STUDY ON THE HEMICELLULOSE OF FORMOSAN BAMBOO (Sinocalanus Latiforus Munre)

by

Hoang—Hwa Yang

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Summary. (Chinese)
1. INTRODUCTION

Bamboo is one of the most common plants in Formosa, China, Japan and India. It is regarded in our island as an important item for various economical ends, making poles for various uses, bucket hoops, cages or baskets and paper-pulp, etc., and also as ornamental plant.

The bamboo sends out shoots which consist of two parts, the culms or stems, and the sheaths. The shoots, the young culms, are so tender that they can be eaten boiled, and are greatly esteemed as delicious vegetables by Chinese and Japanese both. The stalks which are interrupted in their internal Communication by the nodes or joints, are enveloped in a sheath which rises from the lower and of each node. In China, Formosa and in some districts of Japan, paper is usually manufactured from the crude pulp prepared from bamboos a year old. But nowadays papers manufactured from bamboo at Taichung and Hwaiienkang by the magnesium sulphite method of Zuchia have no good quality. The color of the paper is more or less yellow after bleaching. The bad bleachability and black spots formation after bleaching of bamboo pulp may due to the hemicellulose, lignin and pectinous substances because the kind of ash present was said have no influence on the quality of paper. And lignin, pentosan, pectin contents of bamboo are exceedingly large compared with ordinary woods such as coniferous. However, recently it was reported that the bamboo pulps were manufactured by Soda Process, have very good quality both in India and China.

The study of the chemical compositions of the bamboos is, therefore, very important from the point of view of industrial chemistry and also of biochemistry.

However, K. Miyake and T. Tadokoro have studied the chemical constituents of the shoots of "Sasa painculata, Shibata and Makino", grown in Hokkaido and confirmed the occurrence of xylan, araban cellulose, glucose, fructose and sucrose, but could not detect any starch, galactan, and methyl pentosan.

Yasuo Sasaoka has investigated the carbohydrate of young shoot of bamboo Madake (Phyllostachys quiliol FM) by means of hydraulic press. From the yielded expressed juice, after treatment with dilute sulphuric acid, he succeeded to isolate 1-(+)
xylose, d-glucose, and glucuronic acid.

While by same treatment Sitezo-ogri has studied the pentosan of culms of Madake and Mosochiku (Phyllostachys mitis) and identified the presence of large quantities of xylose with little amount of arabinose in these hydrolysates.

However, so far as writer has learned, concerning the hemicellulose of bamboo only has been investigated by Fritz Hoyer.

This literature, of course can not be found in our island. Consequently, the results is quite obscure. (In Journal of Chemical Abstract Vol. 38, No. 9, 1944 only reported as follows: Hemicellulose from wood, bamboo, straw, grass etc., Fritz Hoyer (to Akt. Ges. fuer Halbzellstoff-Industrie, Ger. 714, 987, Nov. 20. 1941) (c. f. C. A. 35 8297 1941))
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Present study is a small attempt to clarify the chemical composition of the hemicellulose derived from culm of Formosan bamboo Mazu (Sinocalanus Latiferus Munre).

1.1. Definition and kinds of Hemicelluloses.

This term was applied by Schulze\(^{10}\) (1891) to a group of constituents of the cell membrane which unlike cellulose, were soluble in dilute alkali and were readily hydrolyzed to pentoses and hexoses.

Modern work on the hemicelluloses has shown that in most cases the crude product obtained by alkali extraction can be resolved into several fractions distinguished by their extraction solubilities and hydrolytic products, that many of these fractions contain uronic acids rather than pentosan, constitutes the dominant. Such hemicellulose has been proposed to describe as polyuronides, leaving the older term hemicelluloses for those which yield no uronic acids on hydrolysis.

Table 1. The differentiation of the hemicelluloses.

<table>
<thead>
<tr>
<th>Hemicellulose</th>
<th>Not associated with cellulose fraction</th>
<th>Extracted by dilute alkali</th>
<th>Hydrolysed by hot dilute acid</th>
<th>Associated with natural cellulose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not containing uronic acid</td>
<td>Containing uronic acid</td>
<td>Associated with lignin</td>
<td>Polyuronides</td>
<td>Polyoses</td>
</tr>
<tr>
<td>Hexosans</td>
<td>Pentosans</td>
<td>Hexopentosans</td>
<td>Reserves</td>
<td>Mannan</td>
</tr>
<tr>
<td>Cyto-uronides</td>
<td>Encrusting Substance</td>
<td>Pentose+uronic acid</td>
<td>Hoxose+uronic acid</td>
<td>Pentose+hexose+uronic acid</td>
</tr>
</tbody>
</table>

Hemicelluloses from variety of plant materials have now been isolated and examined but few general conclusions can be drawn, the hemicellulose of woody tissues is almost always of xylan glucuronide type which has a high ratio of xylose to uronic acid. The hemicellulose fractions from mesquite wood, for example, contain 6 to 12 xylose units to one of glucuronic acid\(^ {10}\), the bark of trees, on the other hand, yields a hemicellulose of another type, a galactangalacturonide, thus the bark of Ash\(^ {13}\) (Frayinus excelsior) gives 20 per cent of hemicellulose, the hydrolysis products of which are mainly galactose (with little mannose and arabinose) and galacturonic acid.

