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A study of mahogany.

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A STUDY OF MAHOGANY

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A STUDY OF MAHOGANY

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INTRODUCTION

Introduction

To the average person, the word, mahogany, means nothing more than a wood from which furniture is made. Very few people have ever seen a piece of this kind of wood in the green and unfinished state. We have come to recognize this kind of wood by the rather dark brownish stain that is so characteristic of many pieces of furniture constructed from mahogany.

The origin of the word, mahogany, seems to have been forgotten, but it is generally believed by many to have had its origin in native Africa. It is probably the revised form of the native name for the tree. It is said that the African native has the word, Mahana, meaning the largest tree or king of the forest. It is very probable that this is the origin of the word, mahogany.

To the analyst, any kind of wood presents many secrets; mahogany gives us a vast array of problems that are still to be explored and solved. So far, chemical research has not entered the vast field that the study of mahogany offers. Little is really known of the nature of the wood, its compounds and their possibilities. Recorded chemistry shows that practically nothing has been accomplished as to a systematic investigation of the hard woods of tropical regions.

Commercially we find over fifty different kinds of wood bearing some form of the name mahogany (6). According to botanical information this wood is not as plentiful as some manufacturers would have us think. It is estimated that at least half of the wood that is sold as mahogany is of another species, bearing only the slightest resemblance to mahogany. Botanists have classified these woods into several classes. The name of true mahogany has been given to the mahogany that is produced in Tropical America, Floride Keys, and the West Indies. The mahogany that is grown in Africa is very similar in its properties to those of the true mahogany group. The use of this wood in the furniture making industry had gained wide usage in Europe and America before the discovery of the similar wood along the west coast region of Africa. The differences between the African species and those of Tropical America are secondary. These two groups are botanically of the same genus; however, they bear different scientific names more because of the district geographical ranges of the two groups.

The mahoganies as a class are almost homogeneous as to structure and texture (6). The differences are attributed to growth conditions, such as soil, climate, moisture and altitude.

The color of the wood from different sources varies from a light brown to a dark, reddish brown. The specific gravity of the different types of mahogany range from .40 to .90.

In the Philippine Islands, we find several species of trees that bear a marked resemblance to the true mahoganies. This wood has been imported and sold as mahogany for many years. It is difficult in some instances to distinguish these woods after a finish has been applied. To the wood technologist there are many ways to distinguish the so-called Philippine mahoganies and the true mahoganies. An examination of the bark, leaf, fruit and seed of these two classes reveal distinct differences (1). For instance, the leaf of the Philippine variety is simple in structure; its appearance resembles a large elm leaf. The leaf of the Tropical American species is compound in structure, resembling the leaf of the ash tree. The seed of the true mahogany tree is flattened with the wing at one end, while the seed of the East Indian variety is rounded with several terminal wings forming a cluster somewhat like the seed of our maple tree. Few of the flowers of the trees of Tropical America survive, while most of those of the Philippine species develop into single seeds.

Pictures of bark of these varieties of trees show clearly distinct differences. The bark of the Tropical American tree is more coarse and grained than that of the East Indian species. An outstanding characteristic of these woods is the presence or total absence of dark, glistening deposits of gummy substances. In the pores or cells of the true mahogany species and of the African Mahogany, there is present a noticeable quantity of this substance, while in the Philippine woods there is a total lack of this material. This feature is used by wood technologists in verifying samples of mahogany (5). Another determining factor is the color, Philippine varieties ranging from a brown to a tan while the color of the true varieties ranges from a brown to a dark reddish brown (6).

In view of the fact that so little is known of the chemical properties of these woods, it is my objective in this study first, to conduct an investigation of the gummy substance found in certain varieties of mahogany; secondly, to investigate the physical properties as determined through various extractions of African mahogany, Tropical American mahogany, and the so-called Philippine mahoganies, thirdly, to determine the specific gravities of the above mentioned woods; and finally to determine the ash content of the several species.

Geographical Distribution

Map I shows the regions which produce the varieties of mahogany known as true mahogany (10). African mahogany (Kaya ivorensis) is grown on the Ivory Coast, the Gold Coast, and Nigeria, West Africa. Tropical American mahogany (Swietenia macrophylla) is produced in various sections of Mexico. Cuban and Floridian mahoganies (Swietenia mahogani) are grown in the Florida Keys and in the West Indies. Honduras mahogany (Swietenia macrocarpa) is produced in rather large quantities in British Honduras. Some varieties of this wood are now being taken from parts of Brazil and Peru. The above mentioned mahoganies have acquired many trade names; some of the more common are: Mexican, Cuban, Nicaraguan, Tabasco, San Jago, Cispata, Panama, Spanish American and Colombian. The trade name usually bears some portion of the name of the town, port, or region from which it is derived (5). The best grade of this wood comes from slow growing trees on high, dry ground. It is relatively hard, as compared with the soft, spongy mahogany obtained from the rapid-growing trees in the moist soil of the lowlands and coastal regions.

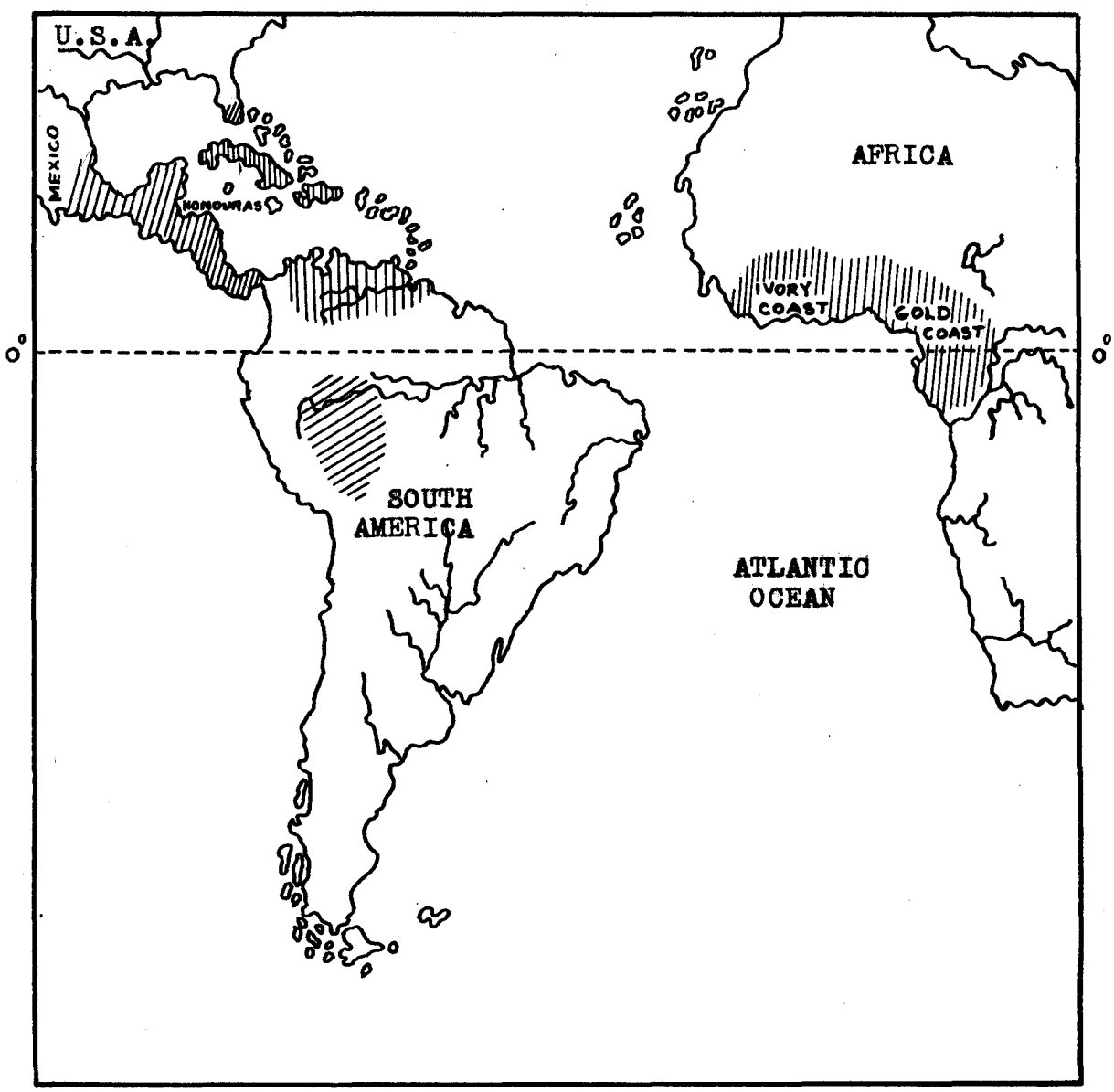
The mahogany that is produced along the west coast of Africa is of fair quality. The wood from this region possesses neither extremes of color nor density. These

