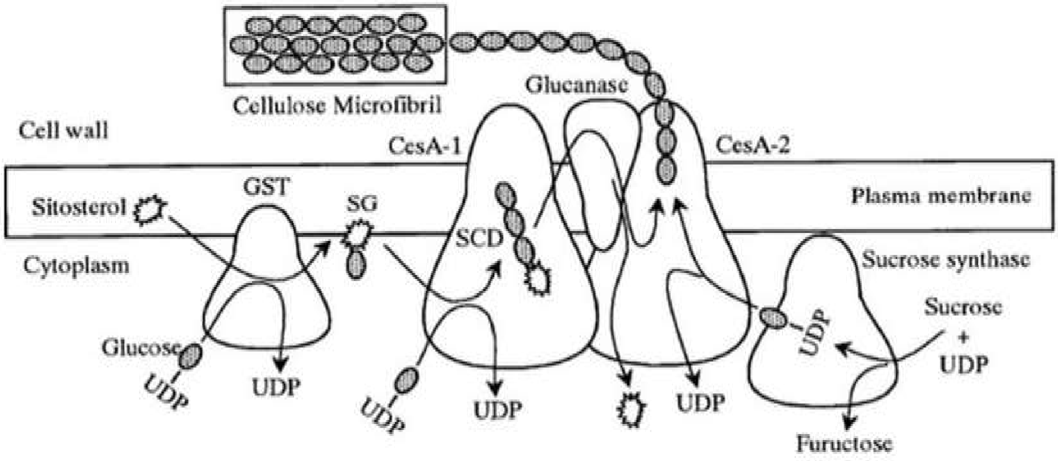

Fig (1.2) Biosynthetic pathway of plant cellulose

Cellulose Synthesis Process:

Currently, there are different hypotheses about the mechanism of cellulose synthesis.

One hypothesis suggests that the extension of the glucan chain is caused by the moving glycosyltransferase catalyzing several glucosyl residues to connect to the end of the growing cellulose chain. The synthesis of acetobacter cellulose may belong to such a mechanism.

The other hypothesis claims that some short glucan could polymerize with lipid or protein and form the mature cellulose polymer.

found that *Ces*A protein adhered to the end of noncrystalline fibers in fiber cell wall fragments treated with herbicide. Meanwhile, a small amount of the attached glucose chain was detected in these fragments, indicating that *Ces*A glycosyltransferase probably took sitosterol-β-glucoside (SG) as primers to start glucan polymerization. First, the SG and UDP-glucose is used as the substrate to generate sitosterol cellodextrin (SCD) and continue polymerization by the cellulose synthase, then enters into the crystallization process of cellulose [11],[12] schrick etal [14] (Fig. 2.2) .(studied the relationship of biosynthesis of *Arabidopsis* sitosterol and biosynthesis of cellulose; they found that sitosterol is important in cellulose.

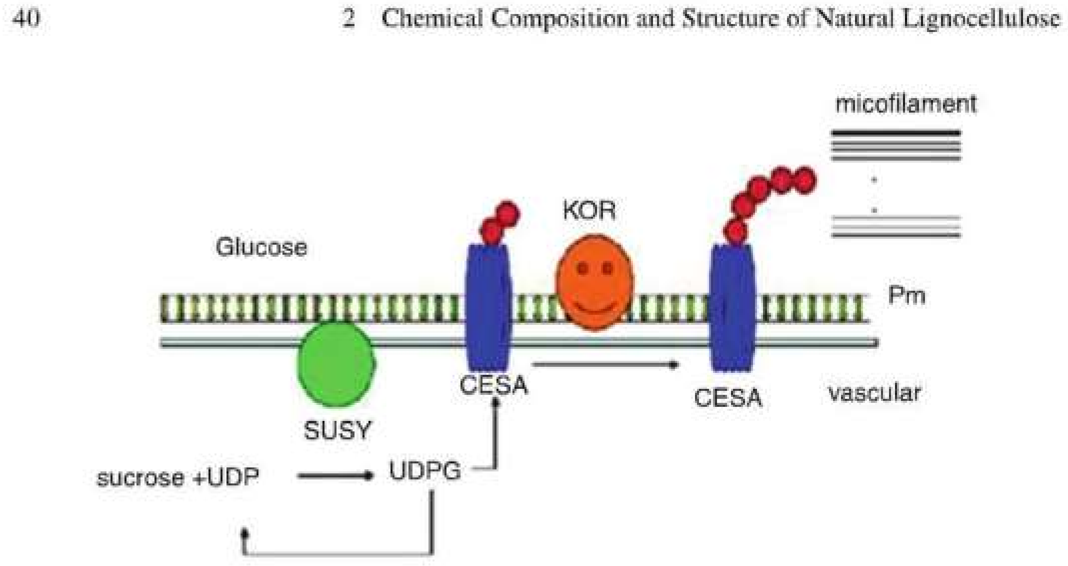

Fig. (1.3) Biosynthetic model of plant cellulose

biosynthesis in *Arabidopsis*, and SG was not the only primer of cellulose synthesis.But, recent research showed that the mechanism of cellulose synthesis in higher plants may belong to the second hypothesis.Cellulose synthesis in plants is the initiation, elongation, and termination of β- 1,4-glycosidic chains.

Under in vitro conditions, it is difficult to prove that UDP-Glu could directly synthesize cellulose, but it is generally considered that UDP-Glu is the substrate for it. A recent study found that SG from cotton fiber can be used as an initial extension when cellulose synthase catalyzes glucoside chains and then forms oligosaccharide linked with lipid, which is called SCDs. In the process of cellulose synthesis, cellulase (KOR) cut down SG from SCD so that the β-1, 4-glucoside chain could extend more effectively.

Further analysis showed that the catalytic subunit of *Ces*A is in one side of the cell membrane; the catalytic subunit of KOR is in the other side. This agrees with the following mechanism: *Ces*A accepts UDP-Glu from hyaloplasm to synthesize glucan, and then glucan crosses the plasma membrane to be further converted under the effect of cellulose. This is another significant discovery in understanding the molecular mechanisms of cellulose biosynthesis [6]. Therefore, the current anticipated process of plant cellulose biosynthesis has three steps:

(1) Sucrose synthase associated with plasma membrane guides the UDP-glucose to provide a substrate for the synthesis of cellulose.

(2) Hexagonal polymer is organized by the coexpressional multiple *Ces*A, and glucose monomers are polymerized to form a glucan chain; in the meantime, the discharged UDP is recycled to sucrose synthase.

(3) KORRIGAN (KOR), a kind of cellulase relating to the membrane, is regarded as the editor or monitor of the cellulose microfilament and can cut defective glucan chains (Fig. 2.3). Therefore, *Ces*A, sucrose synthase, and the KOR protein interact with each other to coregulate the biosynthesis of cellulose in plants [3].

Cellulose Synthase:

In 1996, by adopting complementary DNA (cDNA) random sequencing and series analysis, first cloned the β-1,4-glucosyltransferase gene *Cel*A, which encoded the catalytic subunit of cellulose synthase from cotton and rice [15]

Cellulose synthase has a polygene phenomenon; moreover, it constitutes a huge gene family with proteins such as cellulose synthase. Studies have shown that cellulose biosynthesis requires the participation of multiple cellulose synthase genes.

Furthermore, different cellulose synthase may be related to the different tissues and cellulose synthesis of different cell wall layers. Since the *Ces*A gene was cloned from cotton, cellulose synthase genes in many plants have also been separated and cloned in succession.

The complete genomic sequence of *Arabidopsis thaliana* has been completed, so research on the *Arabidopsis Ces*A gene is the clearest. The length of the cellulose synthase gene is probably in the range of 3.5–5 kb and contains 9–13 introns. The length of the transcription product is between 3.0 and 3.5 kb.

1.2 Lignocelluloses:

of components in the cell wall. Some reports also indicated that xyloglucan is related to plant morphogenesis. However, the generally accepted view is that the main function of hemicellulose is to take part in building the cell wall structure and the regulation of the cell growth process.

1.3 Lignin:

Lignin is one of the most abundant organic polymers in plants, just behind cellulose. It is the exclusive chemical composition of gymnosperm and angiosperm. The content of lignin in wood and Gramineae is 20–40% and 15–20 %, respectively.

Lignin is the name of a group of substances; their inhomogeneity is manifested in different species of plants, length of growing season, and different parts of the plants. Even in the different morphologies of cells of the same xylem or different cell wall layers, the structures of lignin are not the same [16] .

Lignin is a complex composed of complicated phenylpropane units nonlinearly and randomly linked; three main monomers are coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol. Because of the different monomers, lignin can be divided into three types (Fig. 4.1) : syringyl lignin polymerized by syringyl propane, guaiacyl lignin polymerized by guaiacyl propane, and hydroxy-phenyl lignin polymerized by hydroxy-phenyl propane. Usually, gymnosperm mainly contains guaiacyl (G) lignin; the dicotyledon mainly contains guaiacyl-syringyl (GS) lignin; the monocotyledon mainly contains guaiacyl-syringyl-hydroxy-phenyl (GSH). At one time, lignin in plant was divided into softwood, hardwood, and grass lignins. Based on the structure of lignin, Gibbs divided lignin into G lignin and GS lignin. G lignin is chiefly formed through dehydrated oligomerization of coniferyl alcohol, and its structure is homogeneous. This kind of lignin has negative Maule reaction because less than 1.5 % of syringaldehyde and about 5 % of p-hydroxybenzaldehyde were generated when oxidized by nitrobenzene. Most lignin in softwood belongs to G lignin, which is copolymerized by guaiacyl and has a positive Maule reaction. GSH lignin is the result of the dehydrated oligomerization of coniferyl alcohol and sinapyl alcohol; the content of lignin is 17–23 %. The ratio of syringyl propane to guaiacyl propane is 0.50.1; it also contains 7–12 % ester groups. p-Coumaryl alcohol in it is linked to lignin in the form of ester [5] .

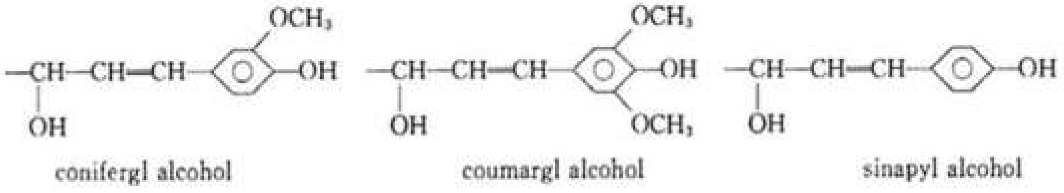

Fig. (1.4) Basic structural unit of lignin

Distribution of Lignin:

Early studies indicated that the lignin concentration in the complex middle lamella(CML) layer is above 50 % (mass ratio), while it is about 20 % in the second wall (S layer). However, because the volume of the S layer is far greater than the volume of the ML layer, most of lignin still presents in the second wall. The lignin concentration of the cell corner of the middle lamella (CCML) layer is generally higher than that of the CML layer, even more than 70 % [17].

Because lignin structural units differ according to timber assortments and measurement regions, the measurement of lignin distribution is uncertain and difficult. Lignin measurement methods include ultraviolet (UV) absorption spectroscopy, EM-EDXA, the interference microscopy (IM) method, CLSM, and so on.

The UV method determines the distribution of lignin in the cell wall because that lignin has a typical absorption at 270–280 nm in the UV spectra. The EM-EDXA method can provide distribution information for lignin in different regions. Simultaneously using UV and EM-EDXA to analyze samples not only could provide information on lignin microdistribution but also offer information on the ratio of G-type and S-type structural units in the different microareas.

The IM method measures the optical path difference first by the inference microscope and then calculates the refractive index; finally, it obtains the volume percentage and mass percentage of lignin. The CLSM method can be used quickly to measure the biological structure of samples and obtain good measurement results in the *Z* direction [17]

Structure of Lignin:

Lignin is a polyphenolic polymer with a three-dimensional network. Because almost all of the delignification process includes covalent bond rupture of natural lignin , with different lignin separation methods and separation conditions, the lignin structure would have great differences. Therefore, a structural model was usually used to present the structure of lignin.

This kind of structural model only describes a hypothetical structure inferred from the average results. Further, different plant sources, or even lignin isolated from the same plant but in different ways, would have different categories of linkages and composition of functional groups, resulting in the complicated lignin structure. Through nearly two decades of research on lignin structure, a dozen structural models have been proposed.Figure (1.4) is a structural model of lignin from softwoods.

It can be seen that the lignin has a complicated structure [18] .Through the study of various types of lignin structural models, lignin is a complicated amorphous polymer with three dimensional network, which is basically composed of phenylpropane units linked to each other by the irregular coupling of C–C and C–O.

Lignin includes three basic structural monomers: p-phenyl monomer (H type) derived from coumaryl alcohol, guaiacyl monomer (G type) derived from coniferyl alcohol, and syringyl monomer (S type) derived from sinapyl alcohol (Fig 4.1) . The structural formula is as follows:
Although lignin only has three basic structures, the quantity proportions of these basic structures vary greatly in different families of plants.

Lignin of hardwood includes large amounts of syringyl units. In the UV-photodegradated production from *Eucalyptus urophylla* lignin, ω (syringyl-type compounds) is 58.10 %, and ω (guaiacyl-type compounds) is 18.75 %. Compared with eucalyptus lignin, the pyrolysis products of sulfate pulp lignin are rich in guaiacol. In the sulfate pulp lignin, M (syringyl)/m (guaiacyl) is 4.3:1; in the eucalyptus lignin, this ratio is 6.4:1. Structural units of softwood lignin are mainly guaiacyl-type units; a small amount of p-hydroxyphenyl-type units remains. Wheat straw lignin mainly consists of noncondensed guaiacyl units, noncondensed syringyl units, and other condensed units; the ratio of n (noncondensed guaiacyl units) to n (noncondensed syringyl units) to n (condensed units) is 1.44:1:3.24. The content of the $–OCH_3$ group in bamboo lignin is similar to the content in hardwood lignin, for example, in Bai jia bamboo (ph, nidularia Mu) lignin, the ratio of n (guaiacyl units) to n (syringyl units).

The coupling modes between each basic unit include β-O-4, β-5, β-1, and so on (Figure 1.5) is a partial section of a softwood lignin structure. Ether bonds in lignin include phenol-ether bonds, alkyl-ether bonds, dialkyl bonds, diaryl ether bonds, and so on. About two thirds to three quarter phenylpropane units of lignin are linked to the adjacent structural units by ether bonds only a small part is present in the form of free phenolic hydroxyl.

Phenolether bonds account for 70–80 % in these groups, guaiacyl glycerol-“-aryl ethers (β-O-4) account for about half of phenol-ether bonds, followed by the guaiacyl glycerol-β-aryl ethers (α-O-4), also containing other types of ether bonds. Lignin in softwood and hardwood mainly contains aryl glycerol-β-aryl-(β-O-4) ether bonds, approximately reaching half of the lignin in softwood and more than 60 % in hardwood. In the C–C bonds of lignin, the dominant coupling type is β-5, β-β linkage, followed by β-1, β-2, 5–5, and so (36).

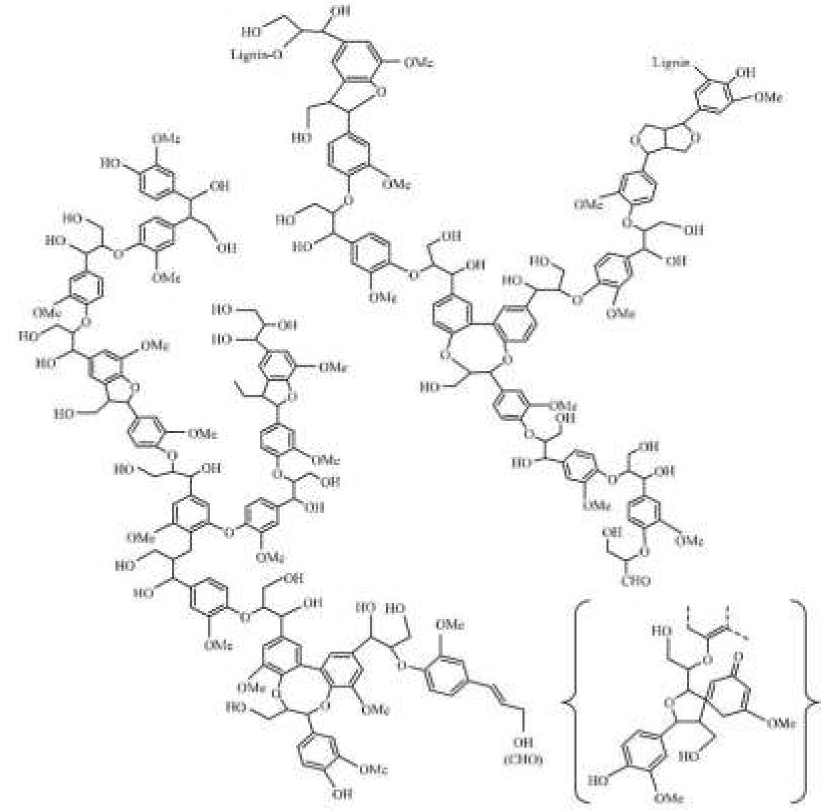

Fig. (1.5) Structural model of a section of cork lignin [18]

The main bond types of grass lignin are the same as those of lignin in wood.

The main bond type of the structural unit is aromatic glycerol-β-aryl-ether bonds; these are fewer than hardwood and are similar to softwood. The proportion of carbon–carbon bonds, such as β-5 and β-β in structural units, is higher than in hardwood. In the structure of grass lignin, a considerable part of p-hydroxyphenylpropane units connects with phenylpropane units in its ester form.

Taking straw as an example, 60 %p hydroxyphenylpropane units are connected in the form of its esters. In addition, grass lignin still contains a small amount of ferulic acid esters. Because the types and positions of functional groups in different types of lignin are different, lignin of gymnosperms has different chemical characteristics. Lignin in gymnosperm mainly contains guaiacyl lignin (G), the G-structure unit of which has a methoxy group, and is hard to remove in the papermaking process because a stable C–C linkage was formed by linkage with other monomers. Monocotyledon mainly contains GSH lignin [19].

Physicochemical Properties of Lignin :

Chemical Properties of Lignin :

The chemical properties of lignin include halogenation, nitration, and oxidation reactions on the phenyl ring; reactions on the benzyl alcohol, the aryl ether bond, and an alkyl ether bond in the side chain; lignin-modified chromogenic reaction; and so on. The chemical reactions of the lignin structural unit are divided into two major categories: nucleophilic reactions and electrophilic reactions .

(1) Chemical reactions of lignin structural unit on the side chain Reactions on the lignin side chains are associated with pulping and lignin modification; the reaction is a nucleophilic reaction. The following reagents can conduct

nucleophilic reactions with lignin:

①In alkaline medium, the effect of HO-, HS-, and S2-nucleophilic reagents leads to the cleavage of the main ether bond (e.g., α-aryl ether bond, a phenol-type α-alkoxy ether bond, and phenol-type β-aryl ether bond) and fragmentation and partial dissolution of macromolecule lignin. In alkaline medium, the phenoltype structural unit is separated into phenolate anions, and an oxygen atom that affects the benzene ring by induction and a conjugative effect, which activates their *ortho*- and *para*- positions and thereby affects the stability of the CO bond and breaks the α-aryl ether bond, then generating a methylene quinine intermediate and resulting in the aromatization of methylene quinone to generate a 1,2-diphenylethene structure :

②In neutral medium, reaction with nucleophile HSO_3 or SO_{32} leads to breaking of the ether bond and brings SO_{32} groups in the degradation of lignin fragments .

③ Acidic media mainly relate to the lignin fragmentation reaction of the acidic sulfite pulping process. SO_2 aqueous solution is taken as an affinity reagent, leading to the breakage of phenol-type and nonphenolic α-aryl ether bonds, sulfonation of α-carbon, and increased lignin hydrophilicity. Phenol-type and nonphenolic α-alkoxy ether bonds may also have a similar reaction. In addition, C_1, C_5, and C_6 on the high electron density centers of the aromatic ring could also have a condensation reaction with methylene quinone intermediates [5].

(2)Chemical reaction of the aromatic ring in the structural unit of lignin are closely related to the lignin-bleaching process and its modification and have been divided into electrophilic and nucleophilic reactions .

① Electrophilic substitution reaction: This mainly refers to substitution and oxidation reactions. Electrophilic reagents include chlorine, chlorine dioxide, oxygen molecule, ozone, nitro cation, nitroso cation, and so on.

The electrophilic reagent replacement breaks the side chains of lignin and leads to the oxidative cleavage of β-aryl ether linkages. The aliphatic side chain is oxidized into a carboxylic acid , and the aromatic ring is oxidized into the compound of the o-quinone structure, which will finally be oxidized into dicarboxylic acid derivatives.

②Nucleophilic reaction: Nucleophilic reagents that can react with the aromatic ring of lignin include hydroxide ions, hypochlorite ions, and hydrogen peroxide ions. These nucleophilic reagents can react with the chromophoric groups in the degraded lignin fragments, breaking the chromophoric structure to some extent.

Physical Properties of Lignin:

(1) Molecular weight and polydispersity:

Any type of separation method may cause some partial degradation and changes in lignin. Accordingly, the molecular weight of the original lignin is unsure. The molecular weight of the separated lignin varies with the separation method and conditions.

Its molecular weight distribution can range from several hundreds to several millions. Under the effect of mechanical action, enzymes, or chemical reagents, the three-dimensional net structure is degraded into different size lignin fragments, which leads to the molecular weight polydispersity of lignin [16].

The molecular weight of separated lignin varies greatly; taking milled wood lignin(MWL) from spruce as an example, depending on the grinding time and extraction methods, its weight average molecular weights include 2,100, 7,100, and 11,000.

The weight average molecular weight of the high molecular weight fraction of MWL from spruce and hardwood is 40,000 and 18,000, respectively, and the low molecular weight fraction is between 3,700 and 5,000. The molecular weight of lignosulfonate ranges from 103 to 105; the maximum is beyond 106.

Kraft lignin has a much lower molecular weight.Determination of lignin molecular weight includes the osmometric method, light-scattering method, supercentrifugation, gel permeation chromatography, high-pressure liquid chromatography, and so on. As for insoluble lignin, such as lignin obtained by acid hydrolysis, their molecular weights are measured depending on the linear relationship between lgMw (the base-10 logarithm of molecular weight) and the heat-softening temperature Ts [5] .

(2) Solubility:

Hydroxyls and many polar groups exist in the lignin structure, resulting in strong intramolecular and intermolecular hydrogen bonds, and making the intrinsic lignin insoluble in any solvent. Condensation or degradation make the separated lignin able to be divided into soluble lignin and insoluble lignin; the former has an amorphous structure, and the latter is the morphological structure of the raw material fibers.

The presence of phenolic hydroxyl and carboxyl makes the lignin able to be dissolved in alkaline solution. Separated Brauns lignin and organosolv lignin can be dissolved in dioxane, DMSO, methanol, ethanol, acetone, methyl cellosolve, and pyridine. Alkali lignin and lignosulfonate usually can be dissolved in a dilute alkali, water, and salt solution. Brauns lignin, phenol lignin, and many organosolv lignins can be completely dissolved in dioxane. Acid lignin is not soluble in any solvents. The best solvents for most separated lignin are acetyl bromide and hexafluoroisopropanol in acetic acid [16].

(3) Thermal properties:

Lignin is an amorphous thermoplastic polymer. It has slight friability under high temperature and cannot form film in solution. It also has glassy transfer properties. Under the glassy transfer temperature, lignin is in the solid glass phase; it begins to move when it is above the glassy transfer temperature.

The lignin is softened to become sticky and has adhesive force. The glassy transfer temperature of separated lignin varies with the raw materials, separation method, molecular weight, and water content. The softening temperature of absolutely dried

lignin ranges from 127 °C to 129 °C, which remarkably decreased with increased water content, indicating that water acts as a plasticizer in lignin. The higher the lignin molecular weight is, the higher the softening point is. For example, for lignins with a MW of 85,000 and
4,300 the softening points, respectively, are 176° and 127 °C [16].

(4) Relative density:

The relative density of lignin is roughly between 1.35 and 1.50. Values vary with the liquid for measurement if measured by water. The relative density of sulfuric acid lignin isolated from pine is 1.451 and is 1.436 if measured by benzene. The relative density of dioxane lignin is 1.33 when measured by water at 20° ıC and is 1.391 by dioxane. Lignin prepared by different methods has different relative densities, such as the relative density of pine glycol lignin is 1.362, but it is 1.348 for pine hydrochloride lignin [16] .

(5) Color:

Intrinsic lignin is a white or nearly colorless substance; the color of lignin seen can be of the result of the separation and preparation process. For example, the color of lignin isolated by Brauns and named after him is light cream, and the colors of acid lignin, copper ammonia lignin, and periodate lignin vary from fawn to deep tan.