In addition, however, the extract contains a contribution from the cellulotic fabric itself, consisting of shorter chain polysaccharides which in situ are oriented and included in the cellulose micelles or reticulate structure, and known as, cellulosans, uronic groups are believed to be largely absent from cellulosans.
1.2. Properties of hemicelluloses.

Hemicellulose preparations are usually non-reducing, and often more or less soluble or dispersible in water, though not originally extractable by water to any appreciable extent. Some may be precipitated from alkaline solution by simple acidification, others only floculate out on the addition of alcohol, acetone, or some similar solvents. They are optically active, more frequently laeo-rotatory than dextro-rotatory. Stable methoxyl groups, presumably in other linkage, appear to be characteristic of many polyuronide hemicelluloses. It seems likely that some of the acetyl groups in wood are associated with the hemicelluloses. These, of course, cannot be found in preparations obtained by alkaline extraction but are present in fractions removed by water from holocelluloses.

1.3. Schematic concept of the possible relationship between the hemicellulose and α-cellulose

The above figure is the scheme derived by Rouis, E. Wise which indicates that the threshold between cellulose and hemicellulose. To obviate schematic difficulties, the designation α-cellulose, deserves amplification. It is defined in analytical terms. It is the alkali-insoluble fibrous residue obtained under carefully controlled condition from mixture of polysaccharides, such as those of found in wood “Cross and Bevan cellulose" or “holocellulose”. Thus, it is largely “true cellulose” (with its long glucopyranose chains). However, it retains some mannose and or xylose and uronic acid unit as well. This “true cellulose" may be defined academically in term of a homopolymer i.e. the alkaliresistant glucose chain in wood.
It is obvious then that α-cellulose and cellulose itself are elusive terms that need clear definition. Either method of definition has its weaknesses. The analytical definition of α-cellulose is dependent on a rigid set of arbitrary definition assumes that only glucose units are present in the resistant cellulose chains that there is no possibility that occasionally mannose, xylose, or glucuronic acid units can occur in such chains. The later assumption is entirely speculative and may be quite unjustified. There are no reliable data either for or against such a hypothesis.

1.4. Structure of hemicellulose.

S. J. Mclory have investigated the structure of hemicellulose of Phormium tenax (N. Z. Flax) by means of methylation and proposed following formula for it.

Hemicellulose of P. tenax.

\[ X_n \times 1:4 X \times 1:4 X_n \]

where: \( n = 9 \) or \( 10 \)

\[ \begin{align*}
X &= \text{xylopyranose.} \\
G &= \text{D-glucuronic acid.}
\end{align*} \]

The calculated equivalent of the hemicellulose (2816-3080) in the formula is in good agreement with equivalent of 3,000 actually found.

1.5. Methods of investigation of hemicellulose.

1.5.1. Methods of isolation of hemicellulose.

a. O'Dwyer's procedure.

Wood is repeatedly extracted with cold 4 per cent NaOH following treatment with water, 0.5 per cent ammonium oxalate and cold 0.2 per cent HaOH, the two former to remove pectic substances, and the later to remove protein, and expedient later found to be unnecessary since the nitrogen content of most wood is exceedingly low.

b. Norris and Preece's procedure.

Prior to extraction employ a pretreatment with boiling alcoholic soda (1 per cent NaOH in 50 per cent ethanol) a device introduced by Norris and Preece with intention of reducing the polysaccharides in alkaline extract. Such treatment later shown to have a serious degradative effect on some hemicellulose, preece later recognized this to be so and concurred in its abandonment.

c. Chlorination procedure (Sand and Nutter).

The moist sawdust is treated with excess chlorine gas, and extracted with cold 10 per cent. \( \text{NH}_4\text{OH} \) solution which removes excess chlorine and halogen acids as well as the lignin rendered of the hemicelluloses is extracted with cold 10 per cent NaOH. The
chlorination and extraction are repeated four times before delignification, and presumably hemicellulose extraction, are complete.

d. Extraction of hemicellulose from holocellulose.

Procedures have now been developed for the complete delignification of cellulosic materials, the residue then containing all or nearly all, the polysaccharides of the cell wall. The “Skelettsubstanzen” of Schmidt\(^\text{20}\) and the “holocellulose” of Ritter and Kurth\(^\text{21}\) are representing the cellulose, cellulosans, and polyuronide hemicelluloses, and which provide good starting materials for the study of the hemicelluloses of hard woods. Since their extraction from such residues can be accomplished by mild methods.

i) Schmidt’s procedure.

By chlorine dioxide succeeding treatment to remove lignin he got “Skelettsubstanzen”.

ii) Ritter and Kurth procedure.