trees grow to an unusual size, giving boards of excessive width and length. Because of this extreme width, the logs are cut into veneers and are used extensively in the furniture industry. The hardest of the mahoganies are produced in Florida, the density of this wood being as high as .90, while other species are as low as .40. True annual growth rings are found only in the wood that is grown farther north than British Honduras. These rings of the southern species are uneven, due to the fact that growth in some form continues through out the year. The wood that is produced north of British Honduras commonly shows in transverse sections distinct annual growth rings (5).

MAP I

GEOGRAPHICAL LOCATION OF AFRICAN

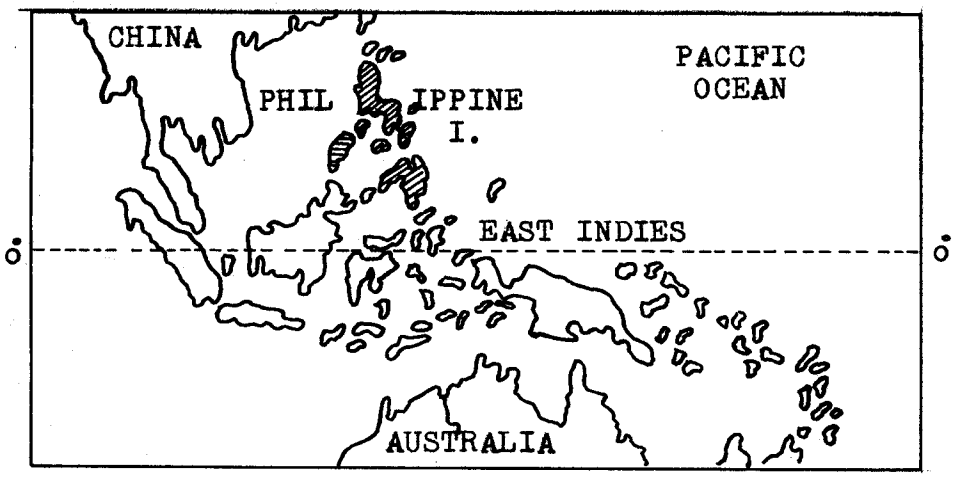
MAHOGANY AND THE SO-CALLED TRUE MAHOGANIES (10)



MAP II

GEOGRAPHICAL LOCATION OF

PHILIPPINE MAHOGANIES (10)



From the Philippine Islands come several species of wood that are known as the so-called Philippine mahoganies. Tanguile and Red Lauan constitute the bulk of the Philippine Mahogany sent to the United States and are generally used as a substitute for true mahogany in the furniture manufacturing industries. White Lauan, Almon and Bagtician are also included in the shipments of wood from the Philippines. Botanically, there is a marked distinction between Philippine mahoganies and true mahoganies from Africa and Tropical America. However, it sometimes is quite a problem to distinguish between the woods after several coats of finish have been applied.

The Philippine mahoganies as a class are neither as hard nor as heavy as the true mahoganies. The pores are very distinct on smoothly cut surfaces, and have fairly uniform grain characteristics. It seasons very well, and does not warp nor split easily. Almon is probably the softest of the Philippine mahoganies. It varies from light brown to tan in color, and is light with coarse grain characteristics. Of this class of woods, Tanguile is the best. It is somewhat harder, heavier, stronger and finer in texture than either the Lauans or Bagtician.

Discussion of Samples

The samples used in this study were obtained from companies importing these species. Samples of several gum pockets were obtained from the Mengel Company of Louisville. Samples of African mahogany, Mexican mahogany, British Honduras mahogany, Cuban mahogany and Floridian mahogany were secured from the same company. The Insular Lumber Company of Philadelphia, exporters of Philippine mahogany, and the Powe Lumber Company of St. Louis furnished samples of the following Philippine mahoganies, White Lauan, Red Lauan, Tanguile and Bagtician.

Each of the above mentioned samples were forwarded to the United States Forest Products Laboratory for verification. Each piece of wood proved to be an authentic sample (12). The samples were obtained from kiln dried boards that had been cut for at least two years. The samples obtained from the Mengel Company were probably ten years old. No information could be obtained, as to the size of the tree nor the location of the piece from which the samples were cut. All samples were cut from the heart wood.

The gum pocket samples were from African mahogany wood, Mexican mahogany, and Floridian mahogany. Samples of the gum were obtained from the siftings of the other mentioned samples of wood.

Preparation of Samples

Each piece of wood was converted into fine sawdust by using a very fine tooth saw. The saw and table was carefully cleaned before each cutting. This sawdust was sifted through a fifty mesh sieve; the particles failing to pass this mesh were rejected. The sawdust samples were placed in air-tight containers. The gums of the several pockets were removed and also placed in closed containers.

In the extraction experiments, the orginal samples were conducted through a series of extractions. In each case, three samples were used and calculations were given for the mean as well as the three runs. The percentages given were in terms of the weight of the samples for the particular extraction.

All determinations in this study were based on oven-dry (105° C.) samples. It was determined that samples required from four to six hours drying in order to reach a constant weight.