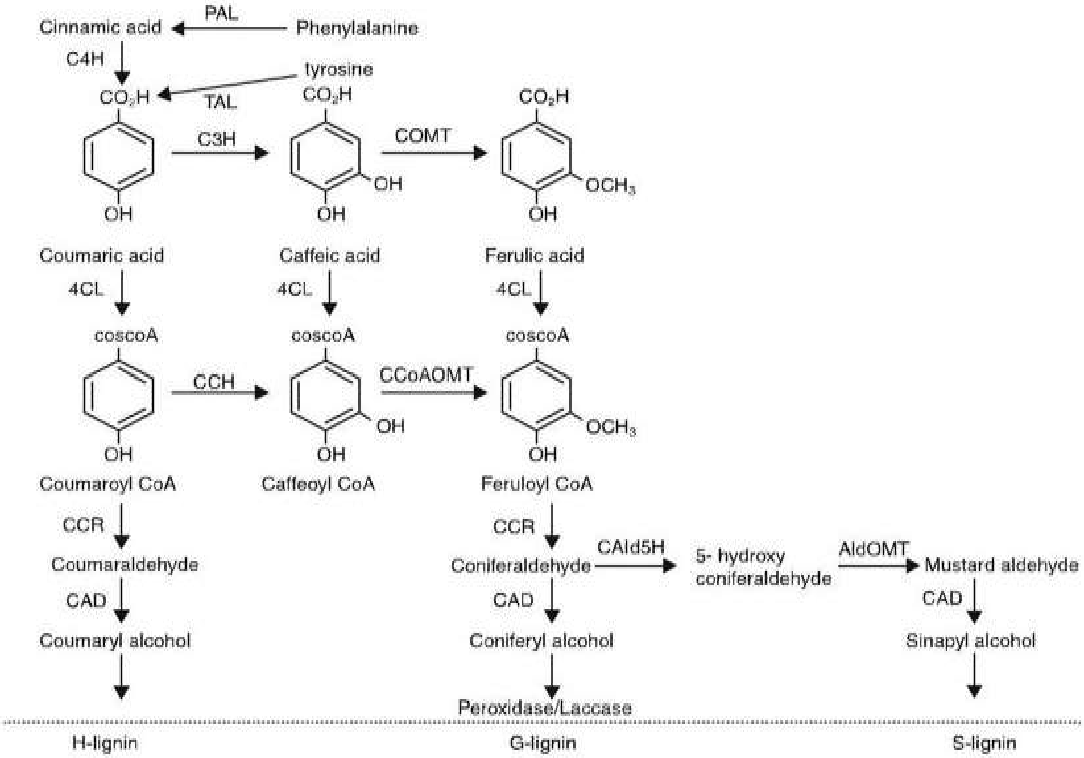

Fig. (1.6) Biosynthetic pathway of lignin monomer

Deposition of Lignin in Plant Tissues:

Lignin biosynthesis in vascular plants is controlled by morphogenesis and the environment. The lignification process is the deposition process of lignin in plant tissues.

Fluorescence detection indicated that, in the normal development of *Arabidopsis* stems, lignin mainly was deposited in the fiber cell wall between the vessel cell wall and vascular bundles. Dystopia anchorage genes ELP1 were isolated from lignin deposited mutants of *Arabidopsis* pith. In mutant stems, lignin could be deposited in the usual parts and ectopically deposited in the pith of parenchyma cells. Such dystopia anchorage would exist in both young stems and mature stems. Associated with this dystopia anchorage, enzyme activity related to lignin synthesis would increase, and COMT could be ectopically expressed in the central cells of the pith.These results suggest that ELP1 genes inhibit lignin synthesis in the pith. Lignin deposition is related to coniferyl alcohol because that methylated ester generated by coniferyl alcohol can be covalently coupled with hydroxyproline-rich glycoproteins (HRGPs), resulting in the deposition of lignin in the cell wall [20]

Factors Influencing Lignin Synthesis:

Different parts of plants would have a different lignin content and composition.

For example, the lignin content and structure are significantly different in the node and internode of reed (*Arundo donax*); the node has a higher density than the internode because of the high content of phenolic acids (p-coumaric acid and ferulic acid).The lignin content in different parts of lettuce is different depending on the harvest-ing time.

Compared with the normal harvest, lignin in the middle of overmature harvested lettuce buds is increased most obviously, secondarily increased in the basal area, and not significantly increased at the top [20].

The reasons for this difference are varied. For instance, methyl jasmonate can significantly improve the POD activity of seedlings and the lignin content.

Both jasmonic acid and gaseous methyl jasmonic acid could induce the expression of chalcone synthase (CHS), thereby increasing the lignin content. In general, overuse of nitrogen fertilizer will reduce the lignin content and thus postpone the lignification of the plant however, nitrogen nutrition can increase the lignin content in the mulch covering of *Pinus sylvestris* L. and *Picea abies* (L.) Karst. Phosphate fertilizer will greatly limit the of rapid growth of plants but increase the lignin content [20] .

1.4 Wood:

For small forests, (Woodland) For wood as a commodity, timber For other uses Wood is a porous and fibrous structural tissue found in the stems and roots of trees and other woody plants. It is an organic material, a natural composite of cellulose fibers that are strong in tension and embedded in a matrix of lignin that resists compression. Wood is sometimes defined as only the secondary xylem in the stems of trees,[21] or it is defined more broadly to include the same type of tissue elsewhere such as in the roots of trees or shrubs In a living tree it performs a support function, enabling woody plants to grow large or to stand up by themselves. It also conveys water and nutrients between the leaves, other growing tissues, and the roots. Wood may also refer to other plant materials with comparable properties, and to material engineered from wood, or wood chips or fiber.

Wood has been used for thousands of years for fuel, as a construction material, for making tools and weapons, furniture and paper, and as a feedstock for the production of purified cellulose and its derivatives, such as cellophane and cellulose acetate.

In 2005, the growing stock of forests worldwide was about 434 billion cubic meters, 47% of which was commercial.[22] As an abundant, carbon-neutral renewable resource, woody materials have been of intense interest as a source of renewable energy. In 1991 approximately 3.5 billion cubic meters of wood were harvested. Dominant uses were for furniture and building construction.[23]

Fig (1.7): Types of wood

In 2005, the growing stock of forests worldwide was about 434 billion cubic meters, 47% of which was commercial.[22]

History:

A 2011 discovery in the Canadian province of New Brunswick yielded the earliest known plants to have grown wood, approximately 395 to 400 million years ago.[24][25]

Wood can be dated by carbon dating and in some species by dendrochronology to determine when a wooden object was created.

People have used wood for thousands of years for many purposes, including as a fuel or as a construction material for making houses, tools, weapons, furniture, packaging, artworks, and paper. Known Constructions using wood date back ten thousand years. Buildings like the European Neolithic long house were made primarily of wood.

Recent use of wood has been enhanced by the addition of steel and bronze into construction.[26]

The year-to-year variation in tree-ring widths and isotopic abundances gives clues to the prevailing climate at the time a tree was cut.[27]

Physical properties:

Growth rings:

Main article: Growth rings

Wood, in the strict sense, is yielded by trees, which increase in diameter by the formation, between the existing wood and the inner bark, of new woody layers which envelop the entire stem, living branches, and roots. This process is known as secondary growth; it is the result of cell division in the vascular cambium, a lateral meristem, and subsequent expansion of the new cells. These cells then go on to form thickened secondary cell walls, composed mainly of cellulose, hemicellulose and lignin.

Where the differences between the four seasons are distinct e.g. New Zealand, growth can occur in a discrete annual or seasonal pattern, leading to growth rings; these can usually be most clearly seen on the end of a log, but are also visible on the other surfaces. If the distinctiveness between seasons is annual (as is the case in equatorial regions e.g. Singapore), these growth rings are referred to as annual rings. Where there is little seasonal difference growth rings are likely to be indistinct or absent. If the bark of the tree has been removed in a particular area, the rings will likely be deformed as the plant overgrows the scar.

If there are differences within a growth ring, then the part of a growth ring nearest the center of the tree, and formed early in the growing season when growth is rapid, is usually composed of wider elements. It is usually lighter in color than that near the outer portion of the ring, and is known as early wood or springwood. The outer portion formed later in the season is then known as the latewood or summerwood.[28] However, there are major differences, depending on the kind of wood (see below).

Diagram of secondary growth in a tree showing idealized vertical and horizontal sections. A new layer of wood is added in each growing season, thickening the stem, existing branches and roots, to form a growth ring.

Knots:

As a tree grows, lower branches often die, and their bases may become overgrown and enclosed by subsequent layers of trunk wood, forming a type of imperfection known as a knot. The dead branch may not be attached to the trunk wood except at its base, and can drop out after the tree has been sawn into boards. Knots affect the technical properties of the wood, usually reducing the local strength and increasing the tendency for splitting along the wood grain, but may be exploited for visual effect. In a longitudinally sawn plank, a knot will appear as a roughly circular "solid" (usually darker) piece of wood around which the grain of the rest of the wood "flows" (parts and rejoins). Within a knot, the direction of the wood (grain direction) is up to 90 degrees different from the grain direction of the regular wood.

In the tree a knot is either the base of a side branch or a dormant bud. A knot (when the base of a side branch) is conical in shape (hence the roughly circular cross-section) with the inner tip at the point in stem diameter at which the plant's vascular cambium was located when the branch formed as a bud.

In grading lumber and structural timber, knots are classified according to their form, size, soundness, and the firmness with which they are held in place. This firmness is affected by, among other factors, the length of time for which the branch was dead while the attaching stem continued to grow.

Knots do not necessarily influence the stiffness of structural timber, this will depend on the size and location. Stiffness and elastic strength are more dependent upon the sound wood than upon localized defects. The breaking strength is very susceptible to defects. Sound knots do not weaken wood when subject to compression parallel to the grain.

In some decorative applications, wood with knots may be desirable to add visual interest. In applications where wood is painted, such as skirting boards, fascia boards, door frames and furniture, resins present in the timber may continue to 'bleed' through to the surface of a knot for months or even years after manufacture and show as a yellow or brownish stain. A knot primer paint or solution (knotting), correctly applied during preparation, may do much to reduce this problem but it is difficult to control completely, especially when using mass-produced kiln-dried timber stocks.

Water content:

Water occurs in living wood in three locations, namely:

- in the cell walls,
- in the protoplasmic contents of the cells
- as free water in the cell cavities and spaces, especially of the xylem

In heartwood it occurs only in the first and last forms. Wood that is thoroughly air-dried retains 8–16% of the water in the cell walls, and none, or practically none, in the other forms. Even oven-dried wood retains a small percentage of moisture, but for all except chemical purposes, may be considered absolutely dry.

The general effect of the water content upon the wood substance is to render it softer and more pliable. A similar effect occurs in the softening action of water on raw hide, paper, or cloth. Within certain limits, the greater the water content, the greater its softening effect.

Drying produces a decided increase in the strength of wood, particularly in small specimens. An extreme example is the case of a completely dry spruce block 5 cm in section, which will sustain a permanent load four times as great as a green (undried) block of the same size will.

The greatest strength increase due to drying is in the ultimate crushing strength, and strength at elastic limit in endwise compression; these are followed by the modulus of rupture, and stress at elastic limit in cross-bending, while the modulus of elasticity is least affected.[29]

Structure:

Wood is a heterogeneous, hygroscopic, cellular and anisotropic material. It consists of cells, and the cell walls are composed of micro-fibrils of cellulose (40% – 50%) and hemicellulose (15% – 25%) impregnated with lignin (15% – 30%).[30]

In coniferous or softwood species the wood cells are mostly of one kind, tracheids, and as a result the material is much more uniform in structure than that of most hardwoods. There are no vessels ("pores") in coniferous wood such as one sees so prominently in oak and ash, for example.

The structure of hardwoods is more complex.[31] The water conducting capability is mostly taken care of by vessels: in some cases (oak, chestnut, ash) these are quite large and distinct, in others (buckeye, poplar, willow) too small to be seen without a hand lens. In discussing such woods it is customary to divide them into two large classes, *ring-porous* and *diffuse-porous*.[32]

In ring-porous species, such as ash, black locust, catalpa, chestnut, elm, hickory, mulberry, and oak,[16] the larger vessels or pores (as cross sections of vessels are called) are localized in the part of the growth ring formed in spring, thus forming a region of more or less open and porous tissue. The rest of the ring, produced in summer, is made up of smaller vessels and a much greater proportion of wood fibers. These fibers are the elements which give strength and toughness to wood, while the vessels are a source of weakness.

In diffuse-porous woods the pores are evenly sized so that the water conducting capability is scattered throughout the growth ring instead of being collected in a band or row. Examples of this kind of wood are alder,[32] basswood,[33] birch,[32] buckeye, maple, willow, and the *Populus* species such as aspen, cottonwood and poplar.[32] Some species, such as walnut and cherry, are on the border between the two classes, forming an intermediate group.[33]

Wood density:

Wood density is determined by multiple growth and physiological factors compounded into “one fairly easily measured wood characteristic[34].

Age, diameter, height, radial (trunk) growth, geographical location, site and growing conditions, silvicultural treatment, and seed source all to some degree influence wood density. Variation is to be expected. Within an individual tree, the variation in wood density is often as great as or even greater than that between different trees[35].Variation of specific gravity within the bole of a tree can occur in either the horizontal or vertical direction.

Hard and soft woods:

It is common to classify wood as either softwood or hardwood. The wood from conifers (e.g. pine) is called softwood, and the wood from dicotyledons (usually broad-leaved trees, (e.g. oak) is called hardwood. These names are a bit misleading, as hardwoods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some softwoods (e.g. yew) are harder than many hardwoods.

There is a strong relationship between the properties of wood and the properties of the particular tree that yielded it. The density of wood varies with species. The density of a wood correlates with its strength (mechanical properties). For example, mahogany is a medium-dense hardwood that is excellent for fine furniture crafting, whereas balsa is light, making it useful for model building. One of the densest woods is black ironwood.

Chemistry of wood:

The chemical composition of wood varies from species to species, but is approximately 50% carbon, 42% oxygen, 6% hydrogen, 1% nitrogen, and 1% other elements (mainly calcium, potassium, sodium, magnesium, iron, and manganese) by weight.[36] Wood also contains sulfur, chlorine, silicon, phosphorus, and other elements in small quantity.

Aside from water, wood has three main components. Cellulose, a crystalline polymer derived from glucose, constitutes about 41–43%. Next in abundance is hemicellulose, which is around 20% in deciduous trees but near 30% in conifers. It is mainly five-carbon sugars that are linked in an irregular manner, in contrast to the cellulose. Lignin is the third component at around 27% in coniferous wood vs. 23% in deciduous trees. Lignin confers the hydrophobic properties reflecting the fact that it is based on aromatic rings. These three components are interwoven, and direct covalent linkages exist between the lignin and the hemicellulose. A major focus of the paper industry is the separation of the lignin from the cellulose, from which paper is made.

In chemical terms, the difference between hardwood and softwood is reflected in the composition of the constituent lignin. Hardwood lignin is primarily derived from sinapyl alcohol and coniferyl alcohol. Softwood lignin is mainly derived from coniferyl alcohol.[37]

Extractives:

Aside from the lignocellulose, wood consists of a variety of low molecular weight organic compounds, called *extractives*. The wood extractives are fatty acids, resin acids, waxes and terpenes.[38] For example, rosin is exuded by conifers as protection from insects. The extraction of these organic materials from wood provides tall oil, turpentine, and rosin.[39]

Uses:

Main article: Wood fuel

Wood has a long history of being used as fuel,[40] which is continuous to this day, mostly in rural areas of the world. Hardwood is preferred over softwood because it creates less smoke and burns longer. Adding a woodstove or fireplace to a home is often felt to add ambiance and warmth.

Wood has been an important construction material since humans began building shelters, houses and boats. Nearly all boats were made out of wood until the late 19th century, and wood remains in common use today in boat construction. Elm in particular was used for this purpose as it resisted decay as long as it was kept wet (it also served for water pipe before the advent of more modern plumbing).

Wood to be used for construction work is commonly known as *lumber* in North America. Elsewhere, *lumber* usually refers to felled trees, and the word for sawn planks ready for use is *timber*.[41] In Medieval Europe oak was the wood of choice for all wood construction, including beams, walls, doors, and floors. Today a wider variety of woods is used: solid wood doors are often made from poplar, small-knotted pine, and Douglas fir.

New domestic housing in many parts of the world today is commonly made from timber-framed construction. Engineered wood products are becoming a bigger part of the construction industry. They may be used in both residential and commercial buildings as structural and aesthetic materials.

In buildings made of other materials, wood will still be found as a supporting material, especially in roof construction, in interior doors and their frames, and as exterior cladding.

Wood is also commonly used as shuttering material to form the mould into which concrete is poured during reinforced concrete construction.

Furniture and utensils:

Wood has always been used extensively for furniture, such as chairs and beds. It is also used for tool handles and cutlery, such as chopsticks, toothpicks, and other utensils, like the wooden spoon and pencil.

Next generation wood products:

Further developments include new lignin glue applications, recyclable food packaging, rubber tire replacement applications, anti-bacterial medical agents, and high strength fabrics or composites.[42] As scientists and engineers further learn and develop new techniques to extract various components from wood, or alternatively to modify wood, for example by adding components to wood, new more advanced products will appear on the marketplace. Moisture content electronic monitoring can also enhance next generation wood protection.[43]

In the arts:

Wood has long been used as an artistic medium. It has been used to make sculptures and carvings for millennia. Examples include the totem poles carved by North American indigenous people from conifer trunks, often Western Red Cedar (*Thuja plicata*).

Other uses of wood in the arts include:

- Woodcut printmaking and engraving
- Wood can be a surface to paint on, such as in panel painting
- Many musical instruments are made mostly or entirely of wood

1.5 Mesquite Tree:

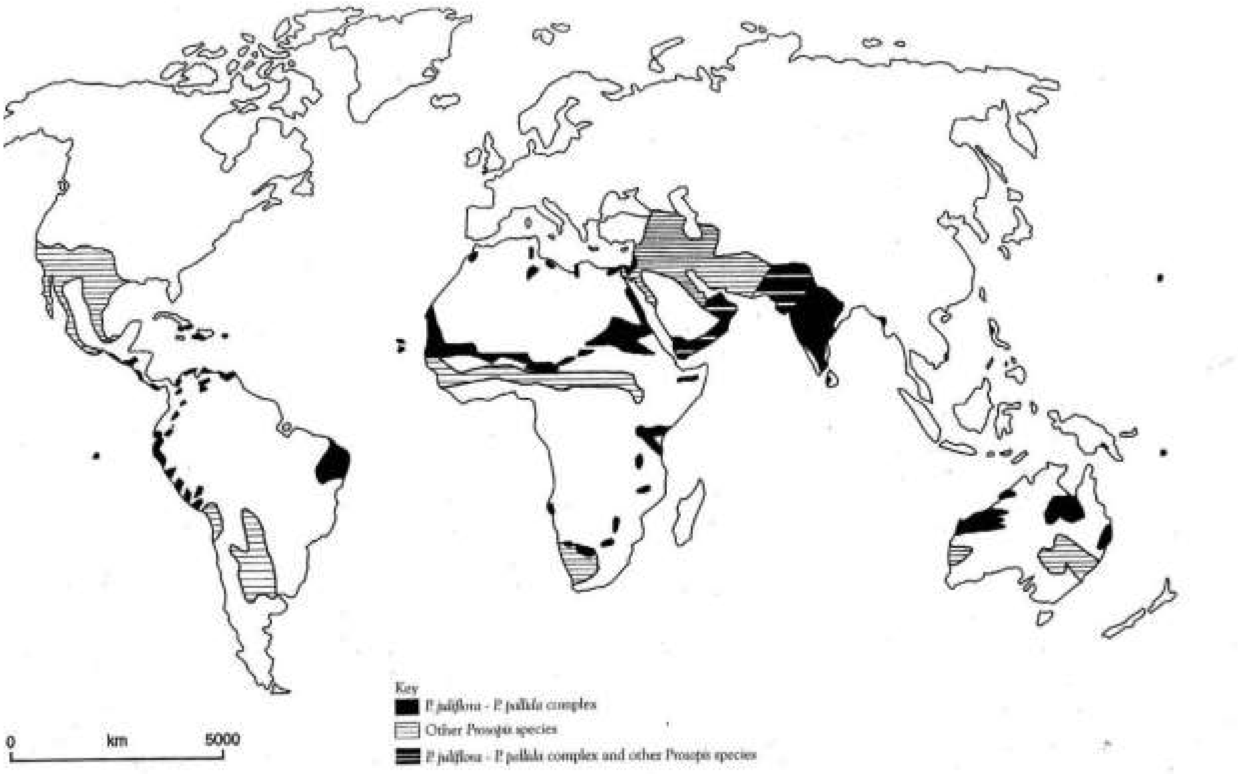

Fig (1.8) Distribution of mesquite tree through out the world

Source: Pasiecznik, N. *et al* (2001).

Reversing the Impact:

Mesquite is an ancient name which means “Towards Abundance”. Mesquite tree belongs to the leguminosae family. Mesquite is originally native to Central and South America. The Mesquite tree has been grown in different countries of the World at different times. There are several species of Mesquite. The Mesquite tree ranges from 1.0-meter tall shrubs to 18.0-meters tall trees with brown twisted stem, flexible branches and long strong thorns. The leaves are bipinnate and the flowers are pale yellow. The roots of Mesquite grow deeply downwards in search for water up to 50.0- meters. Mesquite was brought to Sudan in 1917 from Egypt and South Africa for the purpose of combating dust storms and movement of sand dunes. The growth performance was not good where irrigation is lacking but it grew very good along the Nile, water courses and Gash and Toker Deltas. The Mesquite has created serious economic and environmental problems in these two Deltas, specially the loss of fertile agricultural lands. Several attempts have been made to eradicate the Mesquite, but with no tangible results. During the last decade, the socio-economic and ecological impact of Mesquite has been controversial. Farmers look at Mesquite as a monster that invades and colonizes their agricultural land. On the other hand, nomads consider it a useful tree that provides them with fodder and shade for their livestock.

Toker Delta is one of the areas which have been invaded by Mesquite. The invasion has taken place during several stages. The total area of the Delta is 406,000 feddans. The total invaded area to date is 296,979 feddans, indicating that 73% of the Delta has been covered by Mesquite. At present only an area of 109,021 feddans remains Mesquite-free in the whole Delta, representing 27% of the Delta area. This situation has resulted in loss of agricultural lands, loss of job opportunities and migration of people to outside the scheme area. Several attempts were carried out in the Delta to eradicate the Mesquite, but unfortunately all have failed.،As eradication efforts have failed and they are practically not possible, then it has to be stopped and the money wasted on eradication should be directed to investment on utilization of Mesquite products especially on products that are exportable. There were proposes of three solutions to the Mesquite problem:

1. Prohibition of further spread of Mesquite in the remaining land of the Delta by immediate eradication of seedlings.

2. Immediate utilization of the present forests of Mesquite to produce charcoal and honey from Mesquite's nectar in the future.

3. Gradual replacement of the Mesquite forests by plantations of endogenous or exotic species through the establishment of woodlots and introduction of Agroforestery.

Fig (1.9) Mesquite tree

Source: data of the present study

Prosopis (Mesquite) is an ancient Greek name[44] defined Prosopis "as a kind of prickly fruit" [43] gave the meaning as "bardane", a type of a thorny plant not related to Prosopis. The origin of Prosopis given by [45] was "towards abundance", from the Greek word "pros" meaning towards, and Opis-the wife of Saturn, the Greek Goddess of Abundance and Agriculture. Whichever the origin of the name, there is great confusion in the definition of the Mesquite species. Discrepancies concerning the generic limits of Mesquite are untraceable. Although the taxonomy of [44] is generally accepted by the majority of the foresters and botanists, the debate is still continuing between foresters in Sudan as whether the Mesquite which was introduced to Sudan is Prosopis juliflora or Prosopis chilensis. To avoid ambiguity, the name Mesquite will be used throughout the text to refer to the tree culturally known in Sudan as Mesquite (Fig 1.9) . The reasons for using the common name- Mesquite- are:

1. The research is dealing with the economic aspect of the Mesquite tree and not its biology.

2. The taxonomy and biology of species are not among the objectives of that study.

3. For the target groups and users Mesquite name is familiar. All the literature agrees that there are 44 species of Mesquite in the World [44] The famous species are:

6) Prosopis alba (Argentine Mesquite),

- Prosopis chilensis (Chilean Mesquite) ,
- Prosopis glandulosa (Honey Mesquite, Texas Mesquite) ,
- Prosopis juliflora (Mesquite),
- Prosopis nigra (algarrobo negro),
- Prosopis pubescens (Screw bean Mesquite).