Since Schmidt’s procedure required approximately one month for completion (17-26 days), it was the desire of Ritter and Kurth to device a rapid method suitable for routine purposes. This aim was achieved by repeated alternate treatments of extractive free wood with chlorine and alcohol-pyridine solution, entire operation requiring only the hours for all but a small fraction of the lignin. The residue later removed by a 30-minute treatment with calcium hypochlorite solution (PH 7.0-7.5). The procedure has a further advantage over that of Schmidt in that the chemicals employed do not offer any serious hazards.

iii) Haegglund and Sandelin’s procedure.

In repeating the work of Ritter and Kurth, substituted acetone for the ethanol used in combination with pyridine for extraction of the chlorinated sample.

iv) Monoethanolamine procedure\(^\text{22}\).

Approximately 2 grams of extractive free sawdust (60-80 mesh), whose moisture content is known are chlorinated for three minutes by passing chlorine gas through a funnel inverted over the crucible held in position on a suction flask and kept cool with iced water. The sawdust is then stirred thoroughly and rechlorinated for two minutes.

The excess chlorine and hydrochloric acid produced by the treatment are removed by passing alcohol through sample. The chlorine free sample is allowed to stand in contact with hot alcohol-monoethanolamine mixture for 2 minutes. Then removed with suction. At this stage the hard woods become deep red the soft-woods brown.

The solvent treatment is then repeated. After the second solvent treatment, the sample is washed with 95 per cent ethanol, followed by distilled water. The chlorination and extraction treatments repeated until the residue become white following chlorination and is not colored by the addition of hot alcohol-monoethanolamine.

The author claimed that by this procedure duplicate holocellulose determinations can be made on extractive free wood sawdust in approximately three hours. As further advantages, it is stated that the chemicals used emit no offensive odors, and the distinct color end point is obtained, changing from a light pink or light brown to white on removal of the last trace of lignin.
v) Modification of monoethanolamine procedure.  
Modifying the S. S. Forest Fab. technique Storch and Mueller introduced Cl₂ into moist beech wood shaving under reducing pressure. The temperature rise was slight, and the improvement in chlorine absorption marked.

Each chlorination is followed by washing with H₂O and treatment with a mildly basic solvent (Ca (OH)₂, NH₄OH or Na₂ CO₃) followed by washing and rechlorination. Subsequently material is again washed, bleached with NaClO (0.5% active Cl) for an hour followed by washing.

Each chlorination required about 30 min. with 20 g wood. The holocellulose content calculated on a lignin free basis was 76-77% when NH₄OH or Ca (OH)₂ was used. Holocellulose when treated with 0.2% NaOH lost only about 10% of its original weight, but when such treatment was followed by extn. with 4% NaOH approx. 25% of holocellulose was removed. A loss of 34% of holocellulose was noted when 17.5% NaOH was used. This indicates an α-cellulose content (free from pentosans) of about 43.5%.  

vi) Sodium chlorite procedure.

The advantages of the shortened chlorite-holocellulose procedure are 1) the ease of manipulation. 2) Its reproducibility. 3) The relatively slight degradation of the polysaccharides. 4) The possibility of obtaining large scale laboratory preparations. 5) The fact that it permits the quantitative separation and the study of both the hemicellulose and cellulose fractions, and 6) that it expedites the isolation of small amounts of pectic material found in wood.

Ten-gram sample of air dried unextracted wood prepared by passing through a Wiley mill, are heated to 60°C with a solution containing 50 ml. of water, 50 ml. of acetic acid and 50 g. of sodiumchlorite. After the initial heating the delignification is allowed to proceed at about 80°C for 24 hrs., the mixture being stirred at intervals. At the end of this period the nearly white, which retained its wood structure was filtered by suction and washed with ice water. The hemicelluloses are removed in any desirable number of fraction by successive extractions with aqueous potassium hydroxide in an atmosphere of nitrogen. It was found in this study to begin with 4 to 5% and to end with 24% potassium hydroxide. This procedure is afterward modified by wise, Murphy and Addicott, A. A., so that the total chloriting period could be shortened to 3 to 4 hrs.

vii) Procedure for isolation of hemicellulose directly from wood.

Hemicellulose can be prepared within a single working day and the procedure gives higher yields than do the direct method previously described.

By treating 525 g. air-dried sugar maple sawdust at 65-75°C, with 884 ml, 20% KOH for 2 hrs. then adding 5900 ml. H₂O and heating the stirred suspension for another 2 hrs. an appreciable fraction of the hemicellulose (1) was extracted. The alk. soln. of Hemicellulose was filtered and I was pptd. with an excess of MeOH and bleached with NaClO₂ and AcOH. Hemicellulose obtained in 14.6% yield contained no lignin, 7.1% ash, 2.0% MeO, 76.6% pentosans and 16.67% uronic anhydride. The remaining wood residue, when treated
1.5.2. Methods of identification of hemicellulose.

Identification of component sugars and sugar acids is effected after hydrolysis, usually by boiling with dilute acid or sometimes by pressure treatment. Qualitative methods that have been used in the identification of the sugars ordinarily occurring in hemicelluloses involve mainly the preparation of osazones or some other characteristic derivatives. The benzimidazole compounds and paper partition chromatography, should prove particularly valuable for this purpose. Procedures applicable in the characterization of the uronic acid has been summarized by Norman.


i) Preparation of the osazone.

ii) Preparation of xylopic acid-cadmium bromide double salt.

iii) Detection of small amounts of arabinose in xylose preparations.