TABLE I

CLASSIFICATION OF SAMPLES

Common Name	Scientific Name	Native Habitat	Color
African Mahogany	Kaya ivorensis (6)	West Coast of Africa	Reddish Brown (6)
Mexican Mahogany	Swietenia macrophylla	Mexico	Light Reddish Brown
Cuban Mahogany	Swietenia mahogani	West Indies	Dark Reddish Brown
Honduras Mahogany	Swietenia macrocarpa	North British Honduras	Reddish Brown
Floridian Mahogany	Swietenia mahogani	Florida Keys	Dark Reddish Brown
Bagtician or Philippine Mahogany	Parashorea malaanonan	Philippine Islands	Light Brown
White Lauan or Philippine Mahogany	Pentacme Contorta	Philippine Islands	Light Brown
Red Lauan or Philippine Mahogany	Shorea negrosensis	Philippine Islands	Reddish Brown
Tanguile or Philippine Mahogany	Shorea polysperma	Philippine Islands	Light Brown

PART II

MAHOGANY WOOD GUM

Mahogany Wood Gum

An examination of the literature reveals that no systematic attempt has been made to examine the gums of various trees. The gummy substance found in the cells of the true mahogany species presents an interesting problem. Its presence is used as a determining factor in distinguishing true mahogany wood from that of other species. According to definition, (15) wood gum is a translucent, amorphous substance, most of the gums being slightly soluble in water and practically all possessing the property of swelling when allowed to remain in water for a length of time. Mahogany wood gum is a translucent, amorphous substance having the property of becoming slightly soft in water, but unlike most gums it does not swell when allowed to soak.

The wood gums are generally considered to be decomposition products of cellulose (15), resulting from the action of some hydrolytic ferment, usually stimulated by some unfavorable condition of growth, some injury, or some morbid condition. In mahogany trees, the formation of this substance is doubtless due to changes of degradation in the cell wall. The substance is found with in the cell itself and in spaces formed by the breaking down of numerous cells

called gum pockets or gum streaks. In African mahogany and in the so-called true mahoganies, this product can be seen quite easily with the aid of a low power hand lens. In spruce and other coniferous trees, it is found in distinct receptacles, known as resin-passages.

According to Schorger, (13) wood gum comes under the class of compounds known as the hemicelluloses. He defines a hemicellulose as a polysaccharide, soluble in dilute alkali and convertible into simple sugars by heating with dilute acids. Mahogany wood gum can hardly be classed as a true hemicellulose as it cannot be dissolved in dilute alkali, nor can it be converted into simple sugars through the action of dilute acids and heat.

The first step in my investigation of this gum was to experiment with its solubility. Table I illustrates the various solvents used in an attempt to dissolve the substance. The samples used were taken from gum pockets and from samples of African and Tropical American mahoganies that contained an unusual amount of the material. Various physical means of separating the material from the sawdust were tried, but no satisfactory method was found that would bring about a complete separation. It was found that some of the gum could be removed by shaking the

sawdust with ether, and then quickly pouring off the ether. This process would leave a small amount of the substance in the bottom of the container.

In many cases the gummy substance was allowed to digest in a portion of the solvent for several days, but in some cases, where this was impractical, a test plate method was used. A test plate or watch glass was used, a portion of the material was obtained with the aid of a hand lens and allowed to remain in contact with the solvent for about an hour. Any reaction was carefully watched through the hand lens.

The substance proved to be insoluble in all the organic solvents used. No method other than hydrolysis could be found to remove the material from the wood. This was done by the constant boiling with five percent sodium hydroxide over a period of fourteen hours. Numerous extractions were carried out with hourly examinations of the sawdust to determine the length of time necessary for its complete extraction. The filtrates from these extractions failed to give a precipitate upon neutralization with acids. The filtrate obtained by the extraction of sawdust with cold sodium hydroxide very easily gave a precipitate upon the addition of an acid. I might add that the extractions with boiling sodium hydroxide were conducted on samples that had been previously

extracted with the cold reagent, and which still showed the presence of the gum.

After failing to obtain a precipitate with the use of an acid, other methods were tried and it was found that an equal volume of 95 percent alcohol gave a flocculent precipitate of dark reddish brown color. In several hours this material had settled to the bottom of the container. It was recovered on a filter and dried. This was found to be very soluble in water and could be precipitated from its water solution by the addition of an equal volume of alcohol or acetone. Various methods of separating the mixture into pure compounds were entirely unsuccessful. No method could be devised to separate it through crystalization, fractional precipitation, cooling or heating.

This material proved to be insoluble in the organic solvents; however, there was a slight softening in Gasoline, Benzene and Kerosene.

TABLE II

SOLUBILITY OF MAHOGANY GUM

Solvent (9)	Time in Hours	Conditions	Solubility
Water	148	frequent shaking	slight softening
Water	24	refluxed	slight softening
Alcohol	148	frequent shaking	insoluble
Alcohol	14	refluxed	insoluble
Ether	148	frequent shaking	insoluble
Ether	24	refluxed	insoluble
Benzene	148	frequent shaking	slight softening
Gasoline	148	frequent shaking	slight softening
Kerosene	148	frequent shaking	slight softening
Acetone	148	frequent shaking	slight softening
Lacquer Thinner	148	frequent shaking	insoluble
Sodium Hydroxide-5%	148	frequent shaking	slight softening
Sodium Hydroxide-5%	14	refluxed	hydrolysis
Turpentine	148	frequent shaking	insoluble

TABLE II

CONTINUED

Solvent	Time in Hours	Conditions	Solubility
Methyl Alcohol	148	frequent shaking	insoluble
Sodium Carbonate	3	boiling	slight softening
Borax Solution	3	boiling	insoluble
Perborate (4)	3	boiling	insoluble
Schweizer's Reagent (7)	148	frequent shaking	slight softening
Carbon Tetra Chloride	1	test plate	insoluble
Nitro Benzene	1	"	insoluble
Acetic Acid	1	"	insoluble
Nitric Acid (dilute)	1	"	insoluble
Sulphuric Acid (dilute)	1	"	insoluble
Toluene	1	"	insoluble
Tartaric Acid	1	"	insoluble
Amyl Ether	1	"	insoluble
Xylene	1	"	insoluble

TABLE II

CONTINUED

Solvent	Time in Hours	Conditions	Solubility
Benzaldehyde	1	test plate	insoluble
Iso Amyl Acetate	1	"	insoluble
Acetophenone	1	"	insoluble
Butyl Alcohol	1	"	insoluble
Butyl Bromide	1	"	insoluble
Cyclo-hexane	1	"	insoluble
Carbon Disulfide	1	"	insoluble
Acetic Anhydride	1	"	insoluble
Formaldehyde	1	"	insoluble
Ethylene Bromide	1	"	insoluble
Lead Acetate	1	"	insoluble
Hydrochloric Acid Conc.	1	"	insoluble
Soap Solution	148	frequent shaking	insoluble

TABLE II

CONTINUED

Solvent	Time in Hours	Conditions	Solubility
Glacial Acetic Acid	2	frequent shaking	insoluble
Furfural	1	test plate	insoluble
Heptaldehyde	1	"	insoluble
Zinc Chloride Solution (15)	1	boiling	insoluble
Acetyl Chloride	1	frequent shaking	insoluble
Alcohol and Water Mixture	24	frequent shaking	insoluble
Potassium Hydroxide 10%	24	frequent shaking	insoluble
Ammonium Hydroxide	24	frequent shaking	slight softening

PART III

EXTRACTIONS

Cold Water Extractions

In these extractions no attempt was made to identify the extraneous components of the wood, however, mention will be made of the possibilities in each case. The term extraneous components has been used by Hawley and Wise (8) to designate a number of substances that are present in certain woods which are often grouped together under the general heading of extractives. These substances are found in the woody tissue, but are not considered in integral part of the cell wall. They can usually be extracted with various solvents.