The Mesquite tree worldwide is originally native to Peru, Chile and Argentina. It has spread to Mexico, the Southern United States, Brazil, Bolivia, Colombia, El Salvador, Nicaragua, Uruguay, Venezuela, the West Indies and the Bahamas. It is present in Iran, India, Pakistan and Africa [44]. Mesquite species have also become adapted to harsh semi-arid areas of Haiti and the Sahelian Zone of Africa including

Sudan Figure (10.1).It has brown twisted stem, flexible branches and long strong thorns. The leaves are bipinnate and the flowers are pale-yellow arranged in spikes Figure (1.9).The root system includes a taproot that grows deeply downwards in search fo water up to 50.0-meters.

The fruit (pods) is non-dehiscent with hardened epicarp, multi-seeded and curved. It is approximately 4.0mm thick, 1.0cm wide and up to 15.0cm long (Figure 1.4). The fleshy mesocarp is rich in saccharose (20-25%). Mesquite bears fruits at 3 to 4 years of age. Mesquite can propagate by seed, seedlings, and root suckers or by cuttings. Hot water or acid treatment will expedite seed germination. Seeds may be sown in two adjacent rows 50.0cm apart, with a spacing of 30.0cm between the sowings. Transplanting one-year old seedling in the rainy season is preferable to direct sowing. Root and shoot cuttings with minimum diameter 12.5mm at the collar and 10.0cm long are satisfactory [46] The Mesquite, as an invasive woody plant, has now spread throughout many parts of Africa, South Asia and Australia. In the Sub Saharan Africa, Mesquite has been introduced for shelterbelts against desert creep and in Asia as fuel and fodder species, but has now spread out of control [47]

Mesquite Tree in the Sudan:

Mesquite was brought to Sudan, in 1917, from Egypt and South Africa. The plants were established at “Shambat”, Khartoum North, from which, they have spread by goat’s droppings. In 1928, another plot was established near Khartoum Airport. In 1938 and subsequent years other plantations were established near “El Shagara .Plantations were also established on the eroded slopes near Sennar and else where in the Fung area. Mesquite was equally established in Port Sudan and Toker on sandy soils characterized by high salt content. Plantations were also established at Kassala Green Belt and the Gash in 1948. However, the introductions into Darfur and Kordofan were not successful. Since then, Prosopis was introduced in different parts of the country, for the tree is reported to combat desertification and to slow down the sand movement. Encouraged by the newly created environment of the irrigated Khartoum Green Belt in 1962, Mesquite has spread in all directions. The high number of goats, sheep and cattle around the belt area, namely at "Al Salama" Village, resulted in further spread of the Mesquite [48].

In the late 80th, a British Organization-the SOS Sahel- has intensively introduced the tree to North Sudan. Although the introduction was very near to the Nile, it passed without objection from neither the Government nor the local people. Further more, all along Khartoum-Port Sudan and Khartoum-El-obied Highways, isolated patches of Mesquite are seen.

Other newly constructed roads created water-catchments suitable for the growth of the Mesquite. In terms of density, the Mesquite stands are found in two different forms .

Dense areas: and these are mainly in Gash Delta, New Halfa Agricultural Scheme and Toker Delta. The isolated and scattered stands are found along the Blue Nile River and White Nile River and highways.

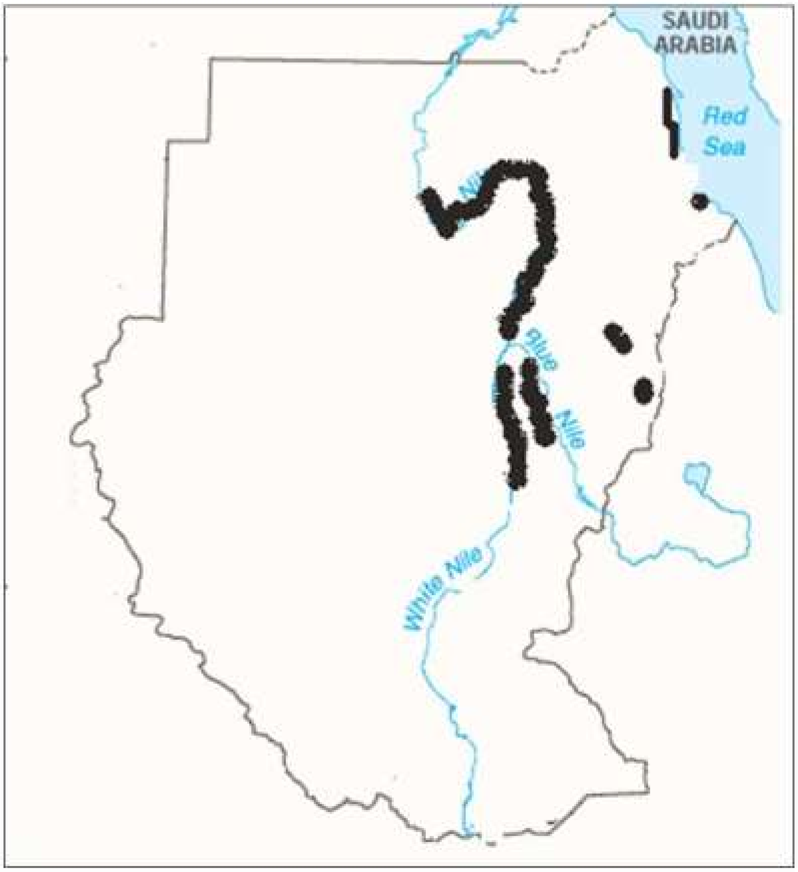

Fig (1.10) Distribution mesquite tree in Sudan

Source: this map is drawn by the author based on his observation in different parts of Sudan, readings and personal communication with professional individuals Scale: 1: 20,000,000

Mesquite Introductions into Some Countries [49] reported that, Mesquite, Prosopis juliflora, was introduced to Pakistan in 1878 in an attempt to develop forests in the desert. Mesquite has quickly become a popular source of fuel while its beans were used for animal fodder. The tree is adept at invading a variety of habitats capable of creating monoculture and greatly reducing bio-diversity. Mesquite was able to survive severe droughts and to produce massive number of seeds. The use of these seeds for animal fodder increased the spread of this invader and the native Acacia nilotica has been widely replaced by Mesquite. Continued to report that, “Mesquite was also introduced to South Africa for plantation use, where it has caused a myriad of environmental problems. Mesquite now covers 1.8 million hectares of the Northern Cape and Northwest Province, where it has invaded water catchments. The species replaced grassland, negatively impacted bio-diversity, ecosystem functioning, and catchments hydrology [50] stated that, Prosopis juliflora was introduced to India around 1877 to check encroaching desert sands as a re-greening tool. As the tree spread, the resulting shrinking pastures may have been the cause of the decline of many wild grassland and animals. It has also spread to sand dunes, which used to be important wintering grounds for birds. It is being responsible for damaging water supply systems of the villages, as the roots penetrate and choke up the pipes. [51] reported, “In 1974 Prosopis juliflora, a tropical American leguminous tree, was introduced into Yemen to combat soil erosion. Since then and because of its competitiveness and adaptability it has spread rapidly to large areas. Today over 250ha of important agricultural lands (particularly the scarcely available irrigated area) in different regions of the country have been invaded by this species, and the rapid uncontrolled growth is likely to increase dramatically if methodologies for its use and control are not urgently introduced into the country [52] reported that, Mesquite was found in 1974 as single trees in Wadi Hahdramout and by the year 1996, it has spread into thick bush-land along the Wadi.

The Relation of Mesquite to Salinity and Water:

Salinity and water are the most determinant factors affecting the growth and the distribution of Mesquite tree [46] mentioned that, Prosopis species differ in their tolerance to salinity in soil ,in a field experiment in India, in 1992-1994, planted different species including Prosopis juliflora in salt affected soil. The latter species showed the best survival. It had the greatest plant height and collar diameter [49] reported that, “a stand of Mesquite trees uses approximately the same amount of water as grassland in the same area during the rainy season, but during the dry season, when grasslands become dormant, the trees continue to require water. It is estimated that one tree uses 40-50 litres of water per day. Extended root systems allow Mesquite to tap deeper into underlying water tables, causing the water tables to recede and diminishing the possibility for replenishment during the next rainy season. Receding water tables have led to the drying up of streams, reducing the ability of existing water supply schemes to deliver sufficient water to meet human needs [53] compared the germination of seed for nine species of tropical trees (Including Acacia nilotica and Prosopis juliflora) under water stress conditions. Water stress prohibited seed germination in all of them except for one called Leucaena leucoceppala.

Health Impacts of Mesquite:

There are minor human health hazards caused by the Mesquite [54] studied the allergen city to Prosopis juliflora in Saudi Arabia. He noted that, pollen antigen has been reported from only a few countries, including the US, South Africa, India and Kuwait. In some parts of Saudi Arabia, millions of Prosopis trees have been introduced as roadside ornamentation. A total of 473 allergic patients suffering from bronchial asthma in four different geographical regions (Abha, Qassim, Hofuf and Gizan), and attending allergy clinics and chest disease centres were tested for immediate hypersensitivity reaction to Prosopis juliflora allergens. It was found that, the role of Prosopis pollen as a sensitizing factor in allergenicity is evident[55] reported that, the thorn from Mesquite, on penetrating the eye, causes more inflammation than expected from the physical injury. The irritation may be due to waxes. Injection of cerotic acid is destructive to the eye. Using the wood in a fireplace has caused dermatitis. The gum has irritant properties. Although Mesquite pods are normally, considered excellent feed for cattle and horses, serious digestive disturbances or death may occur when large amounts of beans are consumed continuously over a 2-month period. The disease known as "jaw and tongue trouble" is characterized in cattle by profuse salivation, continuous chewing, a protruding tongue, and a tilted head. The animal gradually emaciates and may lose up to 50 percent of weight [56] mentioned that, if acute symptoms, such as loss of appetite, rapid weight loss, nervousness, a wild expression, and bulging eyes, develop, animals usually die within 2 to 4 days.

1.6 Okra:

Okra or **okro** (US: /ˈoʊkrə/ or UK: /ˈɒkrə/), known in many English-speaking countries as **ladies' fingers** or **ochro**, is a flowering plant in the mallow family. It is valued for its edible green seed pods. The geographical origin of okra is disputed, with supporters of West African, Ethiopian, and South Asian origins. The plant is cultivated in tropical, subtropical and warm temperate regions around the world.[57]

Vernacular names in English-speaking nations:

The name *okra* is most often used in the UK, United States and the Philippines, with a variant pronounciation in Caribbean English and Nigeria of *okro*. The word *okra* is from the Igbo ọ́kụ̀rụ̀.[58][59] The plant and its seed pods are also known as "lady's fingers".[60]

In various Bantu languages, okra is called *(ki)ngombo* or a variant,[61] and this is possibly the origin of the name "gumbo", used in parts of the United States and the English-speaking Caribbean (via Portuguese *quingombo*).[62]

Origin and distribution:

Okra is an allopolyploid of uncertain parentage (proposed parents include *Abelmoschus ficulneus*, *A. tuberculatus* and a reported "diploid" form of okra). Truly wild (as opposed to naturalised) populations are not known with certainty and the species may be a cultigen.

The geographical origin of okra is disputed, with supporters of South Asian, Ethiopian and West African origins. Supporters of a South Asian origin point to the presence of its proposed parents in that region. Supporters of a West African origin point to the greater diversity of okra in that region.

The Egyptians and Moors of the 12th and 13th centuries used the Arabic word for the plant, *bamya*, suggesting it had come into Egypt from Arabia, but earlier it was probably taken from Ethiopia to Arabia. The plant may have entered southwest Asia across the Red Sea or the Bab-el-Mandeb straight to the Arabian Peninsula, rather than north across the Sahara, or from India. One of the earliest accounts is by a Spanish Moor who visited Egypt in 1216 and described the plant under cultivation by the locals who ate the tender, young pods with meal.[62]

From Arabia, the plant spread around the shores of the Mediterranean Sea and eastward. The plant was introduced to the Americas by ships plying the Atlantic slave trade[63] by 1658, when its presence was recorded in Brazil. It was further documented in Suriname in 1686.

Okra may have been introduced to southeastern North America from Africa in the early 18th century. By 1748, it was being grown as far north as Philadelphia. Thomas Jefferson noted it was well established in Virginia by 1781. It was commonplace throughout the Southern United States by 1800, and the first mention of different cultivars was in 1806.[62]

Botany and cultivation:

The species is a perennial, often cultivated as an annual in temperate climates, and often grows to around 2 metres (6.6 ft) tall. It is related to such species as cotton, cocoa, and hibiscus. The leaves are 10–20 centimetres long and broad, palmately lobed with 5–7 lobes. The flowers are 4–8 centimetres in diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal. The fruit is a capsule up to 18 centimetres long with pentagonal cross-section, containing numerous seeds.

Abelmoschus esculentus is cultivated throughout the tropical and warm temperate regions of the world for its fibrous fruits or pods containing round, white seeds. It is among the most heat- and drought-tolerant vegetable species in the world and will tolerate soils with heavy clay and intermittent moisture, but frost can damage the pods.

In cultivation, the seeds are soaked overnight prior to planting to planting to a depth of 1-2 centimetres Germination occurs between six days (soaked seeds) and three weeks. Seedlings require ample water. The seed pods rapidly become fibrous and woody and, to be edible as a vegetable, must be harvested when immature, usually within a week after pollination.[64] Okra is available in two varieties, green and red. Red okra carries the same flavor as the more popular green okra and differs only in color. When cooked, the red okra pods turn green.[65]

The most common disease afflicting the okra plant is verticillium wilt, often causing a yellowing and wilting of the leaves. Other diseases include powdery mildew in dry tropical regions, leaf spots, and root-knot nematodes.[66]

Food:

The products of the plant are mucilaginous, resulting in the characteristic "goo" or slime when the seed pods are cooked; the mucilage contains soluble fiber.[67] Pods are cooked, pickled, eaten raw, or included in salads. Okra may be used in developing countries to mitigate malnutrition and alleviate food insecurity.[67]

Nutrition:

Raw okra is 90% water, 2% protein, 7% carbohydrates and negligible in fat (table). In a 100 gramme amount, raw okra is rich (20% or more of the Daily Value, DV) in dietary fiber, vitamin C and vitamin K, with moderate contents of thiamin, folate and magnesium (table).

Fig (1.11) Leaves and seeds

Fig (1.12) Stir fried okra with diced chili peppers

Okra bloom with seed pods:

Okra leaves may be cooked in a similar way to the greens of beets or dandelions.[68] The leaves are also eaten raw in salads. Okra seeds may be roasted and ground to form a caffeine-free substitute for coffee.[62] When importation of coffee was disrupted by the American Civil War in 1861, the *Austin State Gazette* said, "An acre of okra will produce seed enough to furnish a plantation with coffee in every way equal to that imported from Rio."[69]

Greenish-yellow edible okra oil is pressed from okra seeds; it has a pleasant taste and odor, and is high in unsaturated fats such as oleic acid and linoleic acid.[70] The oil content of some varieties of the seed is about 40%. At 794 kg/ha, the yield was exceeded only by that of sunflower oil in one trial.[71] A 1920 study found that a sample contained 15% oil.[72] A 2009 study found okra oil suitable for use as a biofuel.[73]

Bast fibre : Bast fibre from the stem of the plant has industrial uses [74] .

Table (1.1) Analysis of Okra

Okra, raw:

Nutritional value per	100 g
Energy	138 kJ
Carbohydrates	7.45 g
Sugars	1.48 g
Dietary fiber	3.2 g
Fat	0.19
Protein	1.9 g
Vitamins :	
Vitamin A equiv	(5%) 36 μg
Thiamine (B1)	(17%) 0.2 mg
Riboflavin (B2)	(5%) 0.06 mg
Niacin (B3)	(7%) 1 mg
Folate (B9)	(15%)

	60 µg
Vitamin C	(28%) 23 mg
Vitamin E	(2%) 0.27 mg
Vitamin K	(30%) 31.3 µg
Minerals :	
Calcium	(8%) 82 mg
Iron	(5%) 0.62 mg
Magnesium	(16%) 57 mg
Phosphorus	(9%) 61 mg
Potassium	(6%) 299 mg
Zinc	(6%) 0.58 mg
Other constituents	
Water	89.6g

Link to Full USDA Database entry .

Units:

µg = micrograms • mg = milligrams IU = International units Percentages are roughly approximated using US recommendations for adults.

1.7 Mulukhiyah:

Mulukhiyah, mloukhiya, molokhia, molokhiya, mulukhiyya, malukhiyah, or **moroheiya** (Arabic: ملوخية) is the leaves of *Corchorus olitorius* commonly known as Jew's Mallow, Nalta jute, or tossa jute.[1] It is used as a vegetable. It is popular in Middle East, East African and North African countries. Mulukhiyyah is rather bitter, and when boiled, the resulting liquid is a thick, highly mucilaginous broth; it is often described as "slimy", rather like uncooked okra. Mulukhiyyah is generally eaten cooked, not raw, and is most frequently turned into a kind of soup or stew, typically bearing the same name as the vegetable in the local language. Traditionally mulukhiyyah is cooked with chicken or at least chicken stock for flavor and is served with white rice, accompanied with lemon or lime.

Origins:

While most scholars are of the opinion that mulukhiya's origins lie in Africa,[2] there is evidence that India is the source of the related species Corchorus capsularis,[3] which is also used for food as well as fiber.

Egyptian cuisine:

As used in Egyptian cuisine, molokhiya, (Egyptian Arabic pronounciation: [moloˈxejjæ]) is prepared by removing the central spine from the leaves, and then chopping the leaves finely with garlic and coriander. The dish generally includes some sort of meat; in Egypt this is usually poultry such as chicken, or rabbit,[4] but lamb is preferred when available, particularly in Cairo.

Cooks in Alexandria often opt to use shrimp in the soup, while Port Said is famous for using fish.

Molokhiya was consumed in ancient Egyptian cuisine,[5] where the name "molokhiya" is thought to have originated from.

Many Egyptians consider molokhiya to be the national dish of Egypt along with ful medames and kushar .

Fig (1.13): Egyptian molokhiya. The soup is usually poured over rice or eaten with Egyptian flatbread (known as ʿeish baladi’

Preparation:

The Egyptian version differs in texture and preparation from the Syrian/Lebanese version. The molokhiya leaves are picked off the stem, often communally with the women sitting with vast amounts of tall stemmed branches picking it, placing the leaves on a large sheet (cloth material) left to completely dry for later use.

Cooking:

The leaves are then fried with coriander, garlic and often chili peppers or capsicum. This cooking process prevents them from becoming slimy. It is then boiled with large chunks of meat, such as boneless chicken, rabbit, beef or lamb (with bone).

Serving:

The soup is served on white rice or with a side of Egyptian flatbread (ʿeish baladi). The bread is normally used to scoop up the soup, but it can also be cut up into small pieces and submerged in the soup. The dish is often accompanied with an assortment of pickled vegetables known as torshi or mekhalel in Egypt.

Nutrition:

The leaves are rich in betacarotene, iron, calcium, Vitamin C and more than 32 vitamins, minerals and trace elements. The plant has a potent antioxidant activity with a significant α-tocopherol equivalent Vitamin E.

In popular culture:

In an episode of the murder mystery television series Murder She Wrote entitled "Death n' Denial", sleuth Jessica Fletcher is coerced into eating a full serving of mulukhiyah after posing as the victim's mother in order to suss out a clue. She is shocked by the spicy nature of the dish but it is explained that she must finish the entire course or it would be considered an insult. The dish serves as somewhat of joke throughout the episode and when Jessica is offered the dish again in the final scene she is quick to decline.

1.8 Adhesives:

1.8.1 Gum Arabic:

Introduction:

Different groups of people use the term Gum Arabic with varying degrees of precision. In the context of its use as a food additive the most recent international specification, published by FAO, defined Gum Arabic as the dried exudation obtained from the stems and branches of Acacia Senegal (LWilldenow) or closely related species. The specification then proceeds to give limit parameters, which have been selected to ensure that only gum from A.senegal (and closely related species) satisfies the specification. The need for such legislation arises from the need to assure the public on safety grounds that there are no hazards associated with ingestion of Gum Arabic , which complies with the definition and specifications that have been tested and shown to be safe to consume./ In Sudan, the term Gum Arabic is used in a wider context to include two types of gum which are produced and marketed, but which are, nevertheless, clearly separated in both national statistics and trade: "hashab" (from A. Senegal) and "talha" (from A. Seyal). In a still wider sense, Gum Arabic taken to mean the gum from any Acacia species (and is sometimes referred to as acacia gum) [80]. Production of Gum Arabic: Gum Arabic is the dried, gummy exudation obtained from various species of acacia trees of the Leguminous family [81]. The JECFA defined Gum Arabic as dried exudates from the trunk and branches of acacia senegal or acacia seyal of the family Leguminous [82]. Acacia trees belong to the botanical family of Leguminous, predominantly species of the groups Fabales and Gummiferae. There are more than two hundred species of Acacia, out of which only ten produced gums with different properties. The only species producing sap eligible for the name acacia gum or Gum Arabic are Acacia Senegal and Acacia Seyal [83]. Acacia Senegal is a small to medium sized thorny tree, with a stem, which is irregular in form and often highly branched. In leaf, like many other Acacias, it has a dense, spreading crown. In common with other members of the A. senegal complex, it has characteristic sets of prickles on the branches, usually in threes with the middle one hooked downward and the lateral ones curved upward. The bark is not papery or peeling [80]. The tree is deciduous, droops its leaves in November in the Sudan [84]. Acacia Seyal has a single straight stem with a characteristic, pronounced color, usually orange-red, to the powdery bark, and straight thorns rather than the curved prickles of A. Senegal [80].

Products of Acacia Tree:

i. Acacia Senegal Gum (hashab) is a pale white to orange-brown solid, which breaks with a glassy fracture. The best grades are in the form of whole, spherical tears of varying size with a matte surface texture. When grounded, the pieces are paler and have a glassy appearance.

ii. Acacia Seyal Gum (talha) on the other hand is more brittle than the hard tears of Senegal Gum [85] as shown in (table 15.1).

iii. Other products of acacia tree locally are sources of fuel wood and an important source of browse for livestock [86].

The Gum Arabic Belt:

The gum belt referred to a broad band, situated at a latitude of between 12° and 16° North, stretching across sub-Saharan Africa, from Mauritania in the West, through Senegal and Mali, Burkina Faso, Niger , Northern Nigeria to Sudan, Eritrea, Ethiopia, Kenya, Somalia and Northern Uganda in the East as shows in (figure

15.1) [87]. Production of Gum Arabic is concentrated in the "gum belt", an area of central Sudan roughly between latitudes 10° and 14° north. Two areas outside these borders are in the north east (Faw-Gedaref-Kassala) and in the south east along the Blue Nile/Upper Nile border. It estimated to cover 520.000 square kilometers, roughly one fifth of Sudan's total area. It spanned over 12 states:-Western Darfur, N. Darfur, S. Darfur, N. Kordofan, W. Kordofan, S. Kordofan, White Nile, Upper Nile, Jonglie, Sennar, Blue Nile and Gedaref. The sandy plains are in the first seven states and the clay plains are in the latter five states as shows in (14.1) [81].

