AN ABSTRACT OF THE THESIS OF

FRANK EDWARD CASKEY

for the...........in............

Date Thesis presented----------------- JUNE 1941

Title------------------------------------- A STUDY OF THE NATURE OF BENZYL ALCOHOL

LIGNIN-------------------------------------

Abstract Approved:---------------------- (Major Professor)

Extraction of lignin from white fir wood meal using benzyl alcohol is described. Benzyl alcohol lignin has been extracted and studied by methylation procedures. A molecular size of the lignin building unit of 892 for white fir lignin has been determined, and this figure is in pretty close agreement to that determined by Brauns (2) for spruce, considering that lignins from different sources are not entirely similar. The presence of a carbonyl group and hydroxyl groups (one acidic and three alcoholic) has been demonstrated.
A STUDY OF THE NATURE OF BENZYL ALCOHOL LIGNIN

by

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A THESIS

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INTRODUCTION

The study of lignin has received great impetus in recent years as a result of the increased interest in the importance of this material as a recoverable waste product of the cellulose industries. Present attempts to find means and methods of utilizing this material are handicapped by an incomplete knowledge of its structure, properties, and reactions. Although many investigators have tried to clarify these topics, results have been conflicting and incomplete.

It has been definitely shown that lignin is made up of only carbon, hydrogen, and oxygen. Although investigators have failed to prove that lignin is a true compound it is generally conceded to have several functional groups that are found in all samples of the material (14). Some of these groups are the methoxyl ($-\text{OCH}_3$), carbonyl ($-\text{C}=$) and both acidic and alcoholic hydroxyl groups ($\text{OH}$).

The presence of these groups has been established in various ways and quantitative determinations have been made. The results have shown an element of inconsistency due for the most part to the fact that the lignin has been obtained by different methods and from various sources.
The methoxyl group has been shown to exist in lignin by treatment of the substance with constant-boiling hydroiodic acid. It has been definitely proven that no other alkoxy1 group than the methoxyl is present (1, 15). The fact the lignin forms a hydrazone derivative and a semicarbazide derivative indicates the presence of a carbonyl group (9). The formation of an acetal derivative substantiates the previous observation, and also indicates that the carbonyl exists as an aldehyde. The presence of hydroxyl groups have been ascertained by acetylation and methylation procedures.

In a recent publication F. E. Brauns (2) has studied the functional groups of lignin. He has determined the number of hydroxyl, carbonyl and methoxyl groups in the spruce lignin molecule.

Brauns' "native" lignin was obtained from spruce meal by a very careful procedure and under strictly controlled conditions. He extracted the lignin with ethyl alcohol at room temperature without the use of an acid or base. However his yield was very low (less than two per cent based on the original wood).

In spite of the apparent similarity in the properties of this native lignin to that existing in wood, it is not justified to assume this sample is representative of the
whole, as Brauns obtained only a small fraction (six percent) of the total lignin.

All the procedures using alcohol to dissolve the lignin from the wood have been limited in that not all the lignin present was extracted. Desiring to overcome this difficulty by finding a method that would extract all the lignin Friedman and McCully (5) found that by the use of benzyl alcohol and three percent hydrochloric acid as a catalyst, almost all the lignin (26 percent of the wood in the case of hemlock and 25 percent in the case of fir) was recovered.

However, since the methoxyl values determined on the lignin extracted with benzyl alcohol were low, Friedman and Erickson (7) investigated the lignin by employing a fractionation procedure with various solvents. The results obtained indicated "benzyl alcohol lignin is a mixture of substances and probably is a degradation product of native lignin."

Before extraction of lignin with benzyl alcohol in the presence of acid can be accepted as a satisfactory method for obtaining lignin for further experimental study, it is evident that a better insight into the nature of this material must be obtained. The present investigation was undertaken to study the composition of benzyl alcohol lignin and to determine whether or not it is a compound
of lignin with benzyl alcohol.

In order to accomplish this it was planned that the lignin extracted by benzyl alcohol and three per cent hydrochloric acid be purified by a series of reprecipitations from dioxane solutions until the methoxyl content became constant.