After removing the bulk of the xylose by crystallization the syrup (0.5 g.) in 75% alcohol (6 ml.) is treated with $\alpha$-benzy. phenylhydrazine (0.5 g.). After 12 hrs. arabinose benzyl-phenyl hydrazone is precipitated and is crystallized from alcohol. M. P. 172°

iv) A simple microbiological method has been developed which permits the determination of 12 to 50 mg. of xylose in the presence of glucose, mannose, arabinose, and glucuronic acid, with an accuracy of 96 to 104%. It depends on the use of Hansenula suaveolens (N. R. R. L. No. 838) which ferments xylose quantitatively but not arabinose, rhamnose, and glucuronic acid. Inasmuch as N. R. R. L. No. 838 also ferments glucose, the hexoses must be fermented prior to its use. Such fermentation is effected by Saccharomyces carlsbergensis (N. R. R. L. No. 379), which has only a very slight action on xylose, an error for which due correction may be made.

b. Identification by preparation of benzimidazole compounds.

The procedure is based on the combination of 1) a potassium hypoiodate methanol oxidation and 2) the use of O-phenylenediamine as reactant for the characterization of the resulting aldonic acids as benzimidazole derivatives according to the following equation.

$$\text{C}_{n}\text{(CHOH)}_m\text{C}_6\text{H}_5\text{N}_2\text{H}_2\text{O} \rightarrow \text{C}_{n}\text{(CHOH)}_m\text{C}_6\text{H}_5\text{N}_2\text{H}_2\text{O} + 2\text{H}_2\text{O}$$
Louis, E. Wise recently reported, paper partition chromatography was applied to the separation of simple sugars obtained by partial hydrolysis of holocellulose, cellulose, and various pulps.

Arabinose in small amount was found in the hydrolyzates of sugar pine, western white pine, and Virginia pine, obtained by heating 0.01 M H_2SO_4. Its presence was shown chromatographically and by formation of diphenyl hydrazone. M. P. 197-200°C.

1.6. The substances resistant to hydrolysis of the hemicelluloses (body X, aldobionic acid, and oxy cellulose).

The hemicelluloses of mesquite wood have been extensively studied by Sand and Gary according modified procedure of O'Dwyer's method. All components were accounted for almost completely in terms of xylose, hexuronic acid, and ether-linked methoxy groups, together with small but variable amounts of an insoluble residua remaining after hydrolysis. This residue, which they described as "body X" was almost certainly lignin.

The development of method for the preparation and examination of the hemicelluloses from wood may well be followed through the sequence of papers by O'Dwyer extending over the past twenty years. In her earlier work, the hemicellulose of American white oak was investigated. The extraction was followed just writer has mentioned in the methods of extraction of hemicellulose. She divided the hemicellulose in two fractions. Fraction A (hemicellulose A) was obtained by precipitation with acetic acid, and Fraction B (hemicellulose B) by subsequent addition of 2 volumes of alcohol. On hydrolysis with 1% sulfuric acid for 3 hrs, xylose was liberated and after neutralization with barium carbonate, the barium salt of an acid was precipitated by alcohol. The analysis of this salt agreed the barium salt of an aldobionic acid composed of xylose and methoxy hexuronic acid.

Campbell has reported that he isolated from the sap wood of oak and walnut starch that contained acidic groups and was composed of approximately 90% anhydroglucose unit linked to an aldobionic anhydride (probably glucose-glucuronic acid) which may be partly methylated.

However, Sand and Nutter have investigated the hemicellulose of mesquite wood by the chlorination procedure and found the substance resistant to hydrolysis was oxy-cellulose.

1.7. Industrial Importance of Hemicelluloses.

1.7.1. In the pulp and paper industry.

There is an increasing realization that this group may be more valuable than hitherto supposed. The process of isolation of cellulose from wood, usually centers round the removal of lignin. Virtually all industrial delignification processes, however, effect at the same time the removal of hemicelluloses to different degrees, according to the conditions of the treatment and the nature of wood. It may sometimes be the case that delignification is less complete than the removal of these accompanying polysaccharides. Because the chemistry of the hemicelluloses is still obscure and the determination difficult,
very few technical studies of their fate in pulping processes have been made. (but hemicellulose in sulfite waste liquor had been investigated by Japanese wood chemist, Uchida).

In practice, an appreciable fraction of the wood may remain unaccounted for, or unnecessarily discarded. There are many purposes for which a higher α-cellulose is not essential. It is forshadowed by a number of interesting papers on the properties and utilization of holocelluloses prepared from wood, preliminary studies on the paper making qualities of holocellulose preparations have given encouraging result. Sheet of good mechanical properties have been obtained despite the relatively high content of non-cellulosic material. Holocellulose obtained from spruce was processed in a laboratory beater, its physical characteristics studied at intervals.