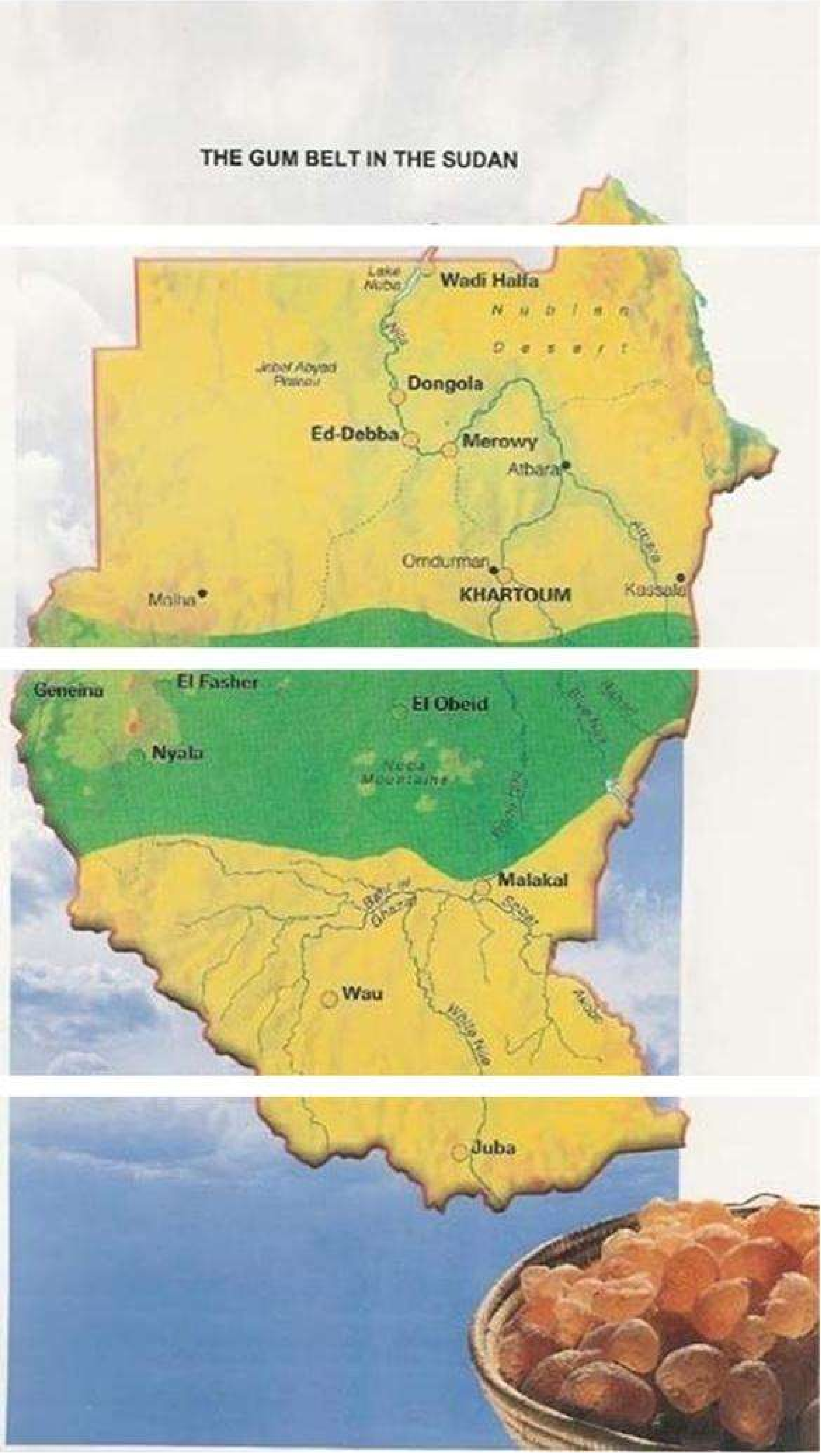

Fig. (1.14): The Sudan Gum Arabic Belt

i.Acacia Senegal Distribution:

Has a wide distribution and remarkable adaptability. It is essentially a semi-arid zone species, but it is both drought, frost resistant, and can grow with a rainfall of between 100 and 800 mm per year. It grows across Africa, from Senegal to Ethiopia, through Mali, Nigeria, Chad and Sudan, to mention only the major producing areas. It is also found in the Middle East, Yemen, India and Pakistan. In the Sudan, particularly in the Kordofan and Darfour provinces, the species is uniform and found in pure stands giving the Sudan an important advantage of being the most important producer of this type of Gum Arabic. In other producing countries, acacia senegal often found mixed with other species. Another feature of the Sudan system of production is that this species occurs both as a wild and as a cultivated species; man in village plantations often replants it.

ii. Acacia Seyal Distribution:

It grown in the Sudano-Sahelian belt where the rainfall is slightly higher than in the regions populated with the acacia senegal. It is grown and regenerated naturally; it does not required tapping and gum exudes naturally. Its biomass calculated to be 50 times greater than that of the acacia senegal, which gave it an important advantage in terms of production potential. It is affected at a later stage than the acacia senegal by the desertification process. It can grow on clay soils and resists well to climatic changes from temporary wet to prolonged dry periods with a consequent cracking of the surface of the soil. Whilst the acacia senegal and the acacia seyal are present together in the same geographical zone, they have their own biotope (for example, nearer to water for the acacia seyal, drier areas for the acacia senegal) [87].

iii. Gum Arabic Cultivation system:

There are two type of cultivation system: A. The bush-fallow cycle: An agro-forestry system which based on integrating annual crops with gum trees in a temporal sequence. B. The agro- forestry system: This system is based on a spatial mixture, where annual crops and gum produced from the same land unit simultaneously and pure stand gum forest used for the production of gum only [88].

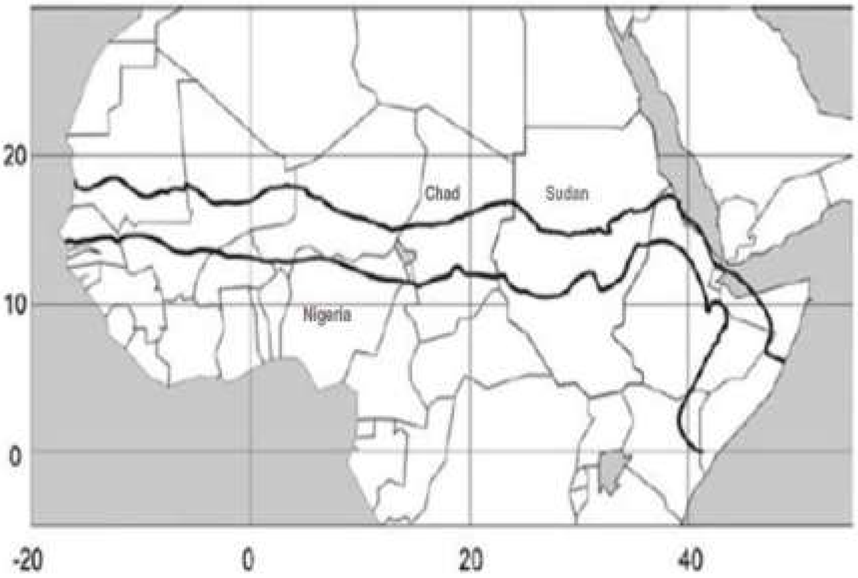

Fig. (1.15): The Gun Arabic Belt in Africa

iv. Regeneration of Acacia Senegal Resources:

Acacia senegal occurred naturally in pure stands on the sandy soils of Kordofan and Darfur, in rotational bush-fallow cultivation system and in areas ,where no cropping activity is practiced. It also grows naturally in the central clay plains of central and eastern Sudan, through rarely in pure stands. The natural regeneration of acacia senegal comes mainly from the natural seed fall. Artificial regeneration of acacia senegal has carried out both by directed sowing of seeds and transplanting of seedlings. More than 50% of Gum Arabic produced in Sudan had been obtained from plantations or naturally regenerated stands. Individuals, government or cooperative bodies own plantations and naturally regenerated stands [81].

Production of Gum Arabic:

Sudan considered Gum Arabic as a national wealth which needed to be conserved, improved and developed, not only to provide a sustained yield of gum but also for other important socioeconomic benefits of production and protection. The gum belt is a national buffer zone between the desert region in the north and the good agricultural tall grass savanna in the south. Therefore, any distribution or misuse in this zone will induce desertification and threaten agricultural production [89]. Gum Arabic production in the Sudan has developed over generations in a tradition handed down from father to son. This long experience was not easily matching in other countries; it backed up by a well-established extension and research service. Gum producers are in general settled farmers and gum is well entrenched in the agricultural rotation. Every Acacia tree in Sudan is under the rightful ownership of somebody who can look after the tree and tap it on his own behalf [87]. Gum Arabic is produced by small farmers either hashab owner or hashab renter [80] , who gives priority to food crop production (usually sorghum or millet) to secure family nutritional needs , but seek other sources of income to meet the household’s basic needs other than grains. They harvest Gum Arabic because this activity constitutes a crop diversification strategy to mitigate crop failure. However, Gum Arabic production competed with food and cash crops for labor resources and land allocation [90].

Table (1.2): Comparison of Gum Arabic Sudan Producing Area and Other Countries

Sudan	Other countries
Uniform stands of monoculture of the right species in large tracks.	Mixed species in batches.
Well- experienced producers, tappers, collectors, cleaners and graders.	Lack of experience in all fields
Land tenure settles - recognized private ownership	Serious land tenure problems, Gum produced in the no man's land.
Producers are mainly settled agriculturists	Producers are mostly nomads not interested in Gum development
The stable system of gum cultivation cycle is practiced in many areas	Over - exploitation and cutting of trees through shifting cultivation is practiced
Development of Gum Projects at all levels	Lack of serious development projects.

Gum Arabic Quality:

The quality of Gum Arabic as received by the importer depended on the source. Gum Arabic hashab from Sudan is the highest quality and sets the standard by which other Gum Arabic judged. Not only does Sudanese gum come from a species acacia senegal which intrinsically produces high quality exudates with superior technical performance, but also the collection, cleaning, sorting and handling of it up to the point of export is well organized and highly efficient. Within Sudan, Gum Arabic from the Kordofan region has the highest reputation, and traders and end-users in importing countries often refer to "Kordofan gum" when indicating their preferences. Gum talha from Sudan "produced from acacia seyal" is intrinsically a poorer quality gum than hashab, it has inferior emulsifying properties and even light-colored samples of whole gum sometimes form dark solutions in water due to the presence of tannins and other impurities. In addition, it is more friable than hashab [80].

Chemical Structure of Gum Arabic:

Gum Arabic consists mainly of high-molecular weight polysaccharides and their calcium, magnesium and potassium salts, which on hydrolysis yield Arabinose, Galactose, Rhamnose and Glucuronic acid. Acacia seyal gum has lower Rhamnose and Glucuronic acid contents, higher Arabinose, and 4-O-methyl Glucuronic acid contents than gum from acacia senegal. Acacia seyal gum contains a lower proportion of nitrogen and the specific rotations are very different. The amino acid compositions are similar with hydroxyproline and serine the major constituents, as regarded in (table 2.5) [91].

Table (1.3): Average Composition of Acacia Gum (APIG).

Sugar composition after hydrolysis	
Galactose	35 - 45 %
Arabinose	25 - 45 %
Rhamnose	4 - 13 %
Glucuronic acids	6 - 15 %
Molecular weight average	350 000
pH solution at 25 %	4.4
Intrinsic viscosity	12 ml/g

Brookfield viscosity, solution at 25%, 60 rpm	70 cP
Protein Content	1 - 2 %
Total ashes (Potassium, Calcium & Sodium Salts)	3 - 4 %
Arabinogalactan (AG)	89 - 98 %
Arabinogalactoprotein (AGP)	1 - 10 %
Glyco Proteins (GP)	Less than 1 %

Physical Properties of Gum Arabic:

i. Solubility:

Yield a solution up to 55% concentration. Gum Arabic is truly soluble in cold water. Other gums are either insoluble in cold water or form colloidal suspensions, solutions not true.

ii. Viscosity:

A 20% aqueous solution will give less than 100 cps, i.e. Gum Arabic is not very viscous at such concentrations. High viscosity obtained only at concentrations of 40% - 50%

iii. Color:

Colorless (top quality) to pale straw color (average quality).

iv. Taste:

Has no off-taste. V. Toxicology and Status: ADI not specified by (JECFA + EEC), general status as (GRAS).

vi. Fiber:

Can be regarded as 95% soluble fiber according to some of the available test methods. **vii.** Film-forming: Super film-forming properties make it ideal for some confectionery coatings and lithographic plate solutions.

viii. Emulsifier:

Produced highly stable emulsions making it very useful in the preparation of oil in-water food flavors emulsions, particularly for citrus oils. As shown in (table 2.6).

Table (1.4): Laboratory Analysis for Powder Kordofan Gum Arabic, Hashab (Acacia Senegal) KB 120(APIG)

Specification	
Purity	99.50% min.
Moisture	15% max.
Total Ash	4.00% min.
Acid Insoluble Matter	00.50% max.
pH	4.2 -- 4.8
Viscosity	75 - 110 CPS
Arsenic	3 ppm max.
Lead	10 ppm max.
Total Heavy Metal	20 ppm max.
Optical Rotation	(-26^{o} -34^{o})

T.V.C.	2000/g. max.
Yeast and Mould	200/g. max
Salmonella	Absent
E-Coli	Absent

Characteristics and Identification of Gum Arabic:

The FAO (JECFA) specification existed for Gum Arabic intended for use as a food additive; in the United States, Food Chemicals Codex specification exists. For pharmaceutical use, Gum Arabic appears in many pharmacopoeias, including the British Pharmacopoeia. The JECFA specification has undergone a number of revisions over the years. The present one specified limits on such things as loss on drying, ash, acid-insoluble matter, arsenic, lead and heavy metals. A departure of the present specification from earlier ones (other than a modified definition) is the inclusion of limits on optical rotation and nitrogen content. Their inclusions, and the numerical limits, are designed to ensure that as far as possible, only gum from A. senegal or closely related species is able to satisfy the requirements (and that, for example, gum talha is excluded) [86]. The following features and characteristics used to identify Gum Arabic both in processed and unprocessed state:

i.Solubility:

One gramme of Gum Arabic dissolved in two cm^3 of water forms an acidic solution and insoluble in ethanol.

ii. Optical rotation:

Water solutions of gum from acacia senegal are Laevorotatory while that from acacia seyal are Dextrorotatory.

iii. Hydrolysis products:

Hydrolysis of Gum Arabic used to identify Arabinose, Galactose, Rhamnose and Glucuronic acid. A chemical test on the hydrolysate will produce greenish yellow color with hexoses, red color with pentoses and brown color with uronic acids.

iv. Purity

(Loss on drying): For granular Gum Arabic, it is not more than 15% (105° , 5 hr) and not more than 10% (104° , 4 hr) for spray-dried material. Ungrounded samples should been powdered to pass through a (No.40) sieve and mixed well before weighing.

v. Total ash: 4%

vi. Acid insoluble ash: 0.5%

vii. Acid insoluble matter: 1%

viii. Arsenic: Not more than 3 mg/kg. ix. Lead: Not more than 5 mg/kg

x. Starch or Dextrin: No reddish or bluish color should been produced when a boiled solution (1 in 50 solutions) is tested with iodine.

xi. Tannin - bearing gums: No blackish coloration or precipitate should be formed when tested with ferric chloride solution [92].

Uses of Gum Arabic:

A. Global Uses of Gum Arabic:

i. Confectionary:

Gum Arabic is an excellent flavor carrier and used by formulators for imparting a clean, long-lasting fresh taste. It used to emulsify the flavor oils or fats in confections. The film-forming ability of Gum Arabic made it a useful ingredient for confectionery coatings including the pan coating of fruits and nuts

ii. Miscellaneous Bakery Applications:

Wherever film - forming and emulsifying properties without affecting product taste or archeology needed, Gum Arabic is an ingredient that considered.

iii. Beverage:

As the emulsifying agent of choice, Gum Arabic widely used in a broad range of beverage. The completeness and stability of the emulsions produced even in normally difficult low acid environments have kept it as an essential ingredient for this usage. It used as a component-clouding agent in a wide range of beverages. It used also as a clarifying agent in the production alcoholic beverages, such as high quality wines.

iv.Encapsulate Flavors:

Dry packaged products such as instant drinks, dessert mixes, soup bases and off-the shelf spray dried flavors may be formulated using Gum Arabic. Flavors protection, desirable flavors release, long shelf life, and high dispersibility are the advantages offered by Gum Arabic. Pharmaceutical, Vitamins and Cosmetics: Gum Arabic used as a carrier in capsules and as a tabulating recipient. One of its oldest and best-known uses has been in cough syrups. It used also in cosmetic products such as facemasks, hair creams and fixatives, protective creams and lotions [93]. Inks: Gum Arabic is an important constituent of many special purpose inks. Watercolor and quick drying inks utilize the suspending and binding properties of Gum Arabic.

vii. Foam Stabilizer:

Used as a foam stabilizer and agent to promote adhesion of foam to glass [6].

viii. Textiles:

Gum Arabic used in the melting yarn chips process. Added it to make the yarn stronger and increase its tensile strength. These days, many textile manufacturers used a modified starch mixed with Gum Arabic.

ix.Gum Prints:

Since the nineteenth century, Gum Arabic combined with a sensitizer and a soluble pigment, applied to paper, and exposed through a negative under a powerful light source. This can produce beautiful prints only surpassed by adding further layers of gum pigments in registration. It is also possible to print color separated black-white negatives to produce gorgeous true color prints, but precise registration is required.

1.8.2 Guar:

There seems to be a semantic ambiguity about the very term "gums". According to the original definition which meant broadly "plant exudates”, the term encompassed also various resins, rubber latex, etc.

The present definition of "gums" is some what narrow errand or specific. It comprises all materials that can be dissolved or dispersed in water to form more or less viscous colloidal solutions or dispersions. Which ever definition we accept, it appears that "gums" have been used in industry and commerce since the beginning of civilization .

According to the Bible , myrrh and frankincense accompanied goldat the Manger. Gums were also used by the ancient Egyptians for embalming the dead and for gluing together strips of clothing for binding mummies.

In different application again gum arabic was for them a convenient adhesive for mineral pigments in paint formulations. Like wise , gums were used as food and form medicinal purposes by many civilizations, up to the present day [95] . Until recently , however, the use of gums was restricted to a relatively low.
Journal of the society of cosmetic chemists:

number of items , randomly harvested , and of limited quality and property range .Only the last decade , or so , has brought about revolutionary changes .Some gum bearing plants have begun to be cultivated on a commercial scale .

Many natural gums are now treated, and, by under going various physical and chemical modifications have their quality improved , have the range of their properties immensely increased. Finally, the creation of new, organic polymers has yielded the whole class of new , synthetic gums.

Guar gum is one of the outstanding representatives of that new generation of plant gums , Its source is an annual pod-bearing , drought resistant plant, called Guar, or cluster bean (Cyamopsis tetragonolobus or C.psoraloides), belonging to the family Leguminosae.

It has been grown for several thousand year in India and Pakistan as a vegetable , and a forage crop . It is interesting to learn that some Guar seeds have even been found in the recently excavated Pharaoh Zoser' stomp in Sakkarah , nr. Cairo .The guar plant is about 0.6 m high, and resembles soybean plant in general appearance, and in its characteristic arrangement of pods along the vertical stem. The pods are5-12.5.

The plant was brought to the U.S.A. at the beginning of this century and grown there in experimental stations in the semi-arid south west {South Texas and Arizona).

It has been found fairly easy to cultivate, undemanding and well adapted to mechanical planting and harvesting, It was, however , only about 1940 that guar became a commercial reality . The war caused shortages in supply of locust bean gum, to which guar gum is closely related, and the American paper industry began to look for possible replacements. Guar gum was found to be a suitable one and , as a result, new plantations of guar bean began to spring up and in 1942 General Mills Inc. introduced - experimentally- the first guar gum to American industry [96].

The success of that introduction and an increasing demand have naturally attracted followers and- among others- in 1953 another major manufacturer(Stein,Hall & Co.Inc.) entered the market [97] Now, guar gum is big business in the U.S.A. as may be seen from table comparing production of more important water soluble gums in 1963 [98]. The more important brands in the U.S.A. are: Guarded , Arearexand

"Super Col"(General Mills Inc.), "Jaguar" series(Stein,Hall & Co.Inc.), "Starguar"(Morningstar - PaisleyInc.), Penguar(S. B. Penick& Co.),T.I.C. Guar Gum{Tragacanth Importing Corp.),Guar gum(Meer Corpora-tion) and several others In Europe- to the writer's knowledge – there are the following brands available: "Guaranate" series made by SocidtdFran9aise des Colloids and American brands, manufactured by their subsidiaries , i.e. "Guaranate and Supercol"of General Mills Inc. in the U.K. (Messrs. Tragasol Products Ltd., Hooton, Wirral, Cheshire)and "Meypro-Guar" of Stein, Hall & Co.

Inc., in Switzerland(Meyhall Chemical AG - Kreuzlingen, Switzerland.) The general outline of the manufacturing procedures as follows: After having been removed from their pods the spherical , brownish seeds, the size of a small pea, are passed rapidly through a flame and thus loosened; hard seed hulls are then removed in a scouring or "pearling" operation .

The decorticated, vitreous looking endosperm is separated from its germin a milling operation and the resulting "splits" are then ground to the required mesh size.

This is so called commercial “guar flour" and it may be used without further processing , except for heat treatment to inactivate enzymes contained in occasional fragments of a seed germ .Various grades are available depending on color (white to grayish) mesh size ,viscosity potential and rate of hydration.

The Chemistry Of Guar Gum:

The chemical analysis of guar flour shows the following typical composition to:

Nitrogen	0.67 corresponding 3.5 - 4.0proteins
with	
Phosphorus	0.06
Ash	1.0

Ournal Of The Society Of Cosmetic Chemists:

Water sol. Polysaccharide	86.50
Water insoluble fraction	7.75
Alcohol sol fraction	1.50

{From24 h Sox let extraction)

The solvent extracted fraction consists mainly of a fatty matter while the water insoluble fraction contains proteins and crude fibers.

The material also contains between10-13% moisture.The water soluble polysaccharide fraction is composed – apart from some pentose's, and traces of protein acetous matter entirely of approximately36.6%D-galactose anhydride, and63.1ø/0 mannose anhydride. The absence of ironic acid differentiates this polysaccharide from the great majority of plant gums and mucilage's.The composition thus found , identifies it as a polymer of D-galactose and D-mannose, i.e. a galactomannan [99].

GUAR GUM AND ITS APPLICATIONS:

Table (1.5): Used Guar gum is in industry

Gums	•o (w/v) for 800 cP
Tragacanth USP	2.75
Sodium alginate (med. visc.)	1.15
Jaguar brand of guar gum	0.2-0.3 (2S°C)
Methyl cellulose(4 000 cP)	1.35
Sodium carboxymethyl cellulose(reed.visc.)	1.9
Sodium carboxymethylcellulose(highvisc.)	0.7
Carbopol934	0.17
Methyl cellulose (1 $00 cP)	1.7

USES OF GUAR GUM:

Table (5.1) shows that guar gum is used in massive proportions in industry . Indeed , due to its unique combination of properties it has proved to be a valuable aid in a multitude of industrial applications , as diverse as already mentioned , mining and food, paper and textile.

In the paper industry it is further used- apart from as a dispersant and suspending agent- also for sizing and coating . In the textile industry , it also serves as a pigment dispersing aid, and above all as a thickening agent for color printing pastes for which use it is unsurpassed.

The ceramic industry also uses sizeable quantities of guar gum as a binder , thickener and fixing agent for enamels, porcelain , etc. In the food industry it is widely used in salad dressings, ice creams , lollipops and sherbets , in bakery products and confections, meats and saus

The Objective of This Work:

The aim of this study is to utilizing the interaction of cellulose material (wood, mesquite, okra and khodra) with adhesives (Gum Arabic Guar, Nocrine , white Glue , Glue) to produce office and house hold utilites for local use and export.

Chapter two

Experimental

Experimental:

Samples:

The following samples of vegetables are commonly used as food in Sudanese kitchen that containing cellulose as main component.

The samples were prepared after getting from the place of origin , then separated into useful pieces , cleaned as well by using water , then dried in shade , and finally were crushed to fine powders and kept into Stoppered container for utilization and testing . The samples comprised:

Okra

Mesquite

Musk wood

khodra

Collection:

Khodra : from shendi market

Okra: from shendi

Mesquite: from shendi university near River Nile

The Adhesives:

Guar

Gum Arabic

nocrine

microne

White glue

Were obtained from Khartoum and Shendi markets as usual commodities . the adhesives were dissolved in water and other solvents to certain viscosities capable to obtain good adhesion strength .

Solvent:

Distilled water.

The equipments:

Press , moulds of glass and iron.

Beakers, glass rods, Petri dishes, magnetic stirrers, hot plates, sensitive balance, ovens, device for testing (impact test).

2.1Gum Arabic:

Experiment (1):

2.1.1 Mixing Gum Arabic with one cellulose sample:

150g of gum Arabic were added to 300cm^3 of water then put in 500 cm^3 beaker fitted with magnetic stirrer to be dissolved, then transferred to volumetric flask and then the volume was completed to the mark.

143g of okra powder were added to 500cm^3 of the above solution, then stirred well and then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for analysis.

The same experiment 1 was repeated using:

Okra powder, Mesquite powder,

Musk powder,

Khodra powder and Gum Arabic.

After one day the mould product adhesives were lesled and the result are shown on table 3.1 on page 103.