A determination of the carbon-hydrogen ratio makes possible the calculation of an empirical formula. From the per cent methoxyl and molecular weight, the number of methoxyl groups per molecule can be calculated. After methylation with diazomethane, redetermination of the methoxyl content makes possible the calculation of acidic hydroxyls. Since diazomethane methylates only carbonyl groups and acidic hydroxyls, the increase in number of methoxyl groups will show the number of the former groups. It will also indicate whether the carbonyl exists as a free group or has been attacked (i.e., to form an acetal compound.)

Further methylation of this diazomethane-methylated lignin with dimethylsulfate and redetermination of methoxyl content establishes the number of alcoholic hydroxyls.
EXPERIMENTAL WORK

Preparation of Lignin.

Lignin IV was extracted according to the following directions. Twenty-five grams of resin-free wood flour obtained from white fir sawdust were constantly stirred at a temperature of 105° C. with 250 ml. of benzyl alcohol and 34 ml. of concentrated hydrochloric acid. The reaction was carried out in a 500 ml. round bottom flask. After one hour the mixture was filtered while hot on a Büchner funnel and washed with 50 ml. of hot benzyl alcohol. The filtrate was then transferred to a vacuum distillation apparatus similar to that shown in Figure I.

The benzyl alcohol was distilled at reduced pressure with a stream of hydrogen bubbling through the liquid. A Kipp generator was used as a reservoir for hydrogen in order to regulate the pressure in the distilling apparatus at 20 mm. Water was used as the confining liquid in the generator. A Claissen flask was used in order to prevent the mixture from bumping over into the receiver. It was found that the use of hydrogen was far superior to glass wool in distilling the benzyl alcohol. The distillation was carried on until near dryness.

After the flask cooled down, dioxane was added and the mixture was carefully refluxed for about fifteen
minutes. After cooling the dioxane was distilled off until the volume remaining in the flask was about 25–30 ml. This mixture was centrifuged and the clear solution was then poured slowly into two liters of well-stirred ether. The lignin was allowed to settle and the supernatant liquid was poured off. The remaining mixture was then filtered through an alundum crucible and dried in a vacuum oven at 60° and 20 mm.

Lignin V was extracted by the use of benzyl alcohol and dry hydrogen chloride. A certain weight of hydrogen chloride (determined by difference) was passed into a given weight of benzyl alcohol. This solution was then diluted until the hydrogen chloride content was three per cent. The same procedure for removal of benzyl alcohol was used as in the case of Lignin IV.

In the preliminary stages of the work three samples of lignin were extracted. Lignin I was extracted with benzyl alcohol and dry hydrogen chloride. These two lignins were extracted under the same conditions as Lignins IV and V. After the cellulose residue had been removed by filtration, the lignin solution was poured into ether.

In a similar manner Lignin III was extracted with aqueous hydrochloric acid and benzyl alcohol. Because the presence of benzyl alcohol in the ether during precipitation tends to keep considerable amounts of the lignin in
Vacuum Distillation
Apparatus

Fig. 1.
solution (§) the procedure was modified to obtain a better yield. After the cellulose residue was washed with hot benzyl alcohol, the solution was transferred to an ordinary distilling flask which was then packed with glass wool, and set up for a vacuum distillation. Trouble was encountered as the material bumped over into the receiver. However, after several attempts the alcohol was distilled off but difficulty was encountered as the glass wool adsorbed the alcohol and prevented the complete removal of alcohol. Since fewer difficulties were encountered in the preparation of samples IV and V, these were used in the methylation studies.

**Purification.**

The lignin samples obtained in the first three preparations were purified in a similar manner. The lignin was treated with dioxane by allowing it to remain in contact with the lignin for a few hours. Then the dioxane solution was drained off from the material by applying suction. The solution was then poured slowly into 2 liters of vigorously stirred distilled water. The procedure was repeated twice to dissolve all of the soluble fraction.

Usually the precipitate would be settled after standing over night, but occasionally a colloidal suspension would be formed. The suspension was decanted and floccu-
lated with sodium sulfate. The residue, remaining after the suspension had been decanted, was filtered through an alundum crucible and was kept separate.

Since it was found that complete solution did not take place when the above procedure was used, lignins IV and V were dissolved in dioxane (enough to make a ten per cent solution) by extraction on the Bailey-Walker apparatus. This solution was then poured into well-stirred water resulting in the formation of a light brown precipitate in the case of the lignin made with aqueous hydrochloric acid and a dark gray precipitate for the lignin prepared by the use of dry hydrogen chloride. Subsequent treatment was as above.