Many of these extraneous components have a decided commercial value. In most cases little is really known as to their true orgin and the function in the plant. Some of these substances have been investigated chiefly for medicinal purposes. The glucosides offer a class of compounds that can be extracted with water or alcohol (2). Among the glucosides that have gained prominence is Arbutin, a powerful diuretic, extracted from the berry tree. Salicin, found in the bark of the Willow and Poplar trees, is used in medicine as antipyretic. Phloridzin, found in the bark of fruit trees, is used as an antiperiodic.

Coniferin, the glucoside of the fir tree, is of importance as the starting point for the synthesis of vanillin (8).

In some investigations, it was found that certain trees possess natural dyestuffs that can be extracted with water, alcohol or ether (8). Some of these dyestuffs are still of commercial value, however, the progress of the synthetic dye industry has greatly lessened the demand for them. The possibilities of the mahogany tree, as to its medicinal and commercial value, are yet to be investigated by chemical research. At present, it is being used only in the manufacture of furniture.

Experimental

Table III gives the results obtained from the cold water extraction of the samples previously classified. The results are based on the oven-dry (105° C.) sample. The procedure used in these extractions is as follows; The samples were placed in the oven and dried for six hours at 105°. Three samples of each of the nine woods were carefully weighed and placed in flasks. They were allowed to digest in 200 C. c. of cold water for a period of sixty six hours.

The filtering process was accomplished with a Buchner funnel. The air dried out the sawdust so that it could be removed without an appreciable loss of materials. The samples were transferred to an evaporating dish and allowed to dry in the oven for a six hour period at 105-110° C. It was then placed in a desiccator until cool, after which it was transferred to a weighing bottle and weighed. This had to be accomplished quickly, as it was found that the dried material took on moisture rapidly. The samples were then placed in flasks in readiness for the next extraction.

The table also gives the colors of the filtrates in each extraction. An examination of the table reveals that the so-called true mahoganies yield a higher percent of water soluble substances than those of the East Indies. Also, it seems, that the amount of water soluble materials is in some way related to the specific gravity of the wood, (see Table IX) the heavier the wood the greater the amount of water soluble materials. The table shows that the samples of Floridian mahogany are entirely out of line with the calculations for the other woods used in the experiments.

Floridian mahogany is the heaviest of all the woods in this class, however, the writer fully realises that one tree does not give a true picture of the species. It was found in some instances that trees of the same species growing within a relative short distance from each other gave quite different results in their analysis (8).

As previously stated no serious attempt was made to determine the substances extracted, however, in each case the filtrate was evaporated to dryness in order to determine the nature of the extracted materials. The residue from the cold water extraction was a chocolate colored substance. No crystals were formed during the evaporation nor could any be formed through cooling, heating, etc.

The results given in these determinations are indicative of what one might expect to find in a thorough quantitative analysis using samples from many trees of the species.

TABLE III

RESULTS OF COLD WATER EXTRACTIONS

Samples oven-dry (105° C.)

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
African Mahogany #1	4.000g	66	frequent shaking	O.Y.T.1(11)	3.45
African Mahogany #2	4.000g	"	"	"	3.56
African Mahogany #3	4.000g	"	"	"	3.85
MEAN	4.000g	"	"	"	3.62
Mexican Mahogany #1	4.000g	66	frequent shaking	O.Y.	3.65
Mexican Mahogany #2	4.000g	"	"	"	3.30
Mexican Mahogany #3	4.000g	"	"	"	3.80
MEAN	4.000g	"	"	"	3.58
Cuban Mahogany #1	4.000g	66	frequent shaking	Y.O.	5.39
Cuban Mahogany #2	4.000g	"	"	"	5.75
Cuban Mahogany #3	4.000g	"	"	"	5.71
MEAN	4.000g	"	"	"	5.61

TABLE III

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
Honduras Mahogany #1	4.000g	66	frequent shaking	O.Y.	1.27
Honduras Mahogany #2	4.000g	"	"	"	1.22
Honduras Mahogany #3	4.000g	"	"	"	1.37
MEAN	4.000g	"	"	"	1.28
Floridian Mahogany #1	4.000g	66	frequent shaking	Y.O.	15.38
Floridian Mahogany #2	4.000g	"	"	"	14.98
Floridian Mahogany #3	4.000g	"	"	"	15.02
MEAN	4.000g	"	"	"	15.12
Bagtician #1	4.000g	66	frequent shaking	no color	1.68
Bagtician #2	4.000g	"	"	"	1.77
Bagtician #3	4.000g	"	"	"	1,49
MEAN	4.000g	"	"	"	1.64

TABLE III

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
White Lauan #1	4.000g	66	frequent shaking	Y.O.T.2	.71
White Lauan #2	4.000g	"	"	"	.78
White Lauan #3	4.000g	"	"	"	.65
MEAN	4.000g	"	"	"	.71
Red Lauan #1	4.000g	66	frequent shaking	Y.O.	.80
Red Lauan #2	4.000g	"	"	"	.77
Red Lauan #3	4.000g	"	"	"	.70
MEAN	4.000g	"	"	"	.76
Tanguile #1	4.000g	66	frequent shaking	O.Y.T.2	1.01
Tanguile #2	4.000g	"	"	"	.99
Tanguile #3	4.000g	"	"	"	.98
MEAN	4.000g	"	"	"	.99

Hot Water Extractions.

The tannins hold an important place among the extraneous component of wood that can be extracted with hot water (8). Within recent years the tannin content of a number of trees has been investigated; however, the literature does not reveal any researches on the tannin content of the mahogany trees. The tannins are very widely distributed, occuring in many different woods, but comparatively few of them have been investigated. Little is really known of their true chemical constitution. The principal uses of the tannin compounds are found in the leather and the dyeing industry.

Experimental

The samples from the cold water extractions were placed in a round bottom flask and refluxed with water for a two hour period. There was some difficulty experienced with these experiments due to the bumping of the mixture. Extreme care had to be exercised to prevent loss of materials. The recovered saw dust was transferred to an evaporating dish and placed in the oven for drying. After cooling and weighing the samples were placed in a flask for the ether extraction process.

Table IV gives the results obtained in these extractions. The percentages are based on the oven-dry weight of the sample at the beginning of each extraction. The table also supports the theory that the density of the wood is indicative of the amounts of water soluble materials. Flordian and Cuban, the two heaviest samples used, give the largest percentage of extracted substances. An examination of the colors of the filtrates show that the Philippine woods give a much lighter colored filtrate than do the other species. The filtrates from these experiments gave residues ranging from a chocolate color to a light tan. The residues are very similar in appearance to those obtained in the cold water extraction. Several attempts were made to obtain a separation of compounds, but none proved successful.