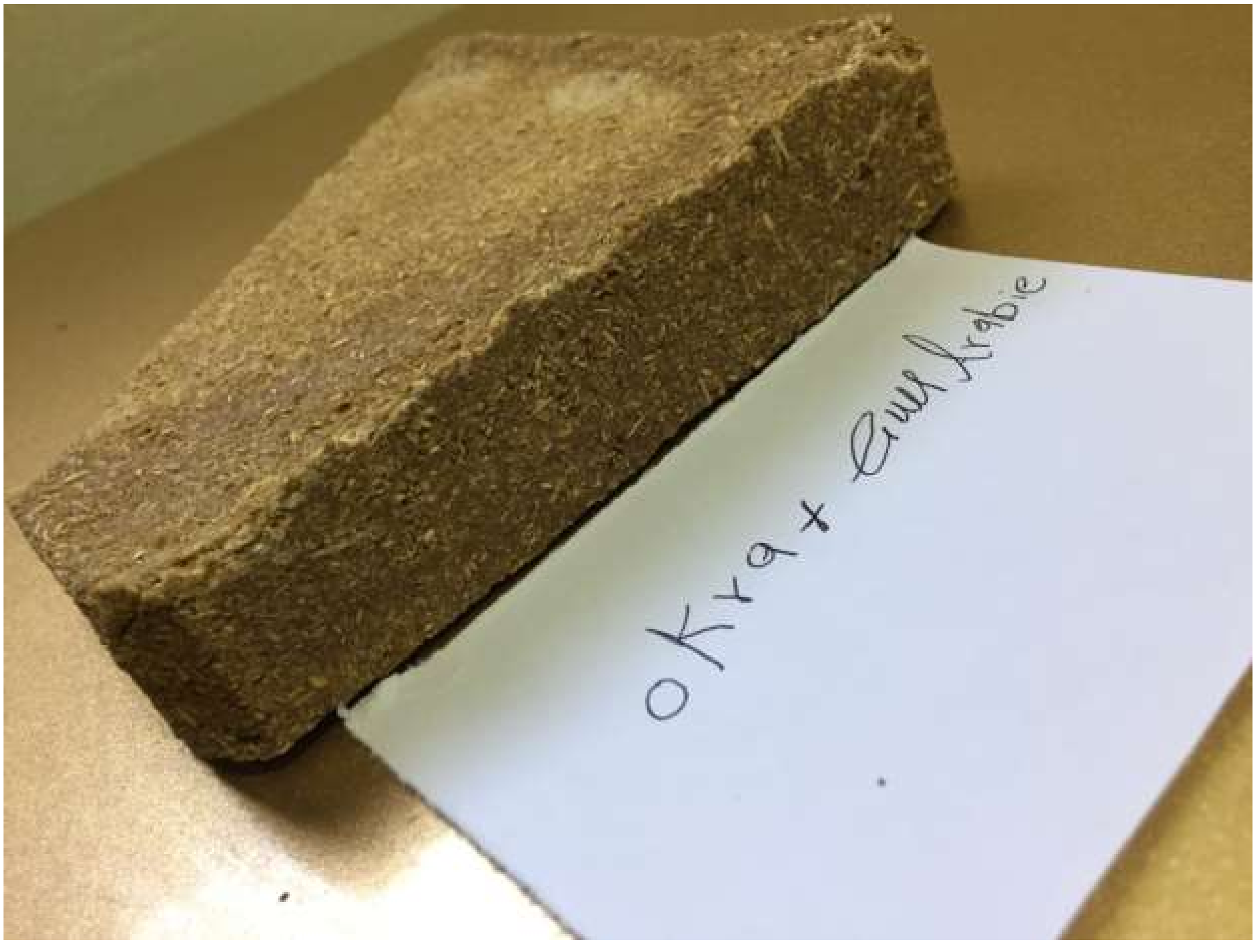

Fig (2.1) Okra + Gum Arabic

The Result are shown on table (3.1)

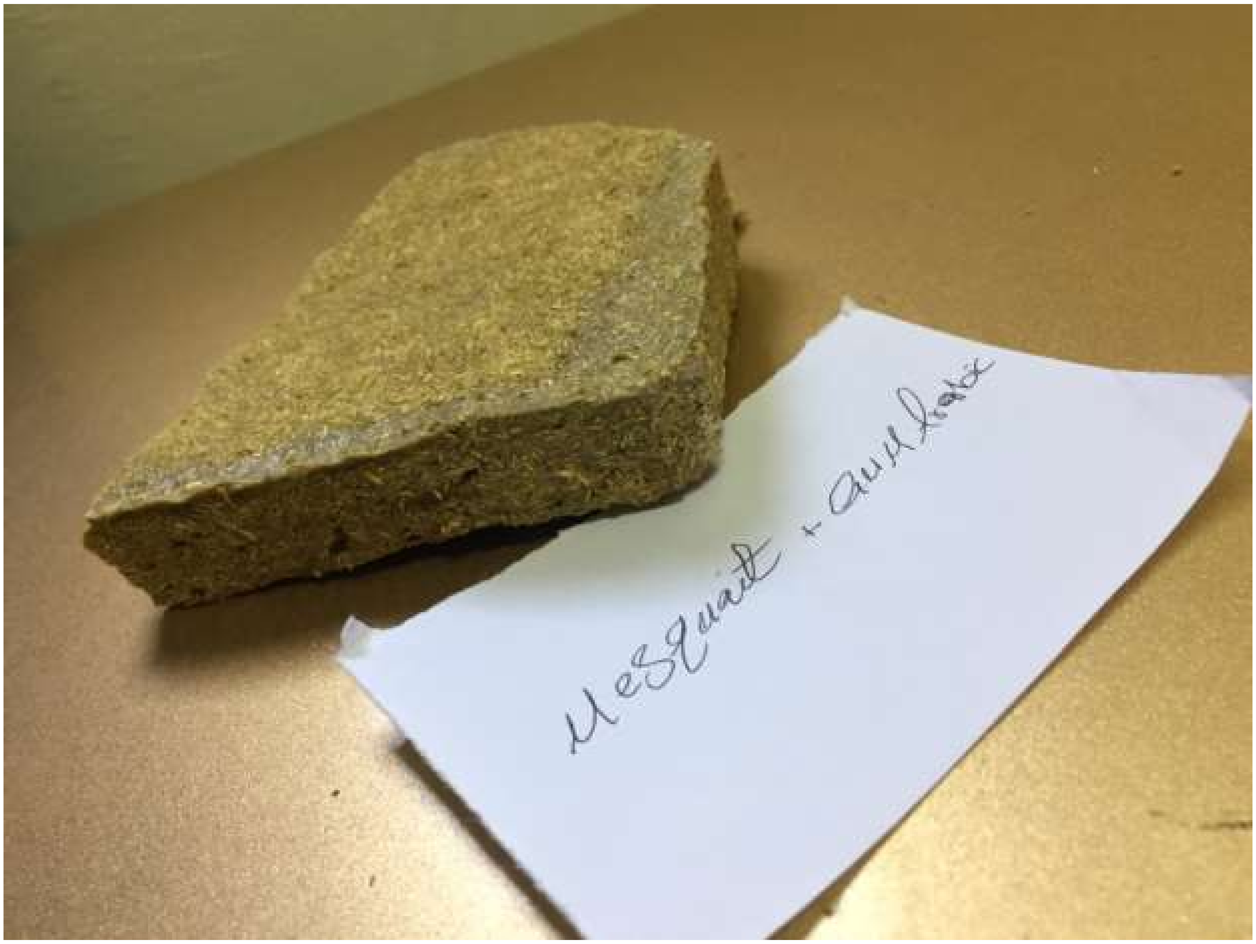

Fig (2.2) Mesquite + Gum Arabic

The Result are shown on table (3.1)

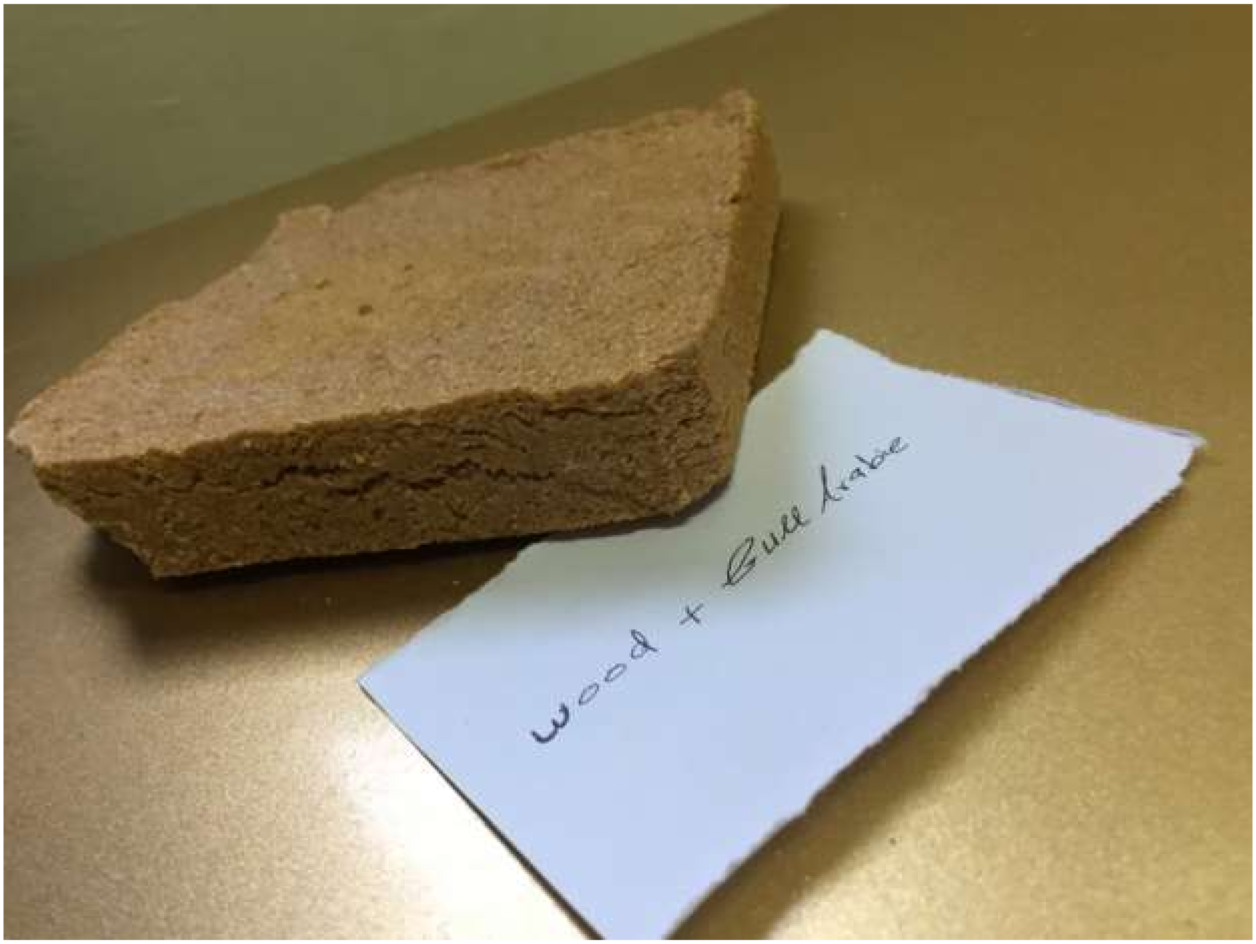

Fig (2.3) Musk Wood + Gum Arabic

The Result are shown on table (3.1)

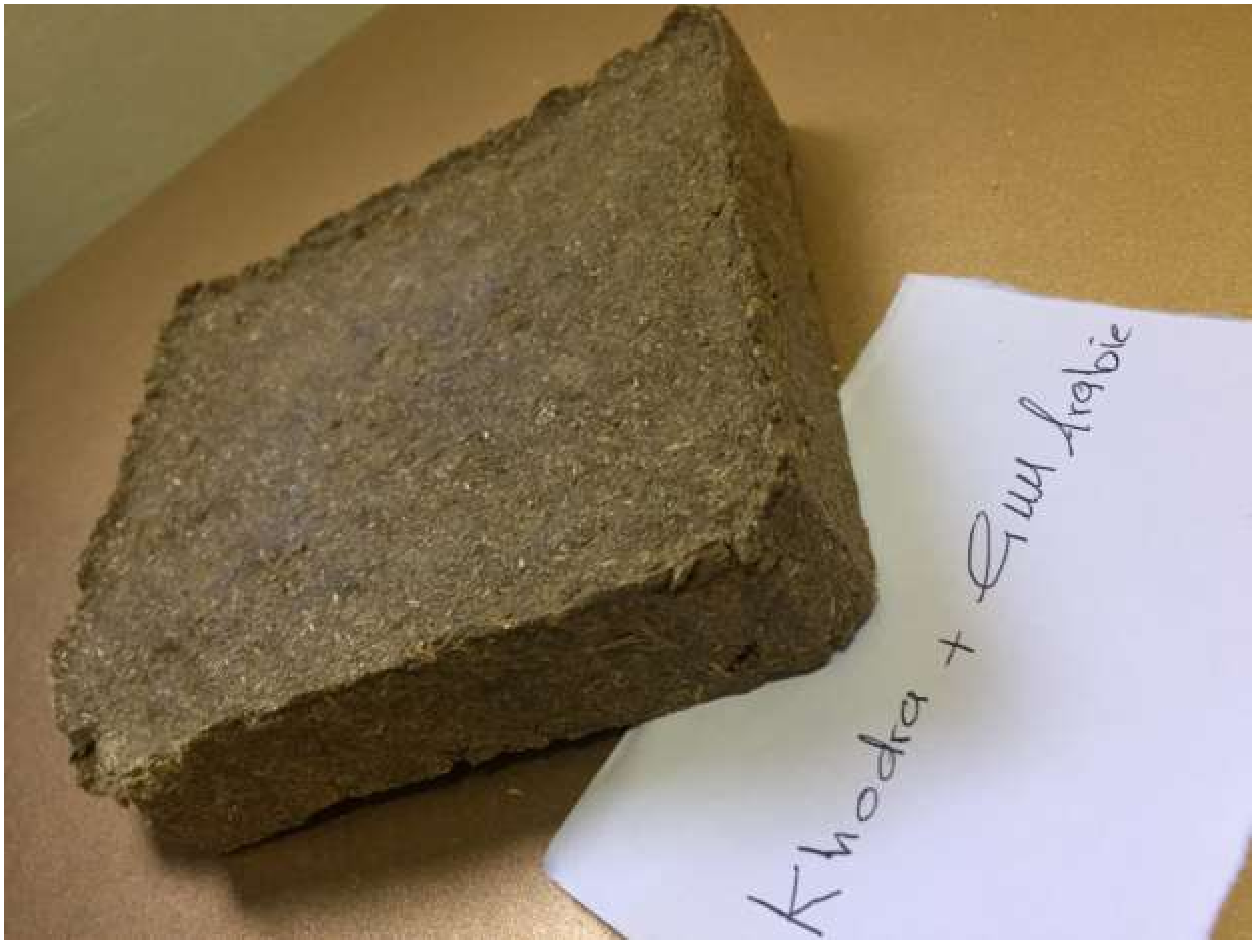

Fig (2.4) Khodra + Gum Arabic

The Result are shown on table (3.1)

Experiment 2:

2.1.2 A mixture of two cellulose samples with Gum Arabic:

200cm^3 beaker fitted with magnetic stirrer to be dissolved then put in 76g of gum Arabic were added to 170cm^3 of water, then transferred to volumetric flask and then the volume was completed to the mark.

200cm^3 of the above solution, then stirred well then 24g of mesquite powder and 24 of khodra powder were added to solution and then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for analysis and the result are shown on table (3.2).

The same experiment (1) was repeated using:

Okra + mesquite

Mesquite + Musk wood

Musk wood + okra

Okra + khodra

Khodra + Musk wood

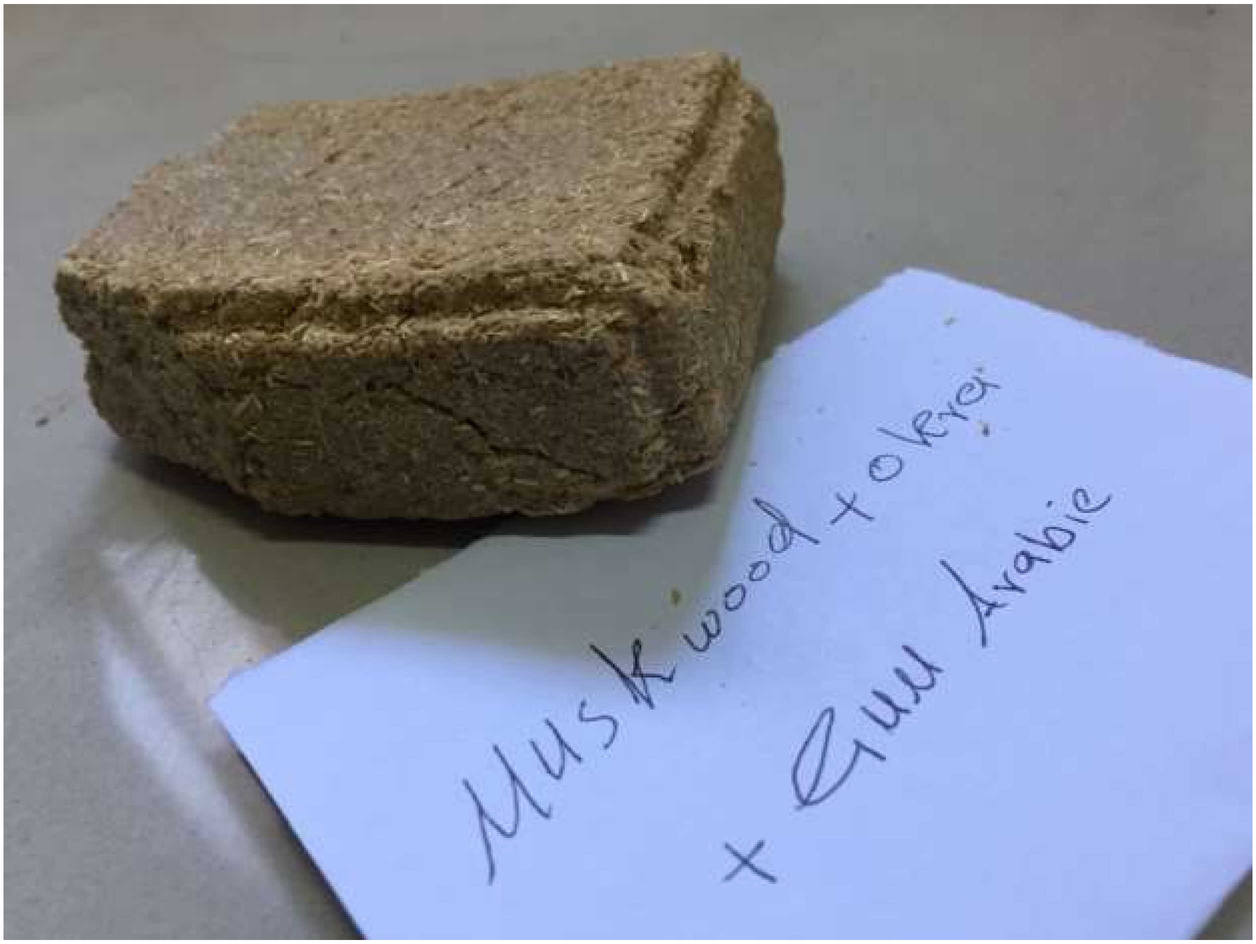

Fig (2.5) Musk wood + Okra + Gum Arabic

The Result on table (3.2).

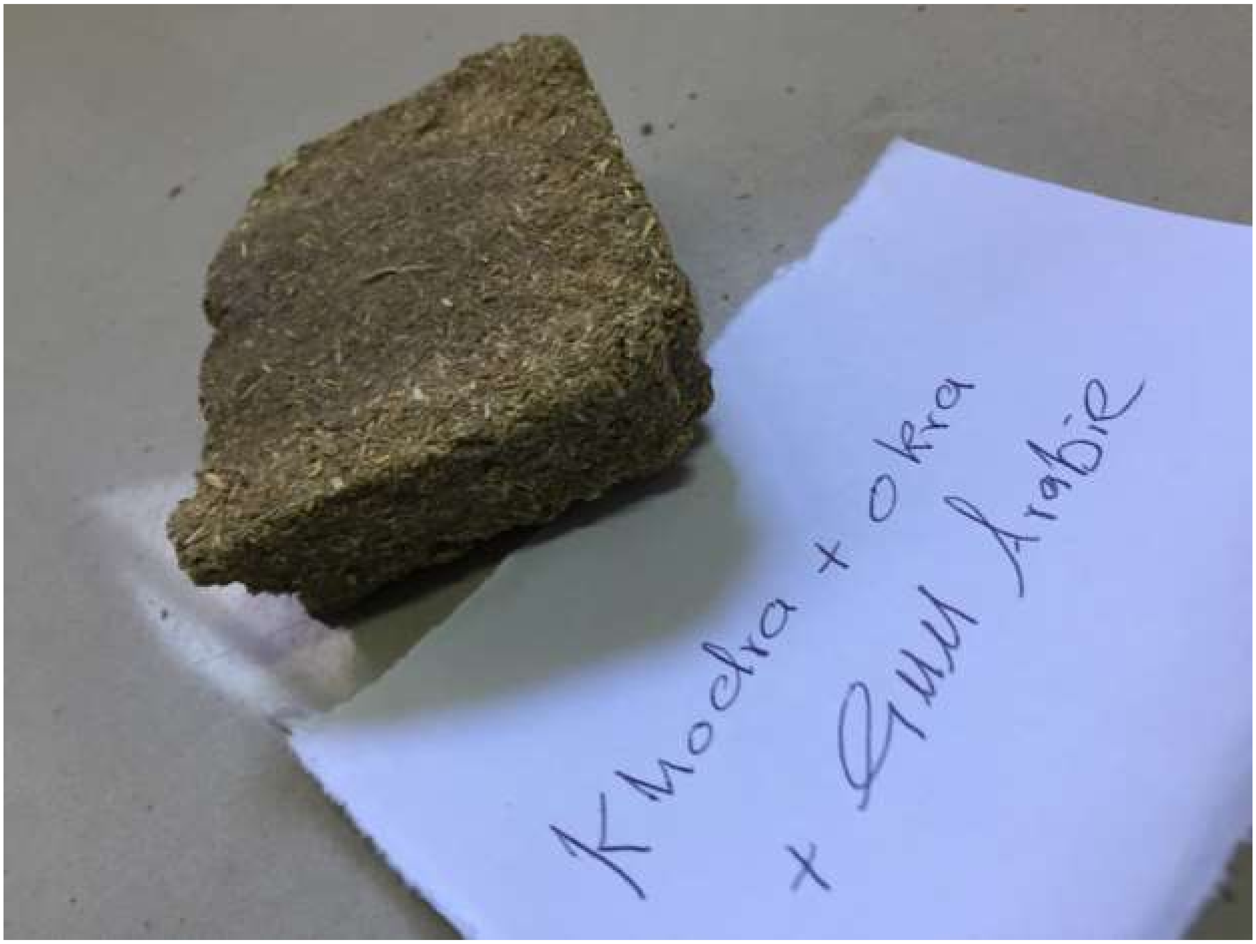

Fig (2.6) Khodra + Okra + Gum Arabic

The Result on table (3.2)

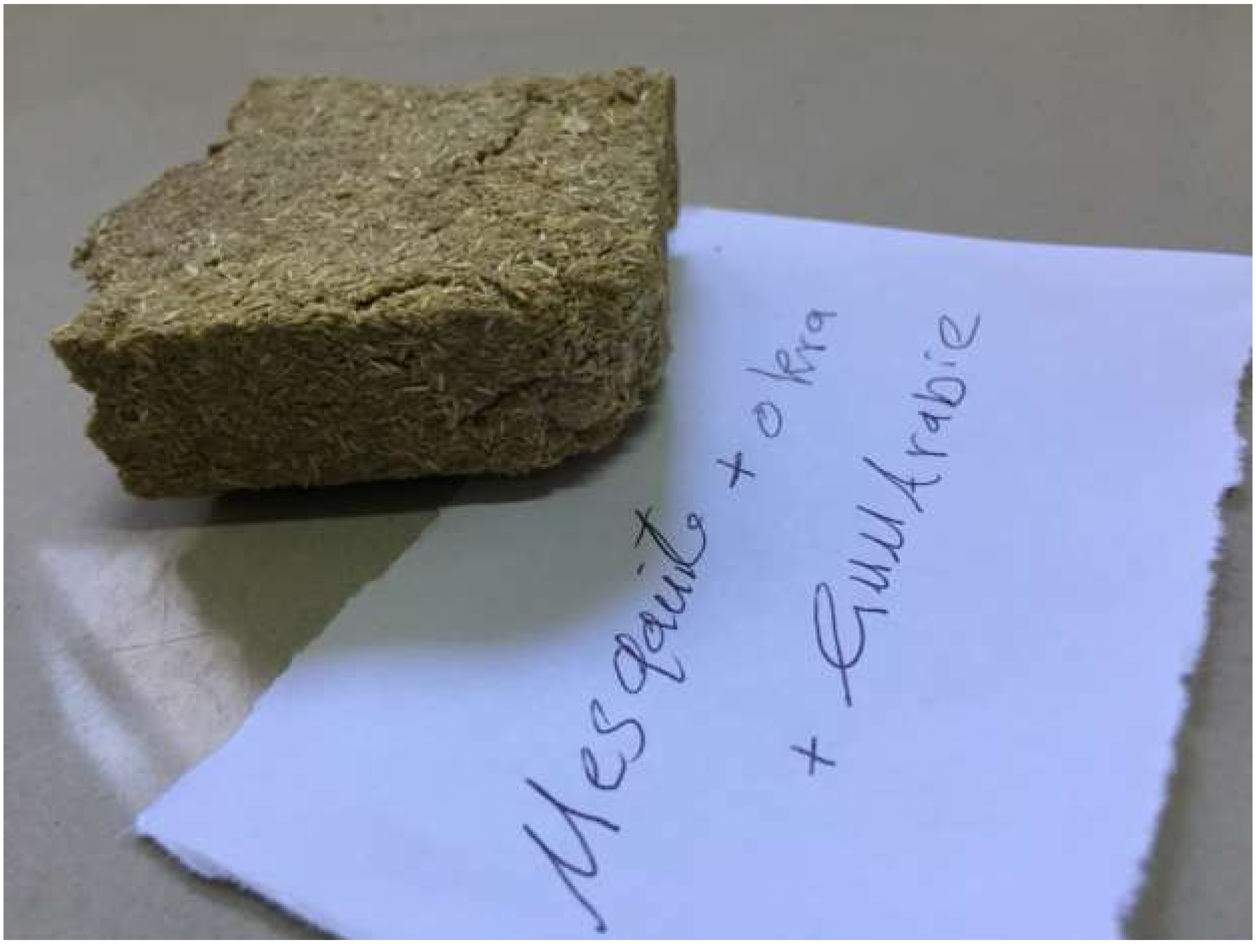

Fig (2.7) Mesquite + Okra + Gum Arabic

The Result on table (3.2)