Procedure for Methoxyl Determination.

The Zeisel method (18) or some modification of it (1, 3, 4, 5, 12, 16, 17) is the most commonly used method for determining the methoxyl content. Attempted determinations made by this method showed so much variation that it was discarded and a procedure developed at Oregon State College by Christensen and Sato (5) was adopted. This procedure differs chiefly in the apparatus used.

From 3-5 mg. of lignin weighed in a porcelain boat were introduced into the reaction chamber (A) along with a few crystals of phenol, and 4-5 drops of acetic anhydride.
The vessel was then connected to the air-condensing unit. (See Figure II).

The U-tube (E) was removed and charged with 0.5 ml. of both 5 per cent cadmium sulfate and sodium thiosulfate solutions, and connected to the apparatus. The absorption flask was charged with 2 ml. of 10 per cent sodium acetate-glacial acetic acid solution and 5 drops of bromine. The flask was evacuated by means of a water pump and connected to the open end of the U-tube (E).

Two ml. of hydriodic acid were introduced through the capillary stopcock, which is connected to an open Kipp generator. The flow of the carbon dioxide was then regulated to approximately 15 bubbles per minute and the reaction vessel brought to a temperature of 130-140° by means of a phosphoric acid bath. After about twenty minutes the rate of gas flow was increased to 30-40 bubbles per minute until the flask came to atmospheric pressure.

After the heating operation which took 30-45 minutes, the flask was disconnected; 5 ml. of 20 per cent sodium acetate were added to the flask; the male joint was again replaced and the flask was shaken. In order to get accurate results, it was found necessary that the flask be thoroughly shaken after the sodium acetate solution was added. It was the writer's experience that when this precaution was not taken a consistently low value was obtained.
Formic acid was then added dropwise and the flask was shaken until the solution became colorless. The male joint was then removed and the adhering liquid was washed into the flask. Four to six drops of formic acid were added in excess. Two ml. of 10 per cent potassium iodide were then introduced and the solution acidified with 5 ml. of 2 N sulfuric acid.

The liberated iodine was titrated with standard sodium thiosulfate solution. From this data the methoxyl content can be calculated by the use of the following equation:

\[ \% \text{OCH}_3 = \left( \frac{31 \text{ (ml. of sodium thiosulfate)}}{(\text{Normality})(100)} \right) \]

The apparatus was standardized by running samples of vanillin and anisic acid.

**Preparation of Constant-Boiling Hydriodic Acid.**

In this work, the hydriodic acid was the constant-boiling fraction of the hydriodic acid manufactured and distributed by General Chemical Co. The acid was distilled from red phosphorous in a distilling outfit (shown in Figure III) which had a flask with a neck of such length that a thermometer could be introduced and yet the acid would not come in contact with the rubber connections. The necessity of this precaution was emphasized by Christensen and Sato (5) who pointed out that an error is introduced by the
action of hydriodic acid on any organic matter similar to rubber stoppers or corks.

When the temperature reached 125°, the remaining material in the distilling flask was transferred to an all-glass apparatus (Figure IV) and the remainder was distilled off. The specific gravity was determined as a check of the concentration.

It was found advantageous as well as economical to re-use the excess hydriodic acid after the methoxyl determination was made.

**Procedure for Methylation with Diazomethane.**

A modification of the method of Pechman (13) for making diazomethane by the action of alkali on N-nitrosomethylurethane, was employed in this work.

Six-tenths ml. of nitrosomethylurethane was dissolved in 15 ml. of ether and 1 ml. of a methyl alcohol solution containing 25 per cent potassium hydroxide, was added. The flask was warmed and a slight stream of nitrogen was introduced to carry the diazomethane over. The diazomethane was collected in a series of test tubes containing 2 ml. of ether in the first; 1 ml. in the second; and 0.5 ml. in the third. The procedure was carried out until only a faint yellow color remained in the flask.

This ethereal solution of diazomethane was added to
Long-neck distilling flask

rubber connection

Thermometer

Fig. III.
All Glass
Distilling Apparatus

Fig. 1 V

Standard taper joints
the dioxane solution of lignin and a large number of bubbles of nitrogen was given off. The beaker, containing the solution was permitted to stand over night.