The less resistant carbohydrates, which include both polyuronide hemicelluloses and cellulosanes, have an important influence on the development of a gelatinous hydrate. The product has good fiber bonding and developed exceptional strength characteristics. On the basis of these results, Hontz and Kurth suggested that the cooking process in production of pulps to be used for highly hydrated papers should be conducted, in such a manner that as much as possible of the hemicellulosic materials is retained.

1. Hemicellulose nitrates

Attempts have been made to prepare the nitrates of hemicellulose. The nitrates obtained by treating hemicellulose with AcOH and HNO₃ and also with H₂SO₄ and HNO₃ containing small amount of H₂SO₄ are stable, and no sign of decomposition was seem in 8 months.

2. Films from hemicellulose acetates.

Chales L. Smart and Royl. Whisher from hemicellulose A (1) (A higher mol. polysaccharide prepared by neutralizg alk. concb hemicellulose upon acetylation with Ac₂O in the presence of 0.25% HNO₃ produces a white fibrous acetate containing 36.6% Ac groups, when cast from dioxane, C₅H₅N, or CHCl₃-MeOH (9.11), clear films are produced showing a tensile strength of 7.2 Kg/s. g. mm.

1.8. unsettled problems.

(1) The structure of hemicellulose must be established in more sure basis.

(2) Is the combination between hemicellulose and lignin entirely physical or chemical? If it is chemical combination in what linkage they are combined?

(3) In what manner hemicellulose combined with cellulose? What is the clear distinction between cellulose and hemicellulose?

(4) In hemicellulose molecule, acetyl and methoxyl groups are in what linkages combine with other groups?

(5) The structure of lignin must be established in more sure basis. In 197, O. Mueller in Gaettingen University investigating the hemicellulose of beech wood and advanced the hypothesis that lignin fragment remaining in holocellulose is polysaccharide in nature and may be an aldose condensation product and that the assumption that carbo-
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Hydrates of cell can be determined quantitatively by difference after making a single lignin determination is erroneous. What may be the fate of this hypothesis?

(6) Is protopectinase and hemicellulase identical or not? (7) What is clear relationship between hemicelluloses and celluloses?

(8) Is the structure of hemicellulose one of relatively simple chain molecules or is one of large chain molecules varying numbers of recurrent?

(9) Hemicelluloses are presumably derived from starch presumably by oxidation and decarboxylation, or from pectin, but is it really to be so?

2. EXPERIMENTAL

2.1. Cutting down of the Bamboo.

The specimens were grown in Zusan near Taichung, and were secured through the courtesy of Mr. S. Lin.

One year old (total length 20.7 m., largest diameter 14.5 cm.) and few years old (total length 16.5 m., largest diameter, 12.0 cm.) of culms of bamboos were cut down on August 24th, 1950, from bamboo jungle. (In each hectre of jungle there are average 1200 stumps of bamboo). The nodes and sheaths were removed. Each other nodes were collected and weighed. The sample has total weight of 56.4 Kg. and contain about 85% of water. The sample transported to the laboratory and started the experiment after 3 days.

2.2. Preparation and analysis of the sample.

Sample was cutted longitudinally in small pieces, chipped by scissors in proper sizes, and passed through a Wiley mill. From 56.4 Kg. of culms, about 10 Kg. of Wood powders were obtained.

That passed 20-48 mesh (mesh to inch) were used for general analysis of the bamboo and the powder has 48-100 mesh sizes were used for the extraction of the hemicelluloses.

The results of general analysis of the bamboo are indicated at Table 2. Analytical Results of Sinocalanus Latiforus Munre.

<table>
<thead>
<tr>
<th></th>
<th>moist.</th>
<th>crude protein</th>
<th>crude fat</th>
<th>crude fiber</th>
<th>crude ashes</th>
<th>pentosan</th>
<th>s.n.n. c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>air dried basis</td>
<td>15.69%</td>
<td>1.50%</td>
<td>1.70%</td>
<td>42.26%</td>
<td>2.63%</td>
<td>16.27%</td>
<td>20.01%</td>
</tr>
<tr>
<td>water-free basis</td>
<td>1.88%</td>
<td>2.3%</td>
<td>50.11%</td>
<td>3.12%</td>
<td>19.32%</td>
<td>23.44%</td>
<td></td>
</tr>
</tbody>
</table>

s.n.n.c. = soluble non-nitrogenous com'pd

From above results it may be safely to say that almost all of soluble-non-nitrogenous compounds may regard as lignin and the contents of pentosans of the bamboo are relatively small compared with other species or varieties of the bamboos; i.e. Phyllostachys reticulatae, Kib., Bambusa sienostacay, Hack., Phyllostachys, cawtis.

The sample was further subjected to brief general analysis of wood. The results are indicated at Table 3.
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moisture   crude ashes  other extract  Cross Bevan cellulose  pento- san  Total nitrogen  lignin
15.69%     3.12%       2.13%    54.95%       19.32%     0.30%      24.44%

The contents of lignins and pentosans were determined according to the method of standard wood analysis of Japan\textsuperscript{45}, and the procedure of U. S. Forest\textsuperscript{46} Products Laboratory, respectively. The estimation of Cross and Bevan's cellulose was carried out after the procedure described in the manual\textsuperscript{47}.