Fig (2.8) Mesquite + Khodra + Gum Arabic

The Result on table (3.2)

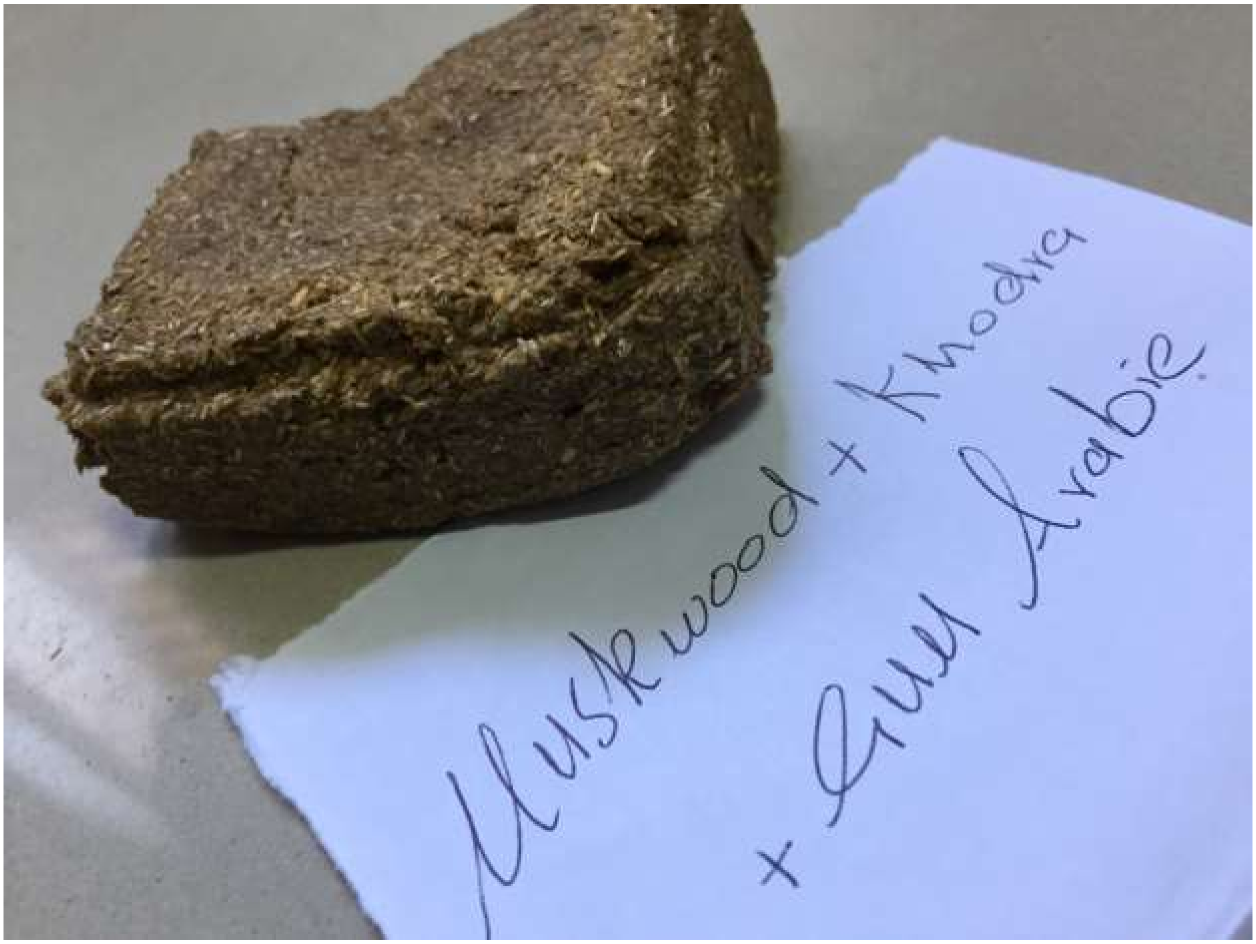

Fig (2.9) Musk wood + Khodra + Gum Arabic

The Result on table (3.2).

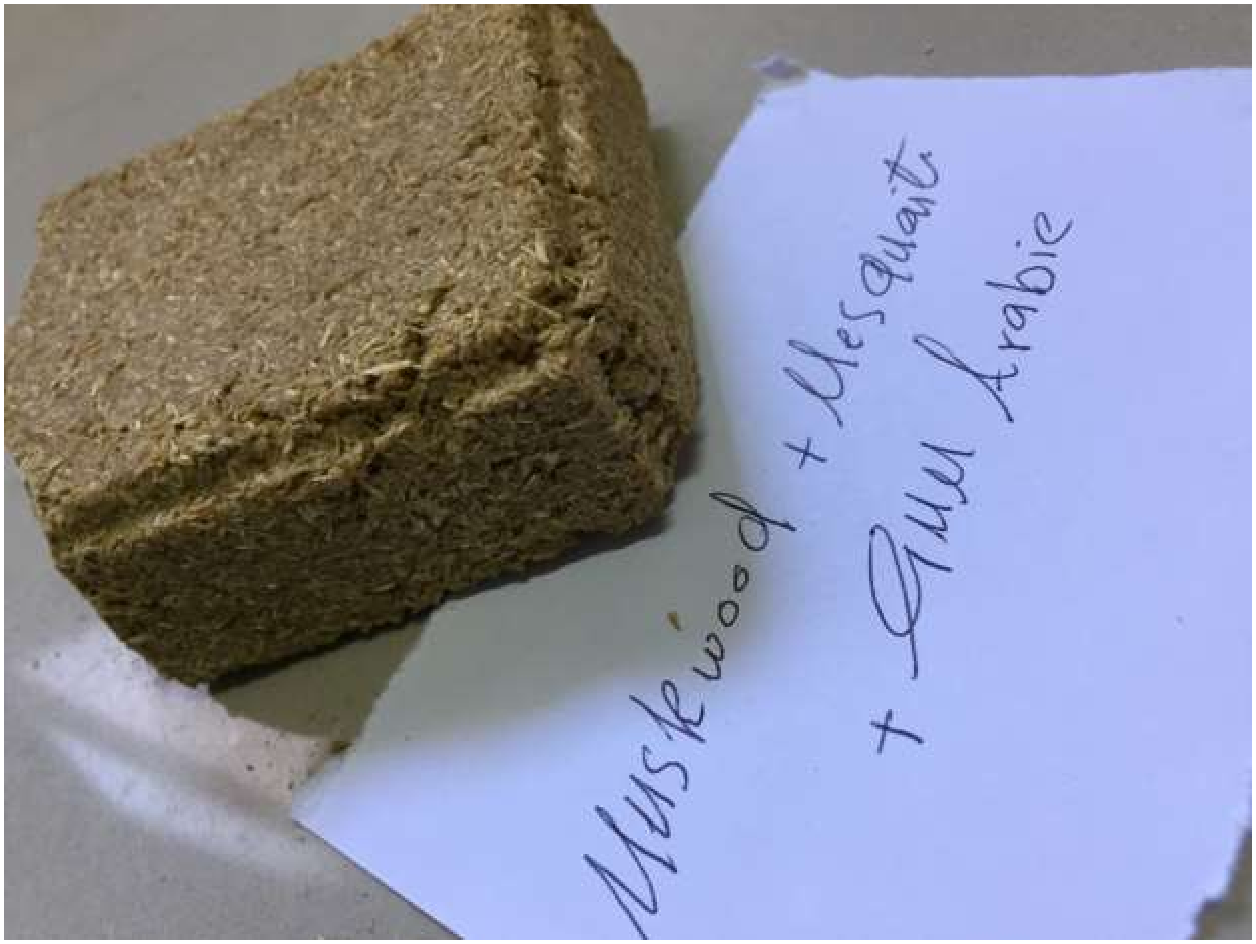

Fig (2.10) Musk wood +Mesquite + Gum Arabic

The Result on table (3.2)

2.2Guar:

Experiment (1):

2.2.1 Mixing Guar with one cellulosic sample:

500 cm^3 beaker fitted with magnetic stirrer and dissolved, 150g of gum guar were added to 300cm^3 of water then transferred to volumetric flask and then the volume was completed to the mark.

500cm^3 of the above solution were added to 143g of okra powder, then stirred well and then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for analysis and the result shown on page 105

The same procedure was repeated using:

Mesquite

Musk

Khodra

Instead of okra

Fig (2.11) Mesquite + Guar

The Result on table (3.3).

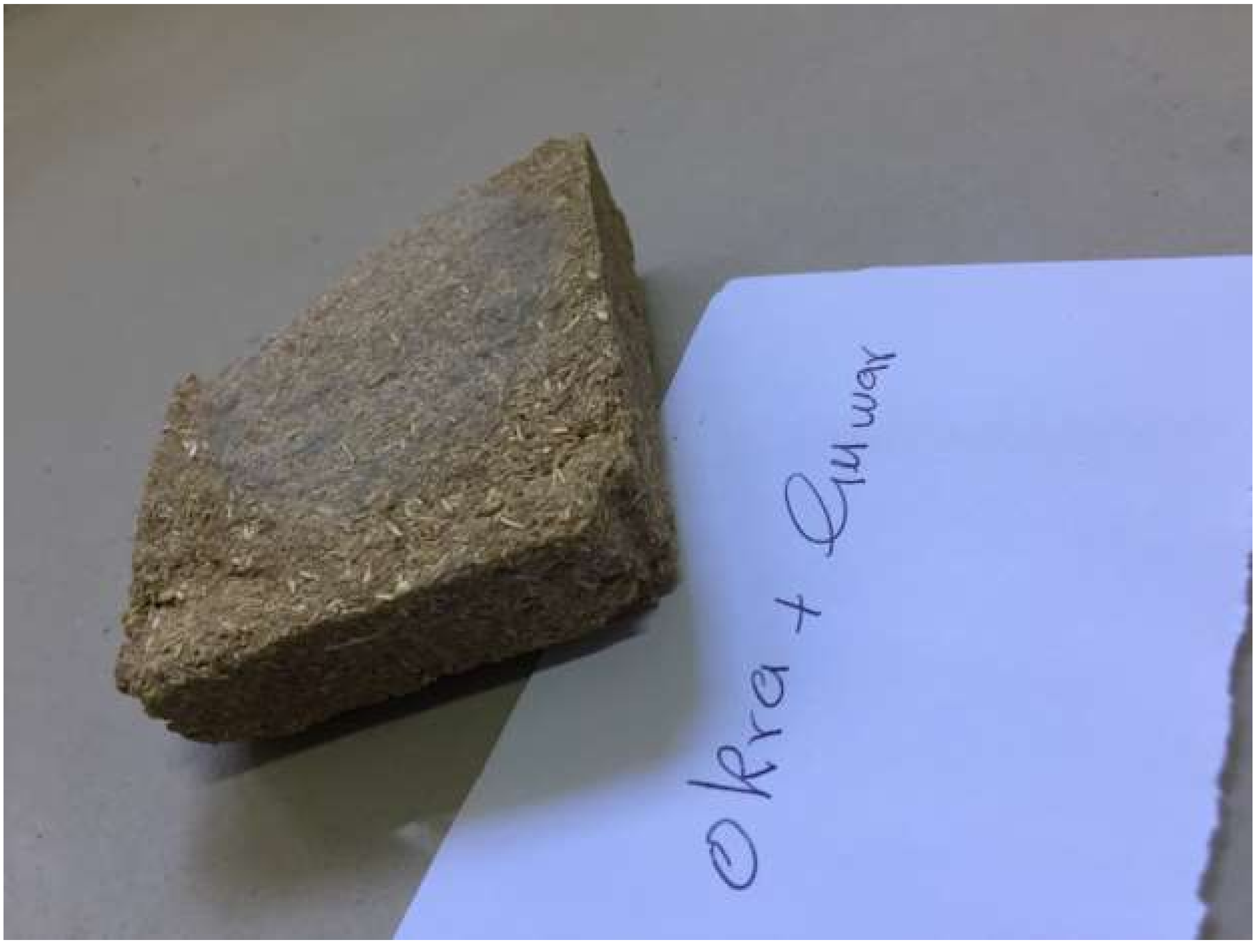

Fig (2.12) Okra + Guar

The Result on table (3.3).

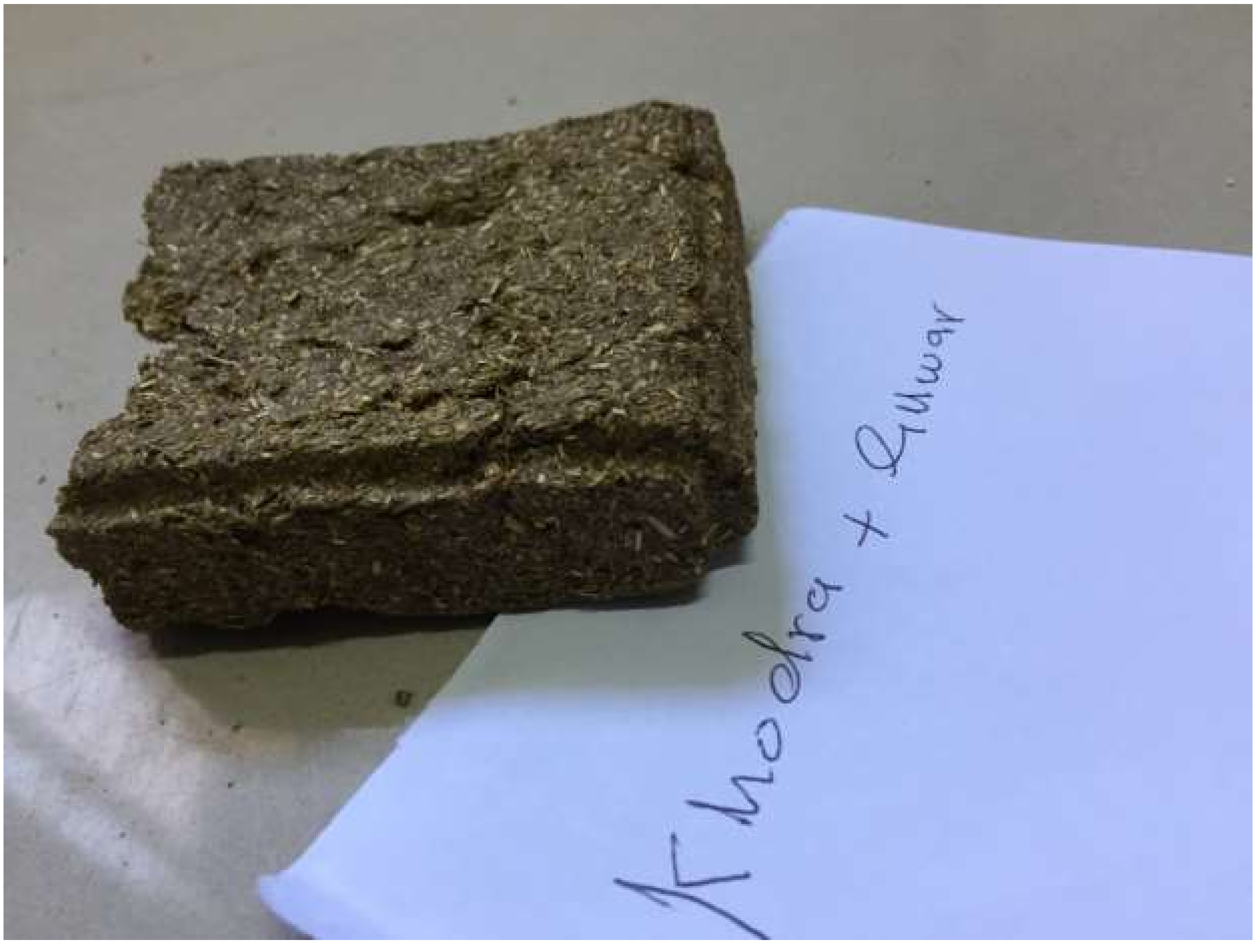

Fig (2.13) Khodra + Guar

The Result on table (3.3).

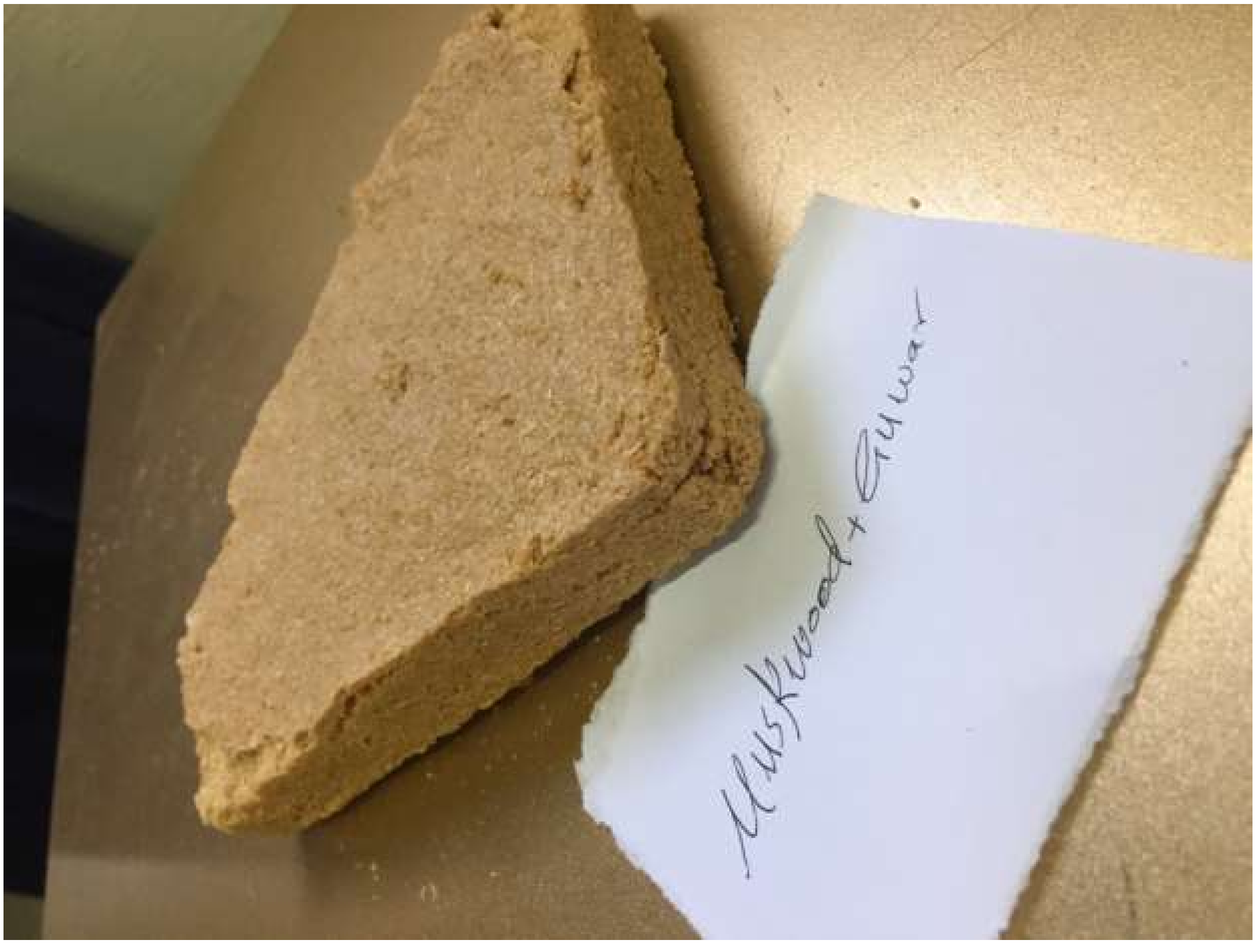

Fig (2.14) Musk wood + Guar

The Result on table (3.3).

Experiment (3):

2.2.2By using a mixing of two cellulosic samples with Guar:

200cm^3 beaker fitted with magnetic stirrer and 76g of guar were added to 170cm^3 of water to be dissolved, then put in then transferred to volumetric flask and then the volume was completed to the mark.

24g of mesquite powder and 24 of khodra powder were added to 200cm^3 of the above solution, then stirred well and then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for physical testing and the results are shown on table (3.5).

The same procedure was repeated using:

Okra + mesquite

Mesquite + Musk wood

Okra + khodra

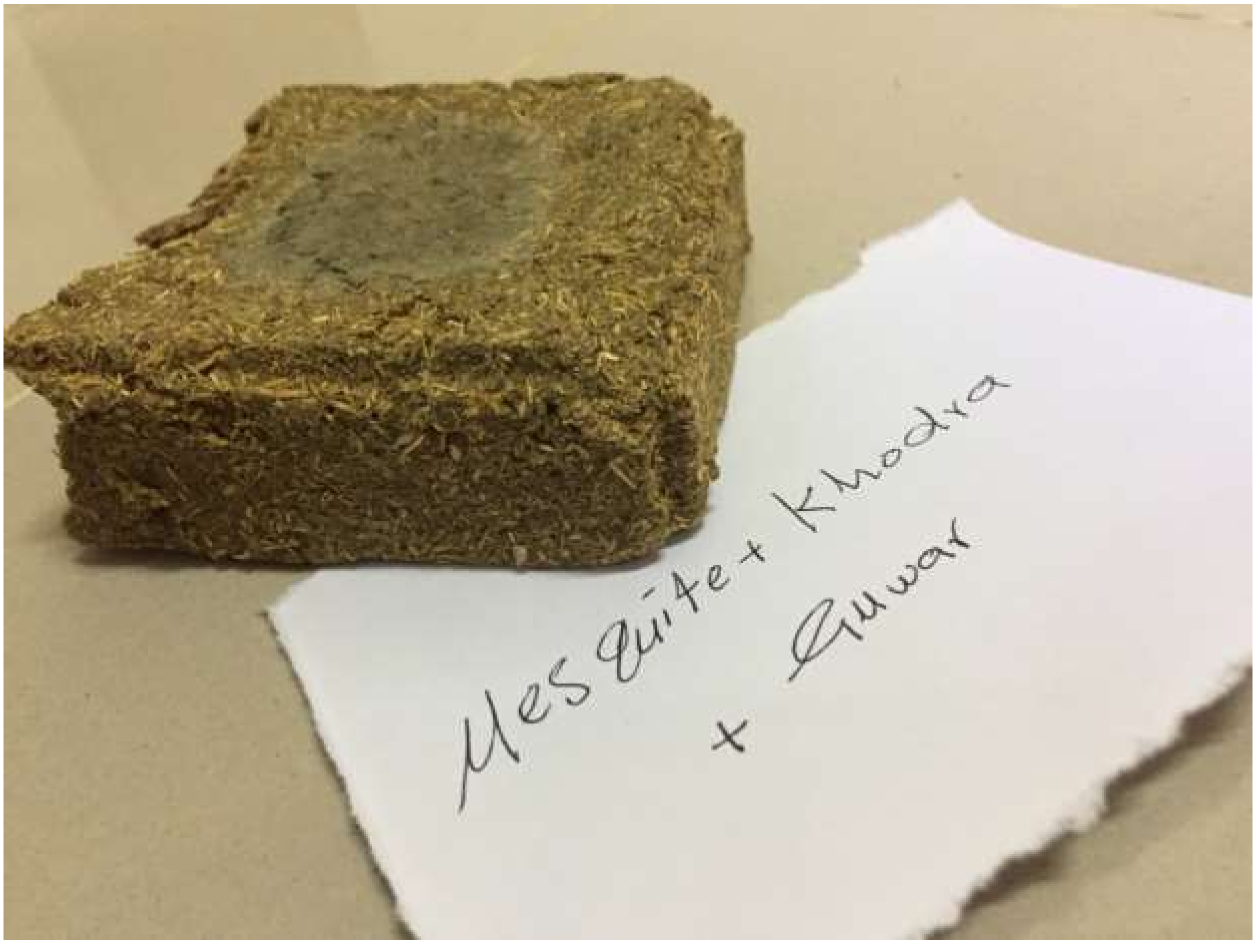

Fig (2.15) Mesquite + Khodra + Guar

The Result on table (3.4).