TABLE IV

RESULTS OF HOT WATER EXTRACTIONS

Samples oven-dry (105° C.)

Species	Weight of Sample	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
African Mahogany #1	3.8621g	2	refluxed	O.Y.	4.04
African Mahogany #2	3.8565g	"	"	"	3.78
African Mahogany #3	3.8458g	"	"	"	3.86
MEAN	3.8548g	"	"	"	3.92
Mexican Mahogany #1	3.8529g	2	refluxed	O.	2.92
Mexican Mahogany #2	3.8689g	"	"	"	3.46
Mexican Mahogany #3	3.8479g	"	"	"	3.35
MEAN	3.8565g	"	"	"	3.24
Cuban Mahogany #1	3.7342g	2	refluxed	R.O.	6.16
Cuban Mahogany #2	3.7679g	"	"	"	6.29
Cuban Mahogany #3	3.7713g	"	"	"	5.85
MEAN	3.7750g	"	"	"	6.10

TABLE IV

CONTINUED

Species	Weight of Sample	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
Honduras Mahogany #1	3.9490g	2	refluxed	R. O.	5.70
Honduras Mahogany #2	3.9507g	"	"	"	5.85
Honduras Mahogany #3	3.9482g	"	"	"	5.43
MEAN	3.9493g	"	"	"	5.66
Floridian Mahogany #1	3.3847g	2	refluxed	R. O.	10.82
Floridian Mahogany #2	3.4008g	"	"	"	11.13
Floridian Mahogany #3	3.3920g	"	"	"	10.91
MEAN	3.3925g	"	"	"	10.95
Bagtician #1	3.9328g	2	refluxed	O.Y.T.1	2.70
Bagtician #2	3.9289g	"	"	"	2.34
Bagtician #3	3.9402g	"	"	"	2.48
MEAN	3.9339g	"	"	"	2.50

TABLE IV

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
White Lauan #1	3.9715g	2	refluxed	O.Y.T.I	.32
White Lauan #2	3.9685g	"	"	"	.29
White Lauan #3	3.9739g	"	"	"	.31
MEAN	3.9713g	"	"	"	.31
Red Lauan #1	3.9679h	2	refluxed	O.Y.T.I.	2.47
Red Lauan #2	3.9692g	"	"	"	2.34
Red Lauan #3	3.9720g	"	"	"	2.51
MEAN	3.9697g	"	"	"	2.44
Tanguile #1	3.9598g	2	refluxed	O.Y.T.I	1.22
Tanguile #2	3.9609g	"	"	"	1.08
Tanguile #3	3.9613g	"	"	"	1.20
MEAN	3.9606g	"	"	"	1.16

Ether Extractions

Many resins and oleoresins are extracted from wood with ether. In my correspondence with the Forest Products Laboratory it was suggested that I remove the resin or mahogany gum by dissolving it in ether, but this method was unsatisfactory. There remains a great amount of study before the subject of the resins will be clarified. Research has been quite active in the study of oleoresins from the conifers. It has been pointed out that there are over ninety conifers species in the United States. Comparatively few of the resins and oleoresins have been extracted and examined (8). In some instances essential oils have been extracted from the waste saw dust or shavings of various industries. At present, the waste products from mahogany are being used for fuel.

Experimental

The samples used in the hot water extractions were allowed to soak in ether for a period of sixty-six hours. The saw dust was collected in an evaporating dish and allowed to dry in the air for two hours, after which they were placed in the oven for further drying. The samples being weighed were transferred to a flask

for the sodium hydroxide extractions.

Table V gives the results obtained in these extractions. The results do not show any great differences in the extracted amounts. As a class, the African and the true mahoganies do show a slightly larger percentage of extracted substances. Floridian mahogany shows the highest percentage of ether soluble materials, and Honduras shows the lowest percentage. Additional investigation, using a larger number of samples, is necessary before any conclusions can be reached as to the ether soluble content. The filtrate from these extractions are colorless with the exception of those from Floridian and Tanguile. The Table does not list any color for Tanguile; however, there is just the faintest shade of orange present after the ether has been reduced to a small volume.

The residue after evaporation of the ether was in the form of globules of oil or fat of reddish color. The color of the residue varied with the filtrates. Those from the Philippine woods gave a much lighter colored substance than those of the other species.

No attempt was made to identify the substances extracted.

TABLE V

RESULTS OF ETHER EXTRACTIONS

Samples oven-dry (105° C.)

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
African Mahogany #1	3.7059g	66	frequent shaking	no Color	2.62
African Mahogany #2	3.7070g	"	"	"	2.29
African Mahogany #3	3.6971g	"	"	"	2.30
MEAN	3.7033g	"	"	"	2.40
Mexican Mahogany #1	3.7403g	66	frequent shaking	no color	3.38
Mexican Mahogany #2	3.7348g	"	"	"	3.44
Mexican Mahogany #3	3.7189g	"	"	"	2.97
MEAN	3.8351g	"	"	"	3.26
Cuban Mahogany #1	3.6516g	66	frequent shaking	no color	2.38
Cuban Mahogany #2	3.5525g	"	"	"	2.23
Cuban Mahogany #3	3.6507g	"	"	"	2.46
MEAN	3.6449g	"	"	"	2.36

TABLE V

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
Honduras Mahogany #1	3.7238g	66	frequent shaking	no color	.56
Honduras Mahogany #2	3.7196g	"	"	"	.54
Honduras Mahogany #3	3.7370g	"	"	"	.60
MEAN	3.7247g	"	"	"	.57
Floridian Mahogany #1	3.0182g	66	frequent shaking	no color	4.41
Floridian Mahogany #2	3.0215g	"	"	"	4.73
Floridian Mahogany #3	3.0218g	"	"	"	4.31
MEAN	3.0205g	"	"	"	4.48
Bagtician #1	3.8263g	66	frequent shaking	no color	1.99
Bagtician #2	3.8368g	"	"	"	2.06
Bagtician #3	3.8424g	"	"	"	2.07
MEAN	3.8351g	"	"	"	2.04

TABLE V

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
White Lauan #1	3.9588g	66	freguent shaking	no color	1.63
White Lauan #2	3.9567g	"	"	"	1.61
White Lauan #3	3.9513g	"	"	"	1.55
MEAN	3.9516g	"	"	"	1.59
Red Lauan #1	3.8696g	66	frequent shaking	no color	2.26
Red Lauan #2	3.8764g	"	"	"	2.31
Red Lauan #3	3.8728g	"	"	"	2.26
MEAN	3.8727g	"	"	"	2.27
Tanguile #1	3.9112g	66	frequent shaking	no color	1.52
Tanguile #2	3.3918g	"	"	"	1.63
Tanguile #3	3.9136g	"	"	"	1.40
MEAN	3.9142g	"	"	"	1.52

Cold Sodium Hydroxide Extractions

Alkali has no specific action on wood, however, it attacks a number of the different components (8). According to Hawley and Wise, dilute sodium hydroxide solutions remove a part of the lignin and part of the hemicelluloses. The hardwoods, which contain a higher percentage of pentosans, are attacked by alkali treatment more than are other woods. However, individual samples of some soft woods have been found to have a higher percentage of alkali soluble substances than do certain samples of hard woods (8).