After methylation was repeated twice, the material was centrifuged and the supernatant liquid was separated and poured into ether to precipitate the product. A light yellow precipitate formed and settled immediately. This methylated lignin was centrifuged and dried.

**Procedure for Methylation with Dimethylsulfate.**

In the methylation of the lignin with dimethylsulfate, the following method was used as modified from the directions of Harold Hibbert and George F. Wright (11) and F. E. Brauns (2).

The diazomethane-methylated lignin (0.5 g.) was dissolved in 5 ml. of dioxane and methylated twice at 20°C. with 5 ml. of dimethylsulfate and 7 ml. of sodium hydroxide solution (30 per cent) keeping the mixture only slightly alkaline. After eight hours of stirring the dioxane had evaporated off and the methylated lignin precipitated as an orange-colored material. This material was centrifuged, followed by washing with ether. The ether was evaporated and the solid dried in a desiccator of phosphorous pentoxide. The compound was redissolved in dry dioxane and dropped into ether with vigorous stirring whereupon the methy-
lated lignin was precipitated as a cream-colored material. It was centrifuged, washed with ether, and dried. Part of the material was dried in an Abderhalden drier at 100° over phosphorous pentoxide at 20 mm. for a few minutes. It was remethylated as before and then a final methoxyl content was determined. The lignin dried in the Abderhalden drier had a higher methoxyl value than that dried in the desiccator.
EXPERIMENTAL RESULTS

Figure V shows schematically the procedures used for the extraction and purification of Lignin IV and for the preparation of the methylated derivatives. Table I gives the experimental results obtained in the analysis of these products for the methoxyl content and carbon-hydrogen ratio.

Figure VI shows procedures used for preparation of Lignin V and its derivatives. It is to be noted that wood was extracted with benzyl alcohol containing dry hydrogen chloride rather than aqueous hydrochloric acid as was the case in preparing Lignin IV. Since the methoxyl values obtained for corresponding materials were the same as those for Lignin IV, it appears that the presence of water in the benzyl alcohol used in preparing lignin IV had no influence.
OUTLINE OF STUDY

White Fir Meal

\[ \text{Cellulose residue} \quad \downarrow \quad \text{Lignin solution (Alcohol evaporated and lignin dissolved in dioxane which is poured into an excess of ether.)} \]

\[ \text{(Extracted with benzyl alcohol containing 3\% dry hydrogen chloride.)} \quad \downarrow \quad \text{Lignin precipitate (39) yield = 20\%} \]

\[ \text{Residue} \quad \downarrow \quad \text{Lignin precipitate (44) yield = 74\%} \]

\[ \text{(Dissolved in dioxane (52\% soluble) which was then poured into an excess of water.)} \quad \downarrow \quad \text{Lignin precipitate (48) yield = 77\%} \]

\[ \text{(Dissolved in dioxane and re-precipitated from ether.)} \quad \downarrow \quad \text{(Methylated with CH}_2\text{N}_2\text{.)}} \]

\[ \text{Partially methylated lignin (50)} \quad \downarrow \quad \text{(Methylated with (CH}_3\text{)}_2\text{SO}_4\text{.)} \]

\[ \text{Completely methylated lignin (52)} \]

FIGURE V
White Fir Meal

(Benzyl alcohol containing aqueous HCl (3% HCl)

Cellulose residue

Solution of lignin

(Alcohol evaporated and residue dissolved in dioxane and precipitated in excess of ether

Lignin precipitate (32)
yield = 16.9%

(Dissolved in dioxane 95% soluble)

Negligible residue

Dioxane solution of lignin

(Poured into excess water)

Lignin precipitate (35)
yield = 81%

(Methylated with CH₂NH₂

Partially methylated derivative (51)

(Methylated with dimethylsulfate)

Completely methylated derivative with Na₂SO₄)

Suspension

Lignin precipitate (41)

yield = 7%

Evaporated and again poured into excess ether

Precipitate (37)
yield = 1.05%

Solution

Negligible Dioxane solution residue of lignin

(Poured into excess water)

Suspension

Lignin precipitate (49)

Completely methylated with Na₂SO₄.)