Fig (2.16) Okra + Khodra + Guar.

The Result on table (3.4).

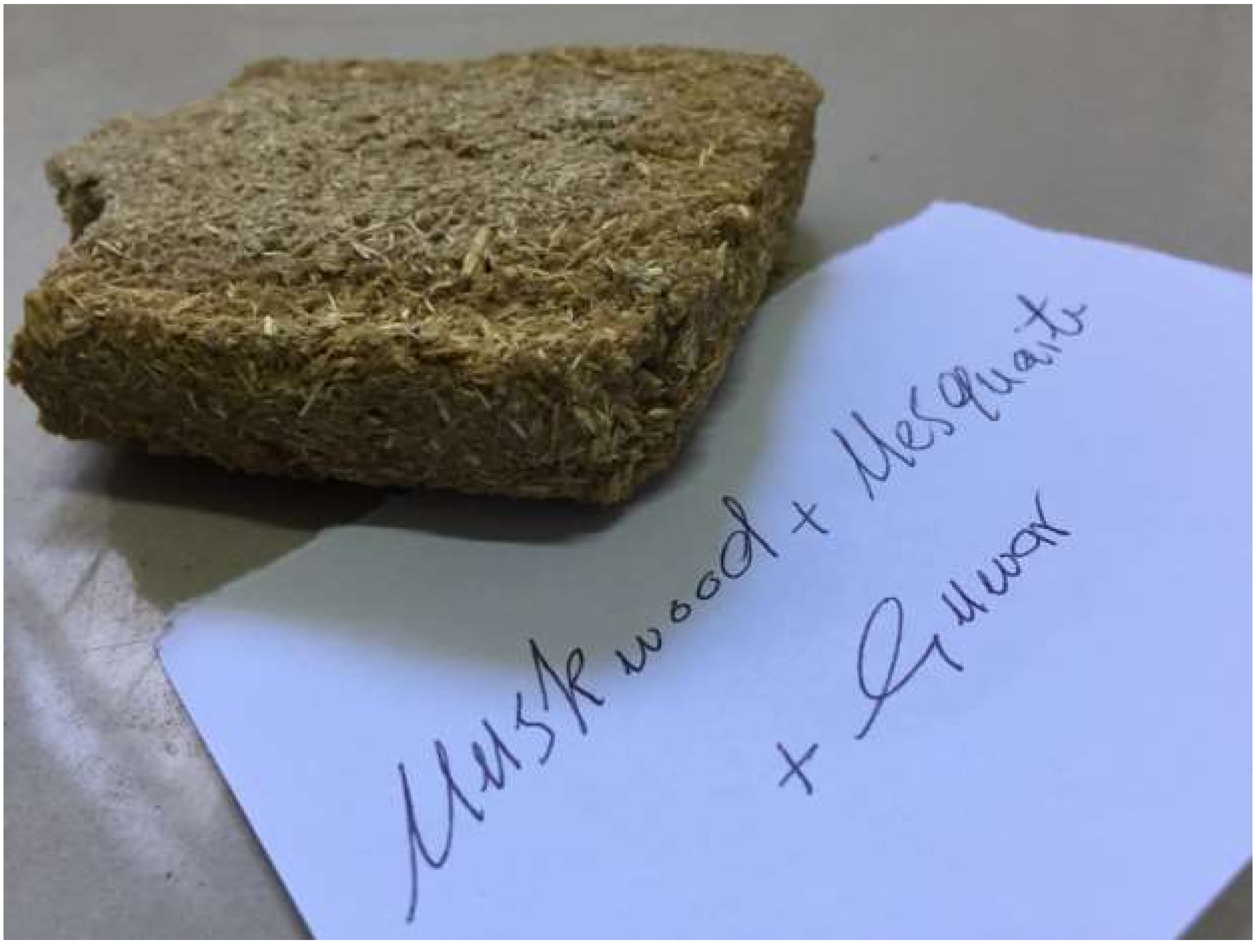

Fig (2.17) Musk wood + Mesquite + Guar.

The Result on table (3.4).

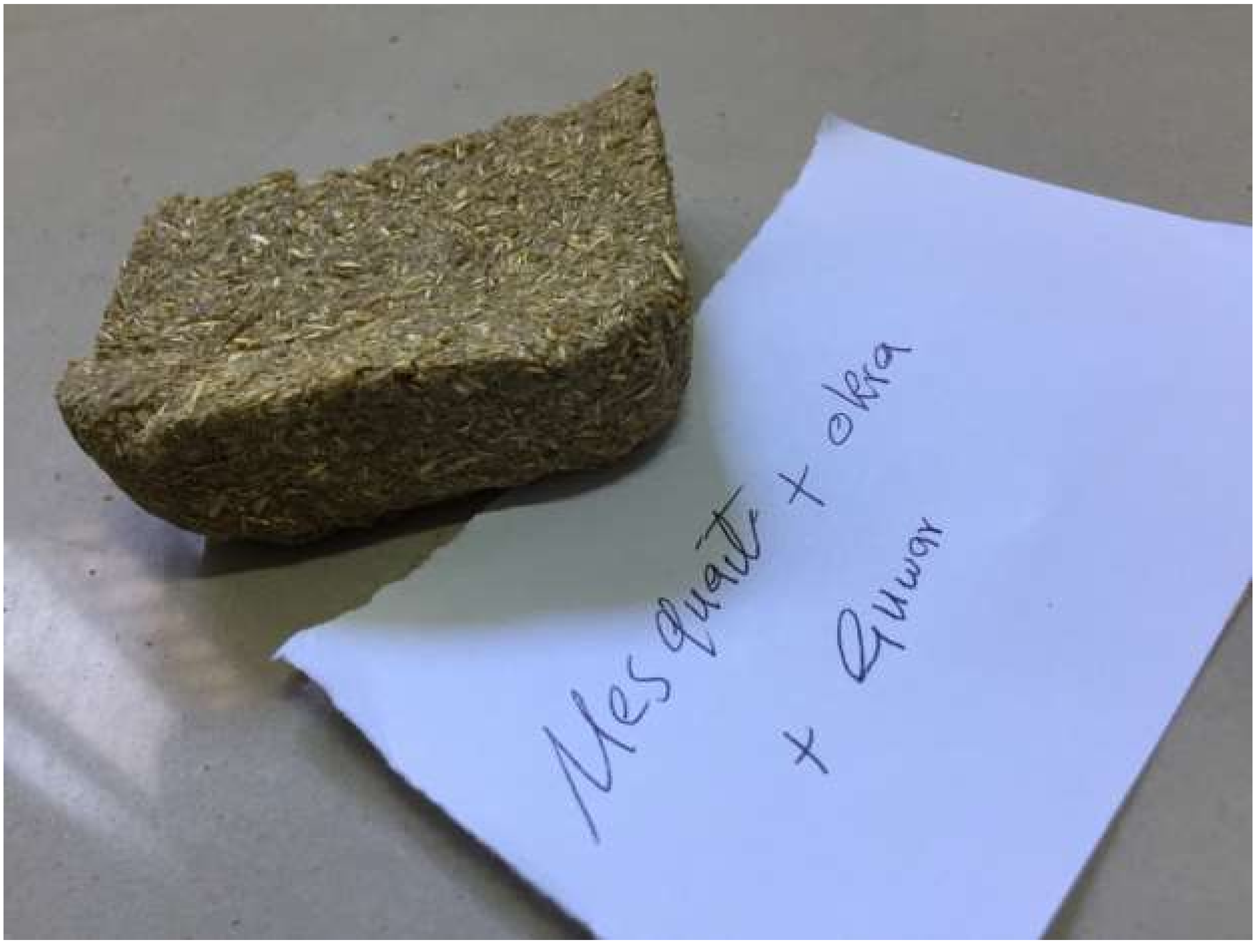

Fig (2.18) Mesquite + Okra + Guar

The Result on table (3.4).

2.3Nocrine:

Experiment (4):

300cm^3 nocrine were added to 143g of musk wood powder, stirred well then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for physical testing and the results are shown on table (3.5).

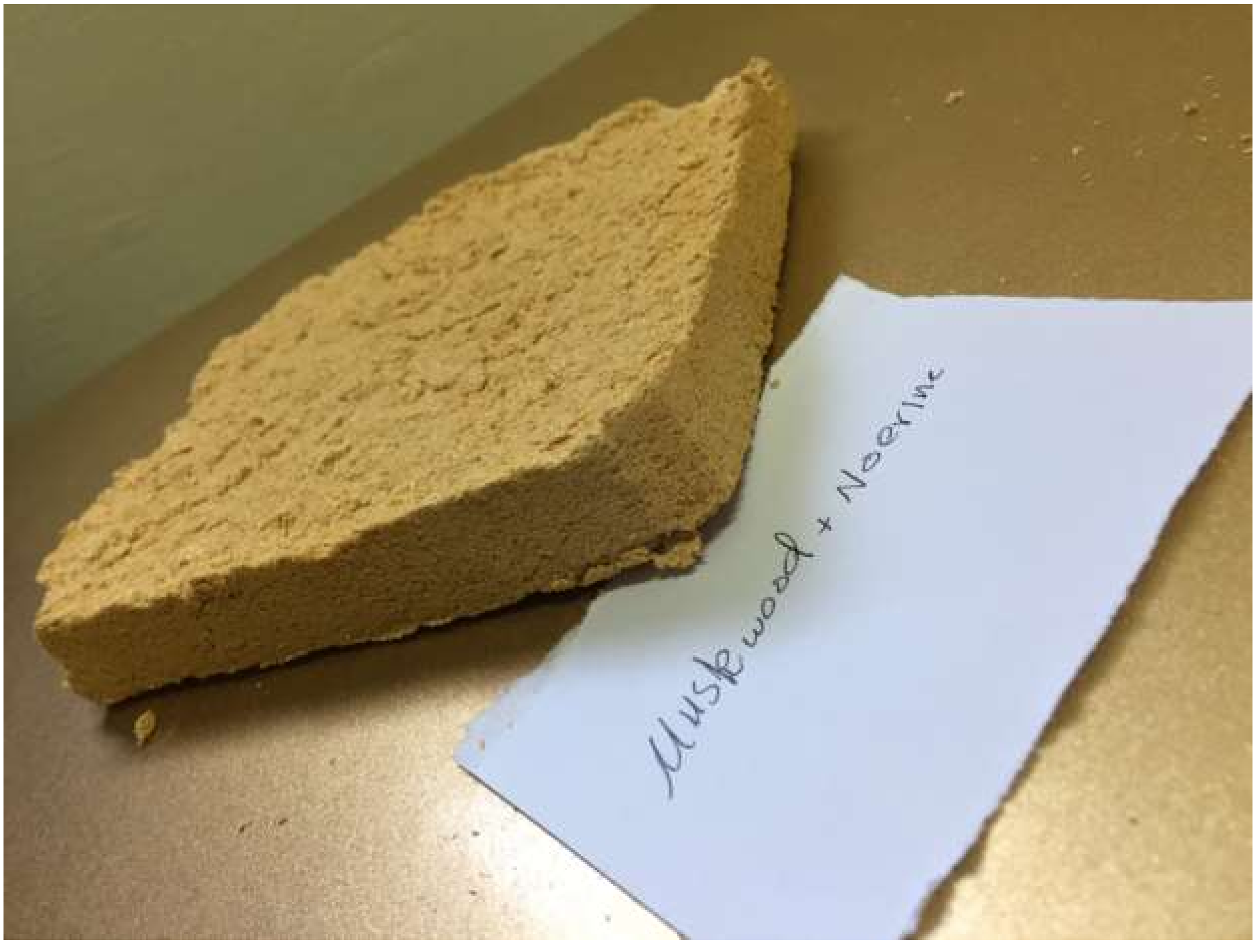

Fig (2.19) Musk wood + Nocrine.

The Result on table (3.5).

2.4Glue (Microne):

Experiment (5):

300cm^3 glue were added to 143g of musk wood powder, stirred well then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for physical testing and the results are shown on table (3.5).

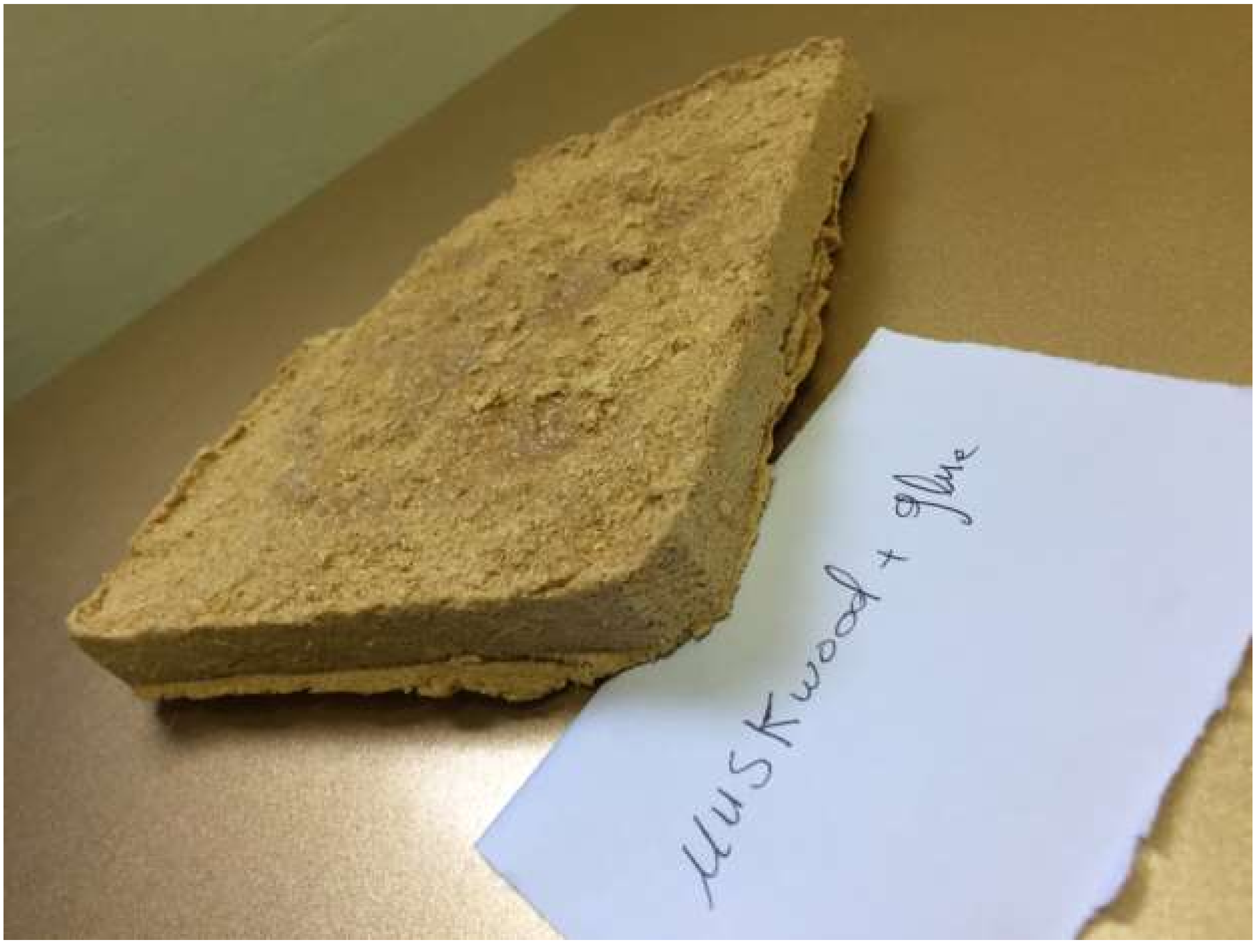

Fig (2.20) Musk wood + Glue.

The Result on table (3.5).

2.5White glue:

Experiment (6):

300cm^3 white glue were added to 143g of okra, then placed and pressed in the mould and, left to dry and kept in a clean stoppered container for physical testing and the results are shown on table (3.5).

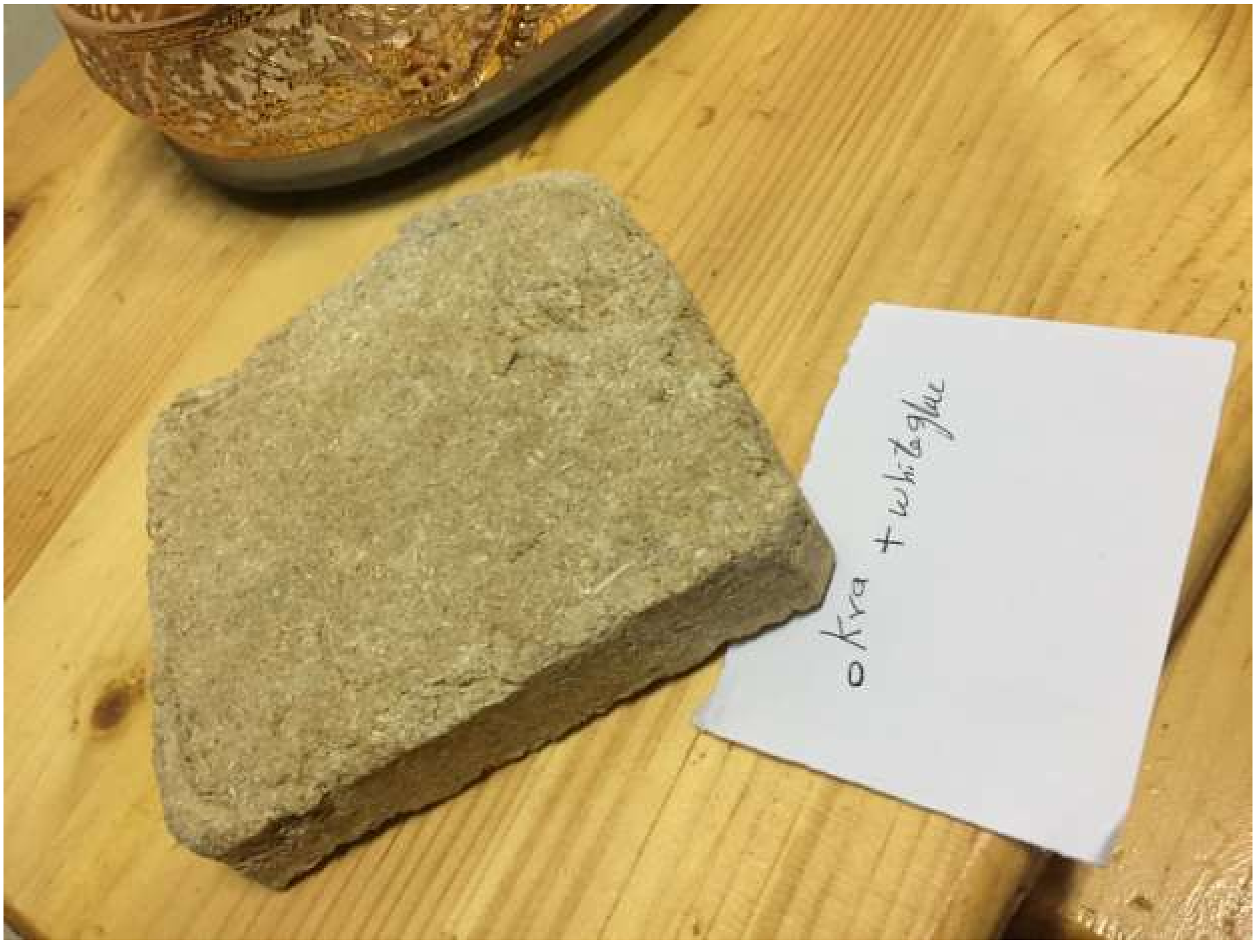

Fig (2.21) Okra + White Glue.

The Result on table (3.5).

Chapter three:

Results and discussion

Measurement operations:

Device used:

Table hardness tester, also retired to as table break force which measures the mechanical integrity of the table

The table hardness used to test the breaking point and structure integrity of table.

Using compression test method:

Used to conduct the test was compression testing.

A cube shape pieces of each samples were taken and put it in the device wich squeezes the table until the breaking point and the breaking force is registered . each samples was tested three times to reach the cohesion results.

The device gives the result in Newton (N).

Device calibration date: 3.6.2017

Cube dimensions: 1 cm x 1cm x 1cm.

Maximum load of the device is 300 N.

Water regain test:

Samples were weighed and then put in the oven for three hours, the weight was taken in different times (3 hours), this method was done for all samples.

The results are shown on table (3.6).

9. Results and discussion:

Result (1) impact test:

Gum Arabic:

Experiment (1):

By using one sample of cellulose with Gum Arabic

Table (3.1)

Samples	1	2	3
Mesquite +Gum Arabic	54.7	54.6	54.9
Musk wood + Gum Arabic	13.9	13.9	13.8
Khodra + Gum Arabic	12.3	14.2	12.5
Okra + Gum Arabic	43.7	20.5	44.6

The mesquite with Gum Arabic gave good adhesion strength of 54.7 N, followed by Okra with Gum Arabic.

Experiment (2):

By using two samples of cellulosic with Gum Arabic

Table (3.2)

Samples	1	2	3
Mesquite + khodra+ Gum Arabic	27.2	25.3	30.3
Mesquite + Okra +Gum Arabic	35.3	42.2	36.7
Musk wood + Okra +Gum Arabic	22.5	25.7	23.4
Mesquite + Musk wood +Gum Arabic	46.5	25.3	43.0
Khodra +Musk wood +Gum Arabic	37.8	20.1	36.7
Khodra + Okra + Gum Arabic	15.6	20	13.2

The Mesquite and musk wood together gave good adhesion strength, followed by khodra and musk wood with Gum Arabic and Mesquite and Okra Adhesion.

Guar:

Experiment (1):

By using one sample:

Table (3.3)

Samples	1	2	3
Khodra + Guar	15.6	14.3	13.1
Okra + Guar	13.8	12.6	13.2
Musk+ Guar	15.1	15.1	15.1
Mesquite+ Guar	24.1	25.3	43.2

Here Mesquite and Guar Gums showed adhesion strength better than others. But generally of lower strength than Gum Arabic.

Experiment (2):

By using two samples:

Table (3.4)

Samples	1	2	3
Mesquite +okra +Guar	21.3	18.7	19.2
Musk wood + mesquite +Guar	32.3	17.8	34.4
Okra+ Khodra +Guar	17.3	2.5	19.8
Mesquite +Khodra +Guar	23.4	24.2	27.5

For combination of two cellulosic materials is better than one cellulosic material.

Other results:

Table (3.5)

Samples	1	2	3
Okra + white Glue	35.4	24.3	35.6
Musk wood +glue	35.8	36.7	35.3
Musk wood + Nocrine	33.6	33.7	33.4
Okra +glue	14.1	14.7	13.1

Cellulosic with glues and Nocrine gave good adhesion strength except Okra and Glue showed less strength.

Water Absorption Results:

Table (3.6): The Absorption of water by one sample:

samples	Weight/g	hour	2 hours	3 hours
Musk + Gum Arabic	6.2	7.3	8.1	8.1
Musk + nocrine	7.1	9.2	10.2	11.4
Okra + Gum Arabic	8	9.7	12.9	12.1
Mesquite + guar	11.3	19.2	16.6	9.6
Mesquite + Gum Arabic	17.4	29.2	30.4	30.9
Musk + glue	9.2	10	11.9	12.4
Musk + nocrine + acetone	3.4	5.2	7.9	8.9
Musk + guar	13.3	18.9	20.03	20.7
Okra + white glue	5.2	10.1	12.4	12.5
Khodra + Gum Arabic	2.1	4.6	5.6	5.6

Mesquite and Gum Arabic presented high water absorption followed by musk wood and Guar that presented the Gum absorption of water since contain sugars and carbohydrates in more amounts.

Table (3.7)

The absorption of water by different formulations.

Samples	Weight/g	hour	2hours	3hours
Musk +okra +Gum Arabic	11.3	16.4	24.2	24.1
Mesquite +musk +Gum Arabic	4.9	5.6	5.00	4.2
Khodra +musk +Gum Arabic	10.8	14.6	22.2	22.8
Khodra +okra +Gum Arabic	20	18.6	29.1	30.1
Mesquite + khodra+ Arabic gum	14.4	22.6	24.06	24.08
Mesquite +okra +Gum Arabic	5.2	8.7	8.5	6.9
Musk +mesquite +guar	5.9	9.05	7.4	4.9

Table (3.8)

The absorption of water by cellulosic and Guar:

samples	Weight/g	hour	2hours	3hours
Okra + guar	7.4	28.7	28.6	18.2
Khodra +guar	5.9	22.6	26.9	29.3
Okra + khodra +guar	6.2	25.5	27.9	20.9
Mesquite +khodra +guar	6.8	18.3	15.3	13.9
Musk +mesquite +guar	5.9	9.05	7.4	4.9
Mesquite +okra +guar	10.3	15.4	17.4	21.7

Okra and Guar, khodra and Guar , also the combination of Okra , khodra and Guar gave high absorption to water after the first hour due to opening of pores by time.