It has been determined that extraction with alkali alters the hemicelluloses (13). Some wood gums, after isolation with alkali, become soluble in water. Little Xylan, Araban, or Mannan can be isolated with boiling water alone; however, once removed with alkali treatment they do become soluble in water.

Experimental

The samples from the ether extractions were extracted with 4% sodium hydroxide for a period of eighteen hours. After filtering and washing, the sawdust was returned to the oven for drying. After drying, it was carefully examined through a hand lens. From all appearances, the condition of the material was not altered by this extraction.

The deposits of gum in the samples of African and Tropical American mahogany remained although they did show a slight softening. Table VI gives the results of these extractions. It appears that these percentages as calculated for the African and Tropical species is somewhat high; however, there is no way to check the results except through additional researches. The filtrates from these extractions present an interesting point. The colors obtained with the Philippine woods range from orange to a tint of orange yellow, while the colors of the other species are all of the orange red shade. The Philippine varieties give a much smaller percentage of extracted substance than do the African and Tropical mahoganies.

The filtrate was neutralized with hydrochloric acid and a flocculent precipitate formed. The Philippine woods gave a smaller and lighter colored precipitate. This substance, after drying, was found to be soluble in water. No attempt was made to separate or purify the substance.

TABLE VI

RESULTS OF COLD SODIUM HYDROXIDE EXTRACTIONS

Samples oven-dry (105° C.)

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
African Mahogany #1	3.6088g	18	frequent shaking	O.R.	29.99
African Mahogany #2	3.6170g	"	"	"	27.68
African Mahogany #3	3.6120g	"	"	"	29.66
MEAN	3.6126g	"	"	"	29.11
Mexican Mahogany #1	3.6137g	18	frequent shaking	O.R.	32.48
Mexican Mahogany #2	3.6070g	"	"	"	33.19
Mexican Mahogany #3	3.6085g	"	"	"	32.59
MEAN	3.6097g	"	"	"	32.74
Cuban Mahogany #1	3.4668g	18	frequent shaking	O.R.	15.85
Cuban Mahogany #2	3.4636g	"	"	"	15.84
Cuban Mahogany #3	3.4631g	"	"	"	16.33
MEAN	3.4611g	"	"	"	16.00

TABLE VI

CONTINUED

Species	Weight of Sample	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
Honduras Mahogany #1	3.7028g	18	frequent shaking	O.R.	17.16
Honduras Mahogany #2	3.6996g	"	"	"	18.07
Honduras Mahogany #3	3.7077g	"	"	"	17.65
MEAN	3.7033g	"	"	"	17.62
Floridian Mahogany #1	2.8848g	18	frequent shaking	O.R.	14.50
Floridian Mahogany #2	2.8783g	"	"	"	14.09
Floridian Mahogany #3	2.8913g	"	"	"	14.51
MEAN	2.8848g	"	"	"	14.36
Bagtician #1	3.7500g	18	frequent shaking	O.	9.41
Bagtician #2	3.7575g	"	"	"	9.22
Bagtician #3	3.7626g	"	"	"	9.60
MEAN	3.7567g	"	"	"	9.41

TABLE VI

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
White Lauan #1	3.8936g	18	frequent shaking	O.T.T.1	3.53
White Lauan #2	3.8927g	"	"	"	3.66
White Lauan #3	3.8898g	"	"	"	3.56
MEAN	3.8953g	"	"	"	3.58
Red Lauan #1	3.7819g	18	frequent shaking	Y.O.	5.99
Red Lauan #2	3.7867g	"	"	"	5.94
Red Lauan #3	3.7832g	"	"	"	5.88
MEAN	3.7839g	"	"	"	5.93
Tanguile #1	3.8516g	18	frequent shaking	Y.O.	4.82
Tanguile #2	3.8549g	"	"	"	4.98
Tanguile #3	3.8588g	"	"	"	4.67
MEAN	3.8551g	"	"	"	4.82

Hot Sodium Hydroxide Extractions

Extracting sawdust with boiling five percent sodium hydroxide for a period of fourteen hours was a pretty harsh extraction process. In this extraction practically all the remaining extraneous components of the wood were removed along with other substances. This particular extraction was carried out solely for the purpose of showing that it does remove the gummy substance of mahogany. The other extractions proved that this substance does resist the action of cold water, hot water, ether and cold sodium hydroxide. No, doubt a quantity of the lignin content of the samples were removed in these extraction. Schorger (13) states that some of the lignin content is removed even through extraction with cold sodium hydroxide solutions.

Experimental

The samples used in the cold sodium hydroxide extractions were transferred to liter flasks connected with reflux condensers. The samples were allowed to digest in vigorously boiling five percent sodium hydroxide for fourteen continuous hours. Table VII shows the percentage of extracted materials for these extractions. The significance of these extractions was not very clear.

The Philippine woods, although totally lacking in the gum content that is typical of the other mahoganies, showed in some cases larger percentages than any of the other species. For instance Bagtician gave results as high as forty percent, while African mahogany, containing a larger quantity of the gum gave only twenty-one percent of extracted substance.

The filtrates of the two groups showed color distinctions similar to those of the cold sodium hydroxide extractions. The filtrates failed to give a precipitate when neutralized with acid; however, it was found that a precipitate formed when an equal volume of alcohol or acetone was added. This precipitate was recovered on a filter paper and dried The materials were soluble in water, but insoluble in many of the organic solvents such as alcohol, ether, chlorform, and acetone. However, there was a slight softening in benzene, gasoline and kerosene.

Various methods of reducing the substance to separate compounds were unsuccessful.

TABLE VII

RESULTS OF HOT SODIUM HYDROXIDE EXTRACTIONS

Samples oven-dry (105° C.)