2.3. Preparation of the hemicellulose.

Under the circumstance, because no sodium chlorite were available, chose the Procedure of Norris and preece.

2,3.1. The removal of pectins.

a. hot water treatment.

In a flask containing 500 g. of the sample added 3.5 L. of water and heated on a water bath at 80-90° C for 15 hrs. The mixture was allowed to cool, filtered through muslin. To the transparent filtrate being acidified with glacial acetic acid, was poured with equal volume of 96% ethanol, a white precipitate was recovered. The residue was further subjected to the same treatment for 1 hrs., but could not obtain any precipitate. Yield of crude pectin obtained from 6.5 Kg. sample was 80.2 g.

This crude pectin has been studied so that not analyzed.

b. 0.5% ammonium oxalate treatment.

The removal of pectin from the residue is completed by repeating extraction with 0.5% ammonium oxalate solution. To the residues after above treatment add 3.5 L. of 0.5% ammonium oxalate solution and were stood for 7 hrs on a water bath at 80-90° C.. To the filtrate of the above mixture poured into 10% copper sulfate, observed blue precipitates are forming, but not recovered.

2,3.2. The removal of lignin.

The removal of lignin of the above residues was carried out two extractions with 3.4 L. of NaOH, each extraction being carried out under reflux for 4 hrs. After second extraction, the filtered tissue was further filtered through muslin, excess liquid was again removed at the press.

2,3.4. The isolation of the hemicelluloses.

a. The extraction with 4% NaOH solution.

From 1000 g. of the above residue the first extraction of the hemicelluloses was carried out with 6 L. of 4% NaOH solution. The mixtures were allowed to stand for 48 hrs. at room-temperature with occasionally stirring. The filtered extract left standing in the refrigerator over one night at 5° C, was gradually added with constant stirring rather more glacial acetic acid than is necessary to neutralize it. Observed the hemicellulose corresponding to the A fraction in O'Dwayer's procedure was precipitating but not separat by the centrifuge. Equal volume of 90% alcohol is then gradually added with constant stirring,
namely, corresponding to A and B fractions of O'Dwyer's procedure are precipitated together. The precipitate is then treated with gradually increasing strengths of alcohol, in the usual way for obtaining a dry product. Drying is completed in vacuo, because no phosphorus pentoxide was available, drying was carried out over calcium chloride.

b. The extraction with 10% NaOH solution.

The above residue was further extracted with 10% NaOH solution, namely, to 2000 g. of the residue was added 7 L. of 70% NaOH solution, and the mixture was allowed to stand for 48 hrs. at room-temperature. At this stage because the viscosity of the solution was very high, so that the stirring was very difficult. The extracted solution was filtered through muslin, the filtered extract let stand over one night in refrigerator and treated as before (as in case of the hemicellulose A), the yields of crude hemicellulose obtained from 6.5 Kg. of the sample calculated on dry weight 230 g..

The study of the above residue and purification of the hemicelluloses were not carried out, because under the circumstance it was quite difficult to accomplish.

2.4. General properties of the hemicelluloses.

The product obtained by this method consists a fine greyish white amorphous mass, and more or less soluble or dispersible in cold water. It is soluble in boiling water, forming a gelatinous mass on cooling. It is easily soluble in cold 4% NaOH solution. It does reduce Fehling solution and is laevo-rotatory, it form gelatinous insoluble copper compound on addition of excess Fehling solution, and the filtrate obtained is quite transparent. The results of the estimations of ash content, specific rotation, pentosans, body x. are indicated at Table 3.

<table>
<thead>
<tr>
<th></th>
<th>Hemicellulose A</th>
<th>Ash</th>
<th>[α] D</th>
<th>78.2°</th>
<th>3.98%</th>
<th>89.2°</th>
<th>86.97%</th>
<th>8.87%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5.07%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xylan</td>
<td></td>
<td>75.67%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body X</td>
<td></td>
<td>6.17%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The hemicellulosos when distillate with HCl (sp. gr. 1.06) yield surfural and it may be regarded as derived from xylan as indicate in later., so that it calculated as xylan. Because some color substances, perhaps lignin, are still remain in the hemicellulose preparation, the observation of rotation of the hemicelluloses were very difficult.

2.5. The estimations of reducing powders of the hemicelluloses.

In order to ascertain the relation between the concentration of dil. acid and the amount of reducing sugars present, each 0.5 g. of the products were subjected to hydrolysis with 500 cc. of 0.1, 0.2, 0.3, 0.4, 0.5, 1% sulfuric acid in autoclave, within 20 min. temperature of autoclave was raised from 100°C to 150°C and maintained this temperature (about 4 atmospheres) for 30 min.

After neutralization and removal of humin substances (Body X) diluted to 200 cc and took 20 cc for ascertaining the reducing power of the hydrolysed solutions in each by Bertrand's method.
It were found that:

<table>
<thead>
<tr>
<th></th>
<th>In case of hemicellulose A,</th>
<th>In case of hemicellulose B,</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄%</td>
<td>0.1 0.2 0.3 0.4 0.5 1</td>
<td>0.1 0.2 0.3 0.4 0.5 1</td>
</tr>
<tr>
<td>reducing power%</td>
<td>86.4 88.3 92.5 94.4 88.2 78.0</td>
<td>89.2 91.0 91.6 94.1 87.3 87.8</td>
</tr>
</tbody>
</table>

of reducing sugar reckoned as xylose were obtained.