10. Discussion:

Adhesives:

The adhesion strength were measured for the prepared cubes and the Gum Arabic was found to have high adhesion strength , Guar was second followed by Glue , Nocrine , and with Glue white found to have the lowest adhesion strength.

Gum Arabic:

Gum Arabic is truly soluble in cold water, other gums are either insoluble in cold water or form colloidal suspension, it gave a high viscosity, colorless (top quality) , it dried quickly and gave good result among all samples.

Guar:

Guar has a good solubility in water but Gum Arabic was better than it because the viscosity was higher. It dried quickly and gave good result from some samples.

Glue:

Glue is insoluble in water and acetone, it has high solubility on the musk wood but its low with okra, it dried after 30 minutes.

Nocrine:

Nocrine is insoluble in water and globular with acetone, it was so good with one sample and gave high solubility than musk wood but it gave low solubility than other samples.

Impact test:

Mesquite:

When mesquite was used only:

Mesquite gets along with water it can searched it for thousand meters , it attempt to develop forests in desert , it's stable plant when we added it to adhesives , it gave very high readability Mesquite by Gum Arabic have a good result(54.9 N).Then mesquite by Guar(43.2 N) that's means mesquite is the best plant it has a strong strength and all readability's was high , so can be used it in a furniture (tables , doors , windows , partitions , beds .. etc) .

From Table (2.3), (4.3):

The descending adhesion strength will be as follows:

When used mesquite and:

Musk wood by Gum Arabic (46.5N), By Guar (34.4N).

Okra by Gum Arabic (42.2N) , By Guar (21.3N).

Khodra by Gum Arabic (30.3N) , By Guar (27.5N).

I realize the best result is Mesquite + musk wood by Gum Arabic(46.5N) then Mesquite + okra by Gum Arabic(42.2N) , Mesquite + Musk wood by Guar(34.4N) , Mesquite + Khodra by Gum Arabic (30.3N) , Khodra by Guar (27.5N) , and Mesquite + Okra by Guar (21.3N). From table (3.1) (3.2) (3.4) Mesquite is strong plant it supports the other plants with it, the good adhesion was observed with Gum Arabic (it gave very high readability on impact test).

From table (3.1), (3.2), (3.3), (3.4), (3.5).

The governments, associations and international organization all are agreed that mesquite is harmful because its roots is parasitic to all plants near to it searching for water , and that leads to screw in all ground of agriculture , mesquite can be good for other uses and good result , mesquite is:

1. Strong.
2. Absorbs water slowly.
3. Good with any adhesives, especially Gum Arabic.

Musk wood:

The result of musk by glue is (36.7N) and Musk by nocrine (33.7N) also that means musk wood is good but the different is on adhesives the glue is best more than nocrine .

The result of musk by guar (14.7N) and musk + gum Arabic (13.9N) the best adhesive of musk is guar.

We all know that the uses of musk wood are mainly with furniture.

Okra:

All Sudanese use the product of leaves and discard down the remainder, but here used the stem of okra as working sample:

When okra only was used:

The result of okra by Gum Arabic (44.6N), by Guar (13.8N) , glue (14.7N) , by white glue (35.6N) then realized okra is good plant with Gum Arabic , white glue was good to some extent with Guar and Glue it has other uses.

When okra was used with:

Musk wood by gum Arabic (25.7N).

Khodra by Guar (19.8N).

Okra with musk wood by Gum Arabic is best from khodra by Guar.

Khodra :

Kohdra like okra also All Sudanese use leaves and cast down remainder.

When used only:

Khodra by Gum Arabic (14.2N) and by Guar (15.6N) then realized that Guar is best adhesive more than Gum Arabic.

When it was used by:

Musk wood by Gum Arabic (13.9N)

When used khodra and Musk wood is best more than khodra only by guar and Gum Arabic.

Absorption test:

Mesquite Only:

By Guar the weight is (11.3g), after hour (19.2g), after 2 hours (16.6g) and then 3 hours (9.6g) it was absorbed that see how the weight is decrease.

By Gum Arabic the weight was (17.4g), after hour (29.2g), after 2 hours (30.4) and then 3 hours (30.9g) then noticed how the weight is decrease that mean the samples is full of water and saving its mould.

Mesquite with two cellulosic materials:

Musk wood the weight is (4.9g) , after hour (5.6g) , after 2 hours (5g) and then 3 hours (4.2g) there is no different on all times and samples saving it's mould so that's is very good because there is no absorption.

Khodra by Gum Arabic the weight is (14.4g), after hour (22.6g), after 2 hours (24.06g) and then 3 hours (24.08g) we see how the weight is decrease.

Okra by Gum Arabic the weight is (5.2g), after hour (8.7g), after 2 hours (8.5g) and then 3 hours (6.9g) how the weight is decrease.

Musk wood by Guar the weight is (5.9g), after hour (9.05g), after 2 hours (7.4g) and then 3 hours (4.9g) we see how the weight is decrease.

Okra by Guar the weight is (10.3g), after hour (15.4g), after 2 hours (17.4g) and then 3 hours (21.7g) we see how the sample is swelling by water.

Musk wood:

When Musk wood only was used:

All samples absorption are increased by time.

By Gum Arabic the weight is (6.2g), after hour (7.3g), after 2 hours (8.1g) and then 3 hours (8.1g) we see how the sample is swelling by water.

By Guar the weight is (13.3g), after hour (18.9g), after 2 hours (20.03g) and then 3 hours (20.7g) we see how the sample is swelling by water.

By nocrine the weight is (7.1g), after hour (2.1g) , after 3 hours (4.3g) we see how the sample is swelling by water .

By glue the weight is (9.2g), after hour (0.8g) , after 3 hours (3.2g) we see how the sample is swelling by water .

By nocrine +acetone the weight is (3.4g), after hour (5.2g) , after 2 hours (7.9g) and then 3 hours (8.9g) we see how the sample is swelling by water .

When Musk wood was used with:

Okra by Gum Arabic the weight is (11.3g) , after hour the moisture and increased to (16.4g) , after 2 hours (24.2g) and then 3 hours (24.1g) we see how the sample is swelling by water .

Khodra by Gum Arabic the weight is (10.8g), after one hour the moisture increased (14.6g) , after 2 hours (22.2g) and then 3 hours (22.8g) we see how the sample is swelling by water .

When Khodra was used with different adhesives:

Gum Arabic the weight is (2.1g), after hour (4.6g) , after 2 hours (5.6g) and then 3 hours (5.6g) we see how the weight is decrease .

Khodra when used with:

Okra by Gum Arabic the weight is (20g), after hour (18.6g) , after 2 hours (29.1g) and then 3 hours (30.1g) we see how the Wight is decrease .

Okra:

Gum Arabic the weight is (8g) , after hour (9.7g), after 2 hours (12.9g) and then 3 hours (12.1g) we see how the sample is swelling by water.

Guar the weight is (7.4g), after hour (28.7g), after 2 hours (28.6) and then 3 hours (18.2g) we see how the Wight is decrease.

White glue Arabic the weight is (5.2g), after hour (10.1g) , after 2 hours (12.4g) and then 3 hours (12.5g) we see how the sample is swelling by water .

11. Conclusion:

The best sample is Mesquite and the best adhesives is Gum Arabic.

The Results obtained were as follows:

Mesquite + gum Arabic =54.9 N, (N for Newton)

Mesquite + Guar =43.2 N

Mesquite +Musk wood by Gum Arabic = 43.00 N

Okra + Gum Arabic =44.6 N

Mesquite +Okra by Gum Arabic = 42.2 N

For humidity and moisture contents the follow result were obtained:

Okra +Gum Arabic:

Gum Arabic the Wight was (8g) , after hour gave (9.7g), after two hours (12.9g) then after 3 hours (12.1g) how the sample was swelling by water.

Mesquite +Gum Arabic:

Gum Arabic the weight of (17.4g), after an hour gave (29.2g), after 2 hours (30.4g) then after 3 hours (30.9g) were obtained the weight was decreased that mean the samples contained water.

Mesquite +Musk wood and Gum Arabic:

(4.9g) of Gum Arabic, after an hour it gave (4.9g), after 2 hours gave (5g) then after 3 hours gave (4.2g).

Mesquite +Okra and Gum Arabic:

Okra by Gum Arabic the original weight was (5.2g), then after an hour gave (5.3g), after 2 hours (8.7g) then after 3 hours (6.9g) as increased by water absorption.

Mesquite + Guar:

Weight was (11.3g), and then after one hour gave (19.2g), after 2 hours (16.6g) then after 3 hours (9.6g) it gave moisture content that means the sample was disintegrated by water

12. Recommendations:

The okra, khodra, mesquite, musk wood as cellulosics of different types of natural materials they respond to many kinds of adhesives.

For future research, one recommends to investigate many plants of cellulosic like sugarcane, cotton,   grain, for different uses.

13. Reference:

1. Reiter W,D;(2002) Biosynthesis and properties of the plant cell wall. Curr Opin Plant Biol.

5(6),536–42.

2. Zhang J,Q, et al (2008),Advance,6,109-14. of studies on structure and decrystallization of cellulose. Chem Ind For Prod.(6),109-14

3. Yang S, H (2008) Plant fiber chemistry. Beijing: China Light Industry Press;

4. Zhan HY ;(2005) Fiber chemistry and physics. Beijing: Science Press.

5. Gao J, Tang LG ;(1996) Cellulose science. Beijing: Science Press.

6. Tai FJ and (Li XB);(2004). Cellulose biosynthesis in plant and the enzymes involved in it. Chin J Cell Biol;26(5),490–4.

7. Mueller SC;(1976). Cellulosic microfibrils: nascent stages of synthesis in a

higher plant cell. Science. 194(4268),949–51.

9. Arioli T, etal (1998) Wittke W, Herth W, Camilleri C, Höfte H, Plazinski J, Birch R. Molecular analysis of cellulose biosynthesis in Arabidopsis. Science.279(5351),717–20.

10. Wang YJ. (2005) Callose in plants. Bull Biol. 40(1),18–9.

11. Zhong R,(2001). Fibers. A model for studying cell differentiation, cell elongation, and cell wall biosynthesis. Plant Physiol. 126(2),477–9.

12. Kimura S, (2002). Recent progress in cellulose biosynthesis. J Plant Res.(115),297–302.

13. Bian HY, Zhou ZG,(2004). Biological synthesis of cellulose during cotton fiber thickening process. Cotton Sci.16(6),374–8.

14. Schrick K, Fujioka etal (2004) A link between sterol biosynthesis, the cell wall, and cellulose in Arabidopsis. Plant J.38(2),227–43.

15. Pear JR, etal (1996), Delmer DP, Stalker DM. Higher plants contain

homologs of the bacterial celA genes encoding the catalytic subunit of cellulose synthase.

Proc Natl Acad Sci U S A. 93(22),12637–42.

16. Jiang TD.(2001), Lignin. Beijing: Chemical Industry Press.

17. Lv WJ, etal (2010)Lignin distribution in wood cell wall and its testing methods. J Beijing Univ ;32(1),136–41.

18. Qiu WH and Chen HZ(2006). Structure, function and higher value application of lignin. J Cellul Sci Technol.; 14(1),52–9.

20. Tao YZ and Guan YT(2003). Study of chemical composition of lignin and its application. J Cellul Sci. Technol;11(1),42–55

19. Li W, Xiong J(2003). Advances in the research of physiological significances and genetic regulation of lignin metabolism. Acta Bot Boreali-Occidentalia Sin;23(4),675–81.

21. Hickey, M.; King, C. (2001). The Cambridge Illustrated Glossary of Botanical Terms. Cambridge University Press.

22. "Global Forest Resources Assessment 2005/Food and Agriculture Organization of the United Nations" (PDF).

23. Horst H. Nimz, et al 2005, Encyclopedia of Industrial Chemistry Wiley-VCH, Weinheim. doi:10.1002/14356007.a28_305

24."N.B. (2011) , fossils show origins of wood". CBC.ca. August 12,. Retrieved August 12, 2011.

25. Philippe Gerrienne; et al. (Aug 12, 2011). "A Simple Type of Wood in Two Early Devonian Plants". Science. doi:10.1126/science.1208882.

26. Woods, Sarah 2017,"A History of Wood from the Stone Age to the 21st Century". EcoBUILDING. A Publication of The American Institute of Architects. Retrieved March 28.

27. Briffa, K.; Shishov, (2008), V.V.; Melvin, T.M.; Vaganov, E.A.; Grudd, H.; Hantemirov "Trends in recent temperature and radial tree growth spanning 2000 years across northwest Eurasia". Philosophical Transactions of the Royal Society B: Biological Sciences. 363 (1501): 2271–2284. doi:10.1098/rstb.2007.2199. PMC 2606779 . PMID 18048299.

28. Wood growth and structure www.farmforestline.com.au

29. Record, Samuel J (1914). The Mechanical Properties of Wood. J. Wiley & Sons. p. 165. ASIN B000863N3W.

30. "Wood Properties Growth and Structure2015 ". treetesting.com.

31. "Timber Plus Toolbox, Selecting timber, Characteristics of timber, Structure of hardwoods". nationalvetcontent.edu.au.

32. Sperry, John S et al (1994), "Xylem Embolism in ring-porous, diffuse-porous, and coniferous trees of Northern Utah and Interior Alaska". Ecology. 75 (6): 1736–1752. doi:10.2307/1939633. JSTOR 1939633.

33. Samuel James Record (1914). The mechanical properties of wood, including a discussion of the factors affecting the mechanical properties, and methods of timber testing. J. Wiley & sons, inc. pp. 44–.

34. Elliott, G.K. (1970). Wood density in conifers. Commonwealth For. Bureau, Oxford, U.K., Tech. Commun. 8. 44 .

35. Timell, T.E. (1986). Compression wood in gymnosperms. Springer-Verlag, Berlin. 2150 p.

36. Jean-Pierre Barette; Claude Hazard et Jérôme Mayer (1996). Mémotech Bois et Matériaux Associés. Paris: Éditions Casteilla. p. 22. ISBN 27135-1645-5.

37. W. Boerjan; J. Ralph; M. Baucher (June 2003). "Lignin biosynthesis". Annu. Rev. Plant Biol. 54 (1): 519–549. doi:10.1146/annurev.arplant.54.031902.134938. PMID 14503002.

38. Mimms, Agneta; Michael J. Kuckurek; Jef A. Pyiatte; Elizabeth E. Wright (1993). Kraft Pulping. A Compilation of Notes. TAPPI Press. pp. 6–7. ISBN 0-89852-322-2.

39. Fiebach, Klemens; Grimm, Dieter (2000). "Resins, Natural". Ullmann's Encyclopedia of Industrial Chemistry. doi:10.1002/14356007.a23_073. ISBN 978-3-527-30673-2.

40. Sterrett, Frances S. (1994-10-12).Alternative Fuels and the Environment(https://books.google.com/books?id=jFvrF 4DaZcgC&pg=PA261&dq=%C2%A0Wood+has+a+long+history+of+being+used +as+fuel&hl=en&sa=X&ved=0ahUK Ewi4svvjr_3UAhUPHGMKHQ MB0QQ6AEIMT AC#v=onepage&q=%C2%A0W ood%20has%20a%20long%20histor y%20of%20being%20used%20as%20fuel&f=false) . CRC Press.ISBN 9780873719780

41. Binggeli, Corky (2013-08-26). Materials for Interior Environments. John Wiley & Sons.ISBN 9781118421604.

42"FPInnovations" (PDF). forintek.ca on(March 19, 2009), Archived from the original (PDF) 43.Allen, O.N. and Allen, E.K. (1981). The Leguminosae: A Source Book for Characteristics, Uses and Nodulation. The University of Wisconsin Press.

44. Burkart, A. (1976) . A monograph of the Genus Prosopis (Leguminosae sub-family). Mimosoideae). J. Arn. Arb. 57(3/4):219-249; 450-525.

45. Perry, G. (1998). Prosopis. In Flora of Australia. Volume 12, Mimosaceae (excl. Acacia), Caesalpiniaceae CSIRO, Melbourne. 7-12.

46. Felker, P. et al. (1981). Screening Prosopis (Mesquite) Species for Bio-fuel Production on Semi Arid Lands, Final Report to US DOE. NTIS. Springfield, VA.

47. NAS (National Academy of Science (1980). Firewood Crops: Shrubs and Tree Species for Energy Production, **1**, NAS Press, Washington DC, USA.

48.Abdel Bari, E. (1986). The Identity of the Common Mesquite, Prosopis spp. Pamphlet No.1, Prosopis Project: Botany Department, University of Khartoum, Forestry Research Centre, Soba.

49. Khatoon, S. (1997). Pakistan’s Alien Forests. IUCN World Conservation, April 1997.

50.Tiwari, J.W. (1999). Exotic Weed Prosopis juliflora in Gujarat and Rajasthan, India”, Tiger Paper, **26**:3 21-25.

51. FAO (2002). Republic of Yemen: National Action Plan to Combat Desertification. Draft Report, Rome, Italy.

52. El Siddig, E.A (1996). Manual for the Management of Mesquite (Prosopis juliflora) in Wadi Hahdramout. Agricultural Research Centre, Seiyun, Yemen.

53.Saxena, S.K. et al (1991). Mesquite: An Ideal Tree for Desert Reclamation and Fuelwood Production. Indian Farming 41: 15-21.

54. Al-Frayh, .A.R. et al. (1998). Human Sensitization to Prosopis Juliflora Antigen in Saudi Arabia.

55. Duke, J.A. (1983). Prosopis juliflora D.C. Handbook of Energy Crops, Unpublished (internet)

56. Shukla, P.C. et al (1984). Prosopis juliflora Pods, new cattle feed source. Animal Nutrition Department, Gujarat Agricultural University, Anand, Gujarat, India.

57. National Research Council (2006-10-27). "Okra". Lost Crops of Africa: Volume II: Vegetables. Lost Crops of Africa. 2. National Academies Press. ISBN 978-0-309-10333-6. Retrieved 2008-07-15.

58. Harper, Douglas. "okra". Online Etymology Dictionary.

59. McWhorter, John H. (2000). The Missing Spanish Creoles: Recovering the Birth of Plantation Contact Languages. University of California Press. p. 77. ISBN 0-520-21999-6. Retrieved 2008-11-29.

60."Alternative Cold Remedies: Lady's Fingers Plant", curing-colds.com (accessed 3 June 2009) Archived May 13, 2009, at the Wayback Machine.

61."gumbo". Oxford English Dictionary (1st ed.). Oxford University Press. 1933.

62."Okra, or 'Gumbo,' from Africa, tamu.edu

63." Okra gumbo and rice" by Sheila S. Walker, The News Courier, unknown date

64."Okra Seed" (PDF). Retrieved (2012-10-17).

65."Red Okra Information, Recipes and Facts". Retrieved(2015-09-30).

66."Growing okra". Department of Primary Industries and Fisheries, Queensland. 19 September (2007). Archived from the original on June 11, 2012. Retrieved 24 (June 2012).

67.Gemede, H. F.; Haki, G. D.; Beyene, F; Woldegiorgis, A. Z.; Rakshit, S. K. (2015). "Proximate, mineral, and antinutrient compositions of indigenous Okra (Abelmoschus esculentus) pod accessions: Implications for mineral bioavailability". Food Science & Nutrition. 4 (2): 223–33. doi:10.1002/fsn3.282. PMC 4779480 . PMID 27004112.

68. Network.com: Okra Greens and Corn Saute, M.S. Milliken & S. Feniger, (1996).

69. Austin State Gazette [TEX.], November 9, (1861), 4, 2, copied in Confederate Coffee Substitutes: Articles from Civil War Newspapers Archived September (28, 2007), at the Wayback Machine., University of Texas at Tyler.

70. Martin, Franklin W. (1982). "Okra, Potential Multiple-Purpose Crop for the Temperate Zones and Tropics". Economic Botany. 36 (3): 340–345. doi:10.1007/BF02858558.

71. Mays, D.A., W. Buchanan, B.N. Bradford, and P.M. Giordano (1990). "Fuel production potential of several agricultural crops". Advances in New Crops: 260–263.

72.Jamieson, George S.; Baughman, Walter F. (1920). "Okra Seed Oil.1". Journal of the American Chemical Society. 42: 166. doi:10.1021/ja01446a023.

73.Farooq, Anwar; Umer Rashid; Muhammad Ashraf; Muhammad Nadeem (March 2010). "Okra (Hibiscus esculentus) seed oil for biodiesel production". Applied Energy. 87 (3): 779–785. doi:10.1016/j.apenergy(2009.09.020).

74.De Rosa, I.M.; Kenny, J.M.; Puglia, D.; Santulli, C.; Sarasini, F. (2010). "Morphological, thermal and mechanical characterization of okra (Abelmoschus esculentus) fibres as potential reinforcement in polymer composites". Composites Science and Technology. 70 (1): 116–122. doi:10.1016/j.compscitech.2009.09.013.

External links

Abelmoschus esculentus in West African plants – A Photo Guide

75.USDA GRIN Taxonomy, retrieved 21 (April 2016) .

76.Christopher Cumo (2013). Encyclopedia of Cultivated Plants: From Acacia to Zinnia [3 Volumes]: From Acacia to Zinnia. Santa Barbara, CA: ABC-CLIO. p. 315. ISBN 978-1-59884-775-8.

77.June 9, 2014.3.G. J. H. Grubben (2004). Vegetables. Wageningen, Netherlands: PROTA. p. 218. ISBN 978-90-5782-147-9.

78.NewsLifeMedia. "Rabbit molokhia". taste.com.au.

79. Sarah Melamed (September 11, 2009). "Mloukhia, an Ancient Egyptian dish". Food Bridge. Retrieved

80.www.afornet.org/images/pdfs/Non-wood%20forest%20products%20 and% 20 services .pdf

81.www.fao.org/docrep/x5402e/x5402e12.htm (December 03, 2007, 9:42:00 AM) Abdel Nour, H. O. Gum Arabic in Sudan: Production and Socioeconomic Aspects. FAO.

82. www.sls.wau.nl/mi/response/Rahim.pdf (November 29, 2007, 11:40:22 AM) Rahim, A, H.; Van Ierland, E. C. and Weikard, H.P. Competition in the Gum Arabic Market: A game theoretic modeling approach. Wageningen University, Netherlands.

83. www.fao.org/ag/agp/AGPC/doc/Gbase/Data/pf000131.htm (December 06, 2007, 11:25:21 AM) FAO.

84. www.fao.org/docrep/W6355E/w6355e0g.htm (December 04, 2007, 6:56:05 PM) Gum Arabic.FAO.

85. www.wageningenuniversiteit.nl/UK/newsagenda/archive/agenda/2006. (January 14, 2008, 11:13:09 AM) Rahim, A. H.. Economic Analysis of Deforestation: The Case of the Gum Arabic Belt in Sudan. (2006). Wageningen University, Netherlands.

86.www.cniworld.com/ (December 05, 2007, 9:06:11 AM) Colloids Naturals International (CNI).

87. www.treegums.org/products/acaciaarabic.html the Association for International Promotion of Gums (AIPG).

88. Macrae, J.; Merlin, G. (2002). The Prospects and Constraints of Development of Gum Arabic in Sub-Saharan Africa. World bank, Paris.

89. http://shop.darsavanna.com/about.php (March 19, 2002, 2:08:01 PM) Dar savanna co-ltd.

90. www.worldbank.org/intafrmdtf/resource//minutes_meeting_oc_n_apr il_17_2007_final.pdf (January 10, 2008, 12:13:04 PM) Policy note: Export & Marketing of Gum Arabic from Sudan. World bank, Sudan.

91. www.fao.org/ag/agn/jecfa-additives/specs/Monograph1/Additive 219.pdf (December 30, 2007, 9:22:47 AM) Weatherwax, J. Gum Arabic. FAO.

92.www.hort.purdue.edu/newcrop/duke_energy/Acacia_senegal.html

(December 31, 2007, 9:17:30 AM)

93. www.gapc-gums.com (January 05, 2008, 10:39:31 PM) Khartoum Gum Arabic Processing Company.

94. www.ars.usda.gov/sp2userfiles/place/36200000/gumarabicsub_flyer.pdf (December 09, 2007, 6:08:34 PM) Cote, G. National Center for Agriculture and Utilization Research. USA.

95.Smith, F. and Montgomery,R (1959). Chemistryofplant gumsandmucilages (Reinhold Publishing Corp., New York).

96. "Guartec"(1963). (GeneralMills Inc.).

97. "Jaguar, (1962). (Stein,Hall&Co.Inc).

98. Kirk and Othmer 10 (1966). "Gums, Natural" by M. Gliksman. Encyclopaediaof Chemical Technology.

99. I-Ieyne,Eileen and Whistler, Roy L. J. Am. Chem.Soc.70 2249 {1948).

100. Eherton, L. E. Platz, P. E. and Cosgrove,F. P. Drug Standards.9.8No. 2, 42-47

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