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
African Mahogany #1	2.5262g	18	refluxed	O.R.	21.64
African Mahogany #2	2.5557g	"	"	"	21.17
African Mahogany #3	2.5405g	"	"	"	22.21
MEAN	2.5408g	"	"	"	21.85
Mexican Mahogany #1	2.3797g	18	refluxed	O	21.26
Mexican Mahogany #2	2.4099g	"	"	"	21.21
Mexican Mahogany #3	2.4333g	"	"	"	20.84
MEAN	2.4076g	"	"	"	21.10
Cuban Mahogany #1	2.9107g	14	refluxed	O.R.	9 .99
Cuban Mahogany #2	2.9064g	"	"	"	10.12
Cuban Mahogany #3	2.8975g	"	"	"	9.92
MEAN	2.9069g	"	"	"	10.01

TABLE VII

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
Honduras Mahogany #1	3.0672g	14	refluxed	O.R.	38.80
Honduras Mahogany #2	3.0295g	"	"	"	41.09
Honduras Mahogany #3	3.0532g	"	"	"	38.21
MEAN	3.0499g	"	"	"	39.36
Floridian Mahogany #1	2.4665g	14	refluxed	R.S.1	28.44
Floridian Mahogany #2	2.4733g	"	"	"	26.86
Floridian Mahogany #3	2.4708g	"	"	"	27.10
MEAN	2.4702g	"	"	"	27.46
Bagtician #1	3.3971g	18	refluxed	Y.O.	40.85
Bagtician #2	3.4108g	"	"	"	40.31
Bagtician #3	3.4011g	"	"	"	38.01
MEAN	3.4030g	"	"	"	39.52

TABLE VII

CONTINUED

Species	Weight of Samples	Time in Hours	Conditions	Color of Filtrate	Percent Extracted
White Lauan #1	3.7559g	14	refluxed	O.T.	16.16
White Lauan #2	3.7502g	"	"	"	17.40
White Lauan #3	3.7608g	"	"	"	16.50
MEAN	3.7556g	"	"	"	16.68
Red Lauan #1	3.5552g	14	refluxed	O.	27.82
Red Lauan #2	3.5617g	"	"	"	27.08
Red Lauan #3	3.5607g	"	"	"	26.81
MEAN	3.5592g	"	"	"	27.23
Tanguile #1	3.6659g	14	refluxed	O.Y.	27.36
Tanguile #2	3.6629g	"	"	"	27.27
Tanguile #3	3.6763g	"	"	"	27.88
MEAN	3.6683g	"	"	"	27.50

PART IV

ASH CONTENT

Determination of Ash

The quantitative determinations of the ash content of the samples used in this study are found in Table VIII. There is no relation between the ash content and the specific gravity of a wood. The table shows that Bagtician, having a specific gravity of . 64 has an ash content of 1.63 percent while Floridian mahogany with a specific gravity of .93 has only .82 percent of ash. Schorger (13) reports that Balsa, one of the lightest of woods, contains 2.0 percent of ash.

In general, the sap wood contains a greater percentage of ash than the heart wood (8). Frequently the ash content is greater in the crown and in the branches than in the trunk. The content of ash materials varies with the age of the tree, usually it is found that the older trees show a decrease in ash content.

The principal metallic components in wood ashes are calcium, potassium, and magnesium. Besides these, small amounts of sodium, maganese, aluminum, iron, sulfates and chlorides are almost invariably present in wood ashes (8). Perhaps the most characteristic, although seldom the most abundant component of wood ashes is potassium carbonate. The presence of this compound explains the value of wood ashes as a fertilizer and as a raw material in the making of

soft soap. In general, the main component of wood ashes is lime. The ash of some of the hard woods has been found to run as high as 70 percent in lime (8).

Experimental

Three samples of each of the nine species were carefully weighed in tared porcelain crucibles. The crucibles with lids were placed in the muffle furnace and allowed to remain at a dull red heat for one hour. The lids were removed and the crucibles were left in the oven until complete combustion had taken place. Occassional stirring insured a more complete combustion. The crucibles were then placed in the desiccator until cool and then weighed. The determinations are based on the oven-dry weights of the samples.

No attempt was made to analyze the ash further for its various mineral components.

TABLE VIII

RESULTS OF ASH DETERMINATIONS

Samples oven-dry (105° C.)

Species	Weight of Sample	Weight of Ash	Percent of Ash Content
African Mahogany #1	1.1346g	.0435g	3.83
African Mahogany #2	1.0308g	.0405g	3.83
African Mahogany #3	2.5959g	.0989g	3.80
MEAN	1.5871g	.0609g	3.82
Mexican Mahogany #1	1.2263g	.0081g	.66
Mexican Mahogany #2	3.3260g	.0219g	.63
Mexican Mahogany #3	1.3576g	.0082g	.60
MEAN	1.9696g	.0113g	.63
Cuban Mahogany #1	2.4173g	.0126g	.52
Cuban Mahogany #2	2.9894g	.0150g	.50
Cuban Mahogany #3	1.7070g	.0087g	.50
MEAN	2.3712g	.0121g	.51

TABLE VIII

CONTINUED

Species	Weight of Sample	Weight of Ash	Percent of Ash Content
Honduras Mahogany #1	2.0478g	.0083g	.41
Honduras Mahogany #2	2.1899g	.0088g	.40
Honduras Mahogany #3	1.1071g	.0053g	.42
MEAN	1.7816g	.0071g	.42
Floridian Mahogany #1	3.1898g	.0306g	.82
Floridian Mahogany #2	2.1293g	.0171g	.80
Floridian Mahogany #3	1.6534g	.0136g	.82
MEAN	2.3041g	.0204g	.81
Bagtician #1	1.4510g	.0220g	1.51
Bagtician #2	1.5044g	.0235g	1.56
Bagtician #3	1.5521g	.0240g	1.54
MEAN	1.5025g	.0231g	1.53

TABLE VIII

CONTINUED

Species	Weight of Sample	Weight of Ash	Percent of Ash Content
White Lauan #1	2.1230g	.0090g	.42
White Lauan #2	1.4028g	.0058g	.41
White Lauan #3	2.3400g	.0093g	.40
MEAN	1.9552g	.0080g	.41
Red Lauan #1	1.2975g	.0083g	.64
Red Lauan #2	1.7310g	.0109g	.63
Red Lauan #3	1.2622g	.0078g	.62
MEAN	1.4302g	.0090g	.63
Tang-uile #1	1.5562g	.0040g	.28
Tang-uile #2	1.9655g	.0058g	.30
Tang-uile #3	2.1370g	.0062g	.29
MEAN	1.8862g	.0053g	.29

PART V

SPECIFIC GRAVITY

Determination of Specific Gravity

The method pursued for the determination of the specific gravities of the samples used in this study was conducted as directed by the Forest Products Laboratory (14). The specific gravity of a wood is a good indication of the strength properties of the wood. But again I might add that to get a true picture of the species a larger number of samples should be used in all determinations. The specific gravity of a substance is its weight divided by the weight of an equal volume of water. The specific gravity determinations in this study are based on the oven-dry samples of kiln dried woods.

Experimental

Table VIII gives the results for these determinations. Two methods for computing the volume of the samples were used; however, the table is based on the volume as found by measurements. The samples were cut to cubes, three fourths of an inch in each dimension and their volumes calculated in terms of cubic centimeters. The samples were allowed to remain in the oven for six hours, after which they were cooled and weighed. Three samples of each species were used. The weights of the samples, as shown in

the table, are indicative of the accuracy used in the cutting of the samples.

A check on the volume calculations was run by determining the amount of water the wood displaced when immersed. This was accomplished by placing a beaker of water on the laboratory balance and taking the weight of the container. A glass rod fastened to a stand was used to push the piece of wood under the surface of the water. The samples were dipped in hot paraffin, and any excess was removed through scraping. A small hole was punched in each sample to aid in keeping it under the water while a reading of the weight was being taken. It was found that the determinations, as computed by measurements varied but .02 with those as calculated by displacement.