FIGURE VI
**TABLE I**

ANALYSES OF BENZYL ALCOHOL LIGNIN AND DERIVATIVES

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Substance</th>
<th>%-OCH₃</th>
<th>% C</th>
<th>% H</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Impure B.L.*</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Purified B.L.</td>
<td>11.3</td>
<td>68.8</td>
<td>5.71</td>
</tr>
<tr>
<td>49</td>
<td>38 after one more re-preditation</td>
<td>11.3</td>
<td>69.3</td>
<td>5.71</td>
</tr>
<tr>
<td>51</td>
<td>B.L. methylated with CH₂NH₂</td>
<td>12.9</td>
<td>67.8</td>
<td>6.07</td>
</tr>
<tr>
<td>53</td>
<td>B.L. methylated with (Me)₂SO₄</td>
<td>21.6</td>
<td>68.0</td>
<td>5.99</td>
</tr>
</tbody>
</table>

B.L.* - Benzyl alcohol lignin

**TABLE II**

METHOXYL VALUES FOR LIGNIN V

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Substance</th>
<th>%-OCH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Impure B.L.*</td>
<td>10.2</td>
</tr>
<tr>
<td>44</td>
<td>B.L. purified once</td>
<td>11.3</td>
</tr>
<tr>
<td>48</td>
<td>B.L. purified twice</td>
<td>11.3</td>
</tr>
<tr>
<td>50</td>
<td>B.L. methylated with CH₂N₂</td>
<td>13.1</td>
</tr>
<tr>
<td>52</td>
<td>B.L. methylated with (Me)₂SO₄</td>
<td>21.6</td>
</tr>
</tbody>
</table>

B.L.* - Benzyl alcohol lignin
DISCUSSION OF RESULTS

Brauns (2) by use of ethanol in the absence of any acid has prepared lignin samples that he claims are actually "native" lignin. He has further pointed out that extraction of lignin from wood by use of alcohols in presence of acids tends to yield a derivative of the lignin due to an acetal formation at a carbonyl group of the lignin.

Brauns gives as the formula of native lignin obtained from spruce wood the following:

\[
\begin{align*}
\text{CH}_2\text{O} & - \\
\text{CH}_2\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{C}_4\text{H}_8\text{O}_6 & \\
\text{OH} & \\
\text{OH} & \\
\text{OH} & \\
\text{OH} & \\
\text{C}=\text{O} & \\
\end{align*}
\]

He also gives the formula for methanol lignin (prepared by extraction of spruce wood with methanol and hydrochloric acid):

\[
\begin{align*}
\text{CH}_3\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{C}_4\text{H}_8\text{O}_6 & \\
\text{OH} & \\
\text{OH} & \\
\text{OH} & \\
\text{OH} & \\
\text{C}=\text{O} & \\
\text{OCH}_3 & \\
\text{OCH}_3 & \\
\end{align*}
\]

The first of the above compounds has a theoretical methoxyl content of 14.8 per cent, and the second 21 per cent.

Since the methoxyl content of benzyl alcohol was
found to be only 11.3 per cent, it seems reasonable to assume that a similar reaction has taken place between the benzyl alcohol and the lignin. On the assumption that benzyl alcohol lignin has four methoxyl groups per molecule, the molecular weight of the compound can be calculated. Then by use of the carbon-hydrogen analysis an empirical formula can be set up. The formula so obtained for benzyl alcohol lignin from white fir wood is

\[
\begin{align*}
\text{CH}_3\text{O} & - \\
\text{CH}_2\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{CH}_2\text{O} & - \\
\end{align*}
\quad \text{C}_4\text{H}_2\text{O}_7
\]

\[= \text{C}_9 \text{OCH}_2\text{C}_6\text{H}_5\]

This would give for the formula of native white fir lignin:

\[
\begin{align*}
\text{CH}_3\text{O} & - \\
\text{CH}_2\text{O} & - \\
\text{CH}_3\text{O} & - \\
\text{CH}_2\text{O} & - \\
\end{align*}
\quad \text{C}_4\text{H}_2\text{O}_7
\]

\[= \text{C} = 0\]

When lignin is methylated with diazomethane, only the carbonyl group and one of the hydroxyl groups (presumably an acidic or phenolic hydroxyl group) are methylated. Since in the case of benzyl alcohol lignin, the carbonyl group is no longer available one would expect that only one methoxyl group should be added per molecule
to form a derivative having the formula:

\[
\begin{array}{c}
\text{CH}_3\text{O} \\
\text{CH}_2\text{O} \\
\text{CH}_2\text{O} \\
\text{CH}_3 \\
\text{C}_{44}\text{H}_{32}\text{O}_7
\end{array}
\]

This compound has a methoxyl content of 14.1 per cent.