Figure 1. the relation of the concentration dil. H₂SO₄ and reducing sugar present.

2.6. The examination of the hydrolysis products.

Rest on the basis of above results to 35 g. of the hemicellulose A in autoclave were hydrolyzed with 2000 cc. of 0.4% H₂SO₄ solution. Within 20 min. the temperature of autoclave was raised for 100° to 150° C. and maintained this temperature (about 4 atmospheres) for 30 min. The hydrolysed solution at the end of this time still contained a small proportion of insoluble matter and has light yellow color. After sufficient quantity of barium hydroxide was added exactly to neutralize the solution. The solution was further neutralized with barium carbonate over methyl-red-methylene blue (pH 5.4) and filtered.

The solution being decolorized with charcoal, was concentrated under reduced pressure below 45° C. to small bulk (50 cc.) and further subjected to the decolorization. 4 times volumes of 95% alcohol was added to it to get rid of any barium sulfate remaining, and after the decolorization and filtering, at end of this stage the solution was already in sirupy condition. The sirup has a light yellow color.

The hemicellulose B 27.4 g. were subjected to same treatment just as before stated, the syrup also has a light yellow color.

A little more alcohol was then added and the syrups were allowed to evaporate slowly over sulfuric acid in the desicator. Then, the desicator let it stand in a refrigerator at 5° C. for 49 hrs. with occasionally stirring of the syrups, a white crystalline mass slowly formed.
The procedure is illustrated at Chart 1.

### Chart 1.

<table>
<thead>
<tr>
<th>Hydrolysis Product</th>
<th>Neutralized with Ba(OH)$_2$ and BaCO$_3$ over methyl-red-methylene blue, allowed to stand for a while and filtered off BaSO$_4$.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body X or humin</td>
<td></td>
</tr>
<tr>
<td>Substance and ppt. of BaSO$_4$</td>
<td></td>
</tr>
<tr>
<td>Filterate</td>
<td>After decolorization concentrated to small bulk (50 cc.) below 45$^\circ$C under reducing pressure. Added 4 times volumes of 96% alcohol and filtered off ppt. formed.</td>
</tr>
<tr>
<td>Ppt. 1. (Fine particle)</td>
<td></td>
</tr>
<tr>
<td>Filterate</td>
<td>After concentration, allowed to stand in a refrigerantor over one night. Small amounts of ppt. formed was filtered off.</td>
</tr>
<tr>
<td>Ppt. 2.</td>
<td></td>
</tr>
<tr>
<td>Filterate</td>
<td>After concentration and decolorization, neutralized it.</td>
</tr>
<tr>
<td>Syrup</td>
<td>Concentrated under vaccum over H$_2$SO$_4$.</td>
</tr>
<tr>
<td>Crystalline mass.</td>
<td></td>
</tr>
</tbody>
</table>


It consists of fine white particles. When it was subjected to naphthoresorcinol test the result was negative. Ppt. 1 when heated in a crucible no charred phenomena was observed.

2.6.2. Ppt. 2.

When ppt. 2. was subjected to char, the white color not turns to black. On further heating ppt. 2 not disappear and still has a white color. Ppt. 2 consists of some inorganic salts is apparent.

2.6.3. The examination of reducing sugars.

The syrups derived from the hemicellulose A and B have the sweetish tastes and have light yellow colors.

The syrups were subjected to general qualitative tests of monosaccharide, the results
are indicated as follow.

a. qualitative tests of pentoses.

1) color test of pentose.
   i) Wheeler and Tollen's test.
      Hemicellulose A (+ +), Hemicellulose B (+ +).
   ii) Schiff's test.
      Hemicellulose A (+ +), Hemicellulose B (+ +).
   iii) Bual's test.
      Hemicellulose A (+ +), Hemicellulose B (+ +).
   iv) Rosenthaler's test.
      Hemicellulose A (+ +), Hemicellulose B (+ +).
   v) Van der Haar's test.
      Hemicellulose A (+ +), Hemicellulose B (+ +).

2) color tests of methyl pentose.
   i) Widtsoe and Tollen's test.
      Hemicellulose A (- ?), Hemicellulose B (- ?).
   ii) Oshima and Tollen's test.
      Hemicellulose A (-), Hemicellulose B (-).
   iii) Maquenn's test.
      Hemicellulose A (-), Hemicellulose B (-).

All the color tests of pentose were predominately positive for its presences, while in cases of methyl pentose were negative.

It will be safely to say that because of the simultaneous presence of large amounts of pentose, those of methyl pentose were greatly inhibited.

b. qualitative tests of hexoses.

1) fermentation test.

The syrups were diluted and subjected to Lindner's micro method by means of the fermentative power of "Press-hefe Rasse 12".

Both syrups derived from hemicellulose A and B were strongly fermented. Consequently, the presences of zymohexoses in the syrup are apparent.