The following formula for the determination of the specific gravity was used:

$$\text{Specific Gravity} = \frac{D}{V}$$

D = Weight in grams

V = Volume in c.c.

TABLE IX

RESULTS OF SPECIFIC GRAVITY DETERMINATIONS

Samples oven-dry (105° C.)

Species	Weight of Sample	Volume by Measurement	Specific Gravity
African Mahogany #1	3.3484g	6.9138 c.c.	.48
African Mahogany #2	3.3950g	"	.49
African Mahogany #3	3.2270g	"	.47
MEAN	3.3234g	"	.48
Mexican Mahogany #1	3.1495g	6.9138 c.c.	.45
Mexican Mahogany #2	3.0979g	"	.45
Mexican Mahogany #3	3.1680g	"	.45
MEAN	3.1381g	"	.45
Cuban Mahogany #1	3.9980g	6.9138 c. c.	.56
Cuban Mahogany #2	3.9250g	"	.55
Cuban Mahogany #3	4.0490g	"	.57
MEAN	3.9910g	"	.55

TABLE IX

CONTINUED

Species	Weight of Sample	Volume by Measurement	Specific Gravity
Honduras Mahogany #1	3.4750g	6.9138 c.c.	.50
Honduras Mahogany #2	3.5690g	"	.51
Honduras Mahogany #3	3.3550g	"	.49
MEAN	3.4660g	"	.50
Floridan Mahogany #1	6.2950g	6.9138 c.c.	.91
Floridan Mahogany #2	6.4930g	"	.93
Floridan Mahogany #3	6.4850g	"	.93
MEAN	6.4240g	"	.93
Bagtician #1	4.4950g	6.9138 c.c.	.65
Bagtician #2	4.4690g	"	.64
Bagtician #3	4.4840g	"	.64
MEAN	4.4820g	"	.64

TABLE IX

CONTINUED

Species	Weight of Sample	Volume by Measurement	Specific Gravity
White Lauan #1	3.1510g	6.9138 c.c.	.45
White Lauan #2	3.0820g	"	.44
White Lauan #3	3.1550g	"	.45
MEAN	3.1290g	"	.45
Red Lauan #1	3.3440g	6.9138 c.c.	.48
Red Lauan #2	3.3140g	"	.47
Red Lauan #3	3.2170g	"	.46
MEAN	3.2910g	"	.47
Tang-uile #1	.4540g	.8307 c.c.	.54
Tang-uile #2	.4450g	"	.53
Tang-uile #3	.4320g	"	.52
MEAN	.4430g	"	.53

PART VI

CONCLUSIONS

Conclusions

The gum that is found in the species of African and Tropical American mahoganies is insoluble in most of the organic solvents. It is believed by the writer that there is a possibility of finding a solvent for this substance. Perhaps a mixture of several organic solvents would be the answer to the problem, however, such a procedure would require an indefinite amount of research. The refluxing of the sawdust with five percent sodium hydroxide for a period of fourteen hours is a method for the removal of the gummy substance. This process alters the product and is not considered satisfactory. The object is to extract the material and to recover it unchanged and not just to effect its removal from the wood.

The results of the various extractions are indicative of the fact that there are possibilities of obtaining data that may be used in distinguishing the various species of mahogany. Indentification of mahogany by the character of the various extract filtrates obtainable from them is an excellent problem for further research. An examination of the tables giving the results of the various extractions, suggests that there might be some relation between the solubility of a wood in certain solvents and their specific gravities.

Table X is a summary of the analytical data obtained in this study. This table differs from the other tables in that the percentages are based on the original 4.000 gram weight of the sample. For instance, the sample of African mahogany was extracted w with cold water and 3.63 percent of its weight was dissolved. The remaining 3.8621 grams were extracted with hot water and 3.78 percent of the original 4.000 grams were removed. This method of calculation was used in all the determinations as shown in Table X.

The scope of this particular problem is vast, and to the best of my knowledge no serious attempt has ever been made to bring together any analytical data, pertaining solely to the chemistry of mahogany. It is hoped that this experimental investigation will result in a more thorough and comprehensive study of the chemical possibilities of the mahoganies.

TABLE X

EXPERIMENTAL DATA FOUND IN THIS STUDY

TABLE X

EXPERIMENTAL DATA FOUND IN THIS STUDY

Results in percentage of oven-dry (105°C.) samples

Species	SOLUBILITY					Ash	Specific Gravity
	Cold Water	Hot Water	Ether	Cold Four Percent Sodium Hydroxide	Hot five Percent Sodium Hydroxide		
African	3.62	3.78	2.26	28.79	13.97	3.82	.48
Mexican	3.58	3.14	3.04	30.05	12.71	.63	.45
Cuban	5.61	5.75	2.09	13.85	7.46	.51	.55
Honduras	1.28	5.59	.53	16.33	30.18	.42	.50
Floridian	15.12	9.25	3.39	10.36	17.01	.81	.93
Bagtician	1.64	2.47	1.96	8.84	33.62	1.53	.64
White Lauan	.71	.30	1.58	3.41	15.42	.41	.45
Red Lauan	.76	2.42	2.23	5.61	24.24	.63	.47
Tanguile	.99	1.16	1.47	4.66	25.20	.29	.53

Bibliography

1. Anonymous, True Botany of Mahogany, Reprint from Hardwood Record, Chicago, October 1935.

2. Armstrong, Frankland, The Carbohydrates and the Glucosides, Langmans, Green and Company, New York, 1924, 187, 195.

3. Doree, Charles, The Methods of Cellulose Chemistry, D. Van Nostrand Company, New York, 1933, 109.

4. Fritsche, Ferdinand, Process for the Production of a Soluble Gum, United States Patent Office, Patent No. 900,274, 1908.

5. Graves, Henry S., True Mahogany, Bulletin No. 474, United States Department of Agriculture, 1927.

6. Greely, William B., The Identification of True Mahogany, Bulletin No. 1050, United States Department of Agriculture, 1922.

7. Hawk, Philip and Bergiem, Olaf, Practical Physiological Chemistry, P. Blakiston's and Company, Philadelphia, 1927, 891.

8. Hawley, L.F., and Wise, L.E., The Chemistry of Wood, Catalog Company, New York, 1926, 97-122, 134, 119, 120.

9. Heaton, Noel, Volatile Solvents and Thinners, D. Van Nostrand Company, New York, 1926.

10. Lamb, George, The Mahogany Book, Mahogany Association Inc., Chicago, 1936.

11. Mulliken, A Method for the Identification of Pure Organic Compounds, Color Charts, John Wiley and Sons, New York, 1904.

12. Ritter, George J., Recent Correspondence, United States Forest Products Laboratory, July, 1937.

13. Schorger, A.W., Chemistry of Cellulose and Wood, McGraw-Hill Book Company, New York, 1926, 141-142, 147, 86, 50.

14. Technical Note, Method for the Determination of Specific Gravity of Wood, Forest Products Laboratory.

15. Thatcher, R.W., The Chemistry of Plant Life, McGraw-Hill Book Company, New York, 1921, 67-75.