The derivative prepared, however, had a methoxyl content of 12.9-13.1 per cent (Lignins IV and V respectively).

A possible reason for this discrepancy might be that the acid hydroxyl group is adjacent to the carbonyl group and attachment of the two benzyl groups causes too much hindrance for methylation to take place with diazomethane, a mild methylating agent.

Complete methylation with dimethylsulfate in sodium hydroxide should give a compound containing 21.6 per cent methoxyl and having the formula:

\[
\begin{array}{c}
\text{CH}_3\text{O} \\
\text{CH}_2\text{O} \\
\text{CH}_2\text{O} \\
\text{CH}_3 \\
\text{C}_{44}\text{H}_{32}\text{O}_7
\end{array}
\]

The compound prepared had a methoxyl content of 21.6 per cent.

In Table III are given the theoretical methoxyl values
and carbon-hydrogen* contents of the compounds based on the above formulas and actual values found by experiment. For comparison, Brauns' values for his "native" lignin have also been included.

The agreement seems definite enough so that it is considered that this investigation has established that benzyl alcohol lignin prepared by the method of McCully and Friedman (8) is actually a compound of lignin with benzyl alcohol and not true or native lignin. The formula for native white fir lignin obtained from this work is in very good agreement with that reported by Brauns for spruce lignin. It is not to be expected that the exact formula should be obtained, since it is acknowledged by all investigators that there are slight differences in lignins from different woods.

*Carbon-hydrogen values were determined by Robert Wong by use of a modified Pregl micro-combustion apparatus designed and built by Wong, Gouley, and Christensen.
<table>
<thead>
<tr>
<th>Lignin Derivative</th>
<th>Mol. wt.</th>
<th>CH₃O</th>
<th>OH</th>
<th>Calc'd</th>
<th>Found</th>
<th>Calc'd</th>
<th>Found</th>
<th>Calc'd</th>
<th>Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Lignin</td>
<td>892.4</td>
<td>4</td>
<td>4</td>
<td>13.9</td>
<td></td>
<td>65.9</td>
<td></td>
<td>5.41</td>
<td></td>
</tr>
<tr>
<td>Benzyl Alcohol Lignin (B.L.)</td>
<td>1090.5</td>
<td>4</td>
<td>4</td>
<td>11.35</td>
<td>11.3</td>
<td>69.2</td>
<td>68.8</td>
<td>5.71</td>
<td>5.71</td>
</tr>
<tr>
<td>B.L. methylated with CH₂N₂</td>
<td>1104.5</td>
<td>5</td>
<td>3</td>
<td>14.1</td>
<td>12.9</td>
<td>69.5</td>
<td>67.8</td>
<td>5.84</td>
<td>6.07</td>
</tr>
<tr>
<td>B.L. methylated with Me₂SO₄</td>
<td>1146.6</td>
<td>8</td>
<td>0</td>
<td>21.6</td>
<td>21.6</td>
<td>70.0</td>
<td>68.0</td>
<td>6.16</td>
<td>5.99</td>
</tr>
<tr>
<td>Native Lignin (Brauns)</td>
<td>840.4</td>
<td>4</td>
<td>4</td>
<td>14.8</td>
<td>14.8</td>
<td>65.7</td>
<td>63.8</td>
<td>5.76</td>
<td>6.15</td>
</tr>
</tbody>
</table>
SUMMARY

Extraction of lignin from white fir wood meal using benzyl alcohol is described. Benzyl alcohol lignin has been extracted and studied by methylation procedures. A molecular size of the lignin building unit of 892 for white fir lignin has been determined, and this figure is in pretty close agreement to that determined by Brauns (2) for spruce, considering that lignins from different sources are not entirely similar. The presence of a carbonyl group and hydroxyl groups (one acidic and three alcoholic) has been demonstrated.
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