2) the color tests of ketose.

The diluted syrups further were subjected to the color tests of ketose. The results is as follow.

i) Pinoff's test.
   Hemicellulose A (-), Hemicellulose B (-).
ii) Selivanoff's test.
   Hemicellulose A (-), Hemicellulose B (-).
iii) Ihla-Pechmann's test.
   Hemicellulose A (-), Hemicellulose B (-).
The results indicated no ketose is present in the syrups.

3) the oxidation of the syrups by HNO₃.

D-galactose, l-galactose, and d-galacturonic acid, when are oxidized, produce music acid. The syrups were subjected to music acid test, but the results were negative.

c. qualitative test of utonic acid.

The syrups were further subjected to naphthoresorcinol test, but the results were negative.

2,6,4, the isopasions of d-xylose.

As illustrating in Chart 1, the syrups derived from hemicellulose A and B in desicator with occasionally stirring, the white crystalline masses were slowly formed.

Yields of crystalline masses from hemicellulose A 35 g. and hemicellulose B 27.4 g. were 18.2 g. and 15.2 g. respectively.

The crystalline mass dissolved if 95% alcohol and allowed to stand in a refrigeranator with occasionally stirring, gradually prismatic crystals formed.

They melted at 142-145° and \([\alpha]_{D}^{25} = +30.4°(\text{after 20 min.}), +28.2°(\text{after 37 min.}), +26.2°(\text{after 40 min.}), +24.3°(\text{after 50 min.}), +22.6°(\text{after 60 min.}), +19.6°(\text{70 min.}), +19.6°(80 \text{min.})\).

According to Brown xylose has \([\alpha]_{D}^{25} = +85.9(\text{after 5 min.})\), and this value gradually decrease with time. After 2 hrs. it shows constant value +18.6°.

However, Schulze and Tollen indicated for xylose \([\alpha]_{D}^{25} = +19.248 (p=10.0829)\).

As a means of further identification, Bertrand's reaction was carried out. Each 1 g. of the white crystalline masses derived from the hemicellulose A and B, were mixed with 2.5 g. of cadmium carbonate and gradually with cooling mixed with 2 g. of bromine. The mixtures were allowed to stand for 20 hrs., then brought to boiling point and the residue washed with boiling water. The filtrates were mixed with alcohol and the salts came out in characteristic boot-shaped crystals. \((C_5H_9O_8)_2Cd-CdBr_2-2H_2O\).

By the properties of melting point, specific rotation and formation of the double cadmium salt of xylose as indicated above, the crystals were identified as xylose.

2,6,5. the examination of other sugars.

a. the preparation of the osazones.

Each of 1.5 g. of the syrup crystalline masses derived from hemicellulose A and B, were mixed with 3.5 g. of phenyl hydrazine, 3 cc. of glacial acetic acid, and 25 cc. of water. After half an hr., no precipitation takes place, so that no trace of mannose is present. The mixtures were then heated on the water bath for 1-1/2 hrs. A little turbid phenomena was observed, so that trace of glucose may present. As mentioned above, by fermentation test had already identified the presence of zymohexose in the syrup, while the ketose and music acid test were all negative, and now indicate no trace of mannose is present in the syrups. Consequently, glucose must a component of both hemicellulose A and B. This fact was further confirmed as below by paper chromatography.
On cooling large amount of xylose osazone came out in yellow crystals.

b. the preparation of arabinose-diphenyl-hydrazone.

After removing the bulk of xylose by the crystallization on the syrups in 75% alcohol were treated with diphenyl hydrazin which have been dissolved in ethanol, and let allowed to stand in the refrigerater for 24 hrs., the white crystals were appeared. Under microscope, they have needle shapes.

c. the analysis by paper patition chromatograph.

The syrup derived from hemicellulose A and B after removing the bulk of xylose, subjected to one dimensionol paper patition chromatograph (ascending methode).

The results are indicated as follow.

<table>
<thead>
<tr>
<th>substance identified</th>
<th>BuOH-AcOH-H20 (4:1:1)</th>
<th>phenol satd. with H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rf</td>
<td>color</td>
</tr>
<tr>
<td>glucose</td>
<td>0.15</td>
<td>a. bright brown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. dark brown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. brownish yellow</td>
</tr>
<tr>
<td>xylose</td>
<td>0.23 (over-</td>
<td>a. red</td>
</tr>
<tr>
<td></td>
<td>lapped)</td>
<td>b. chocolate brown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. pink red</td>
</tr>
<tr>
<td>arabinose</td>
<td></td>
<td>a. color developed with anilin hydrogen phthalate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. color developed with benzidine.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. color developed with α-naphthyl amine.</td>
</tr>
</tbody>
</table>

By the above results, the presences of small amounts of arabinose and glucose in the syrups derived from hemicellulose A and B were confirmed.

2.7. Disussion of the experimental results.

K.Ono has investigated the components of the hemicellulose of bagasse and found the chief product of hydrolysis was xylose. He reported the hemicelluloses were very resemble to Esparto-Xylan (according to Haworth, Esparto-Xylan has a structure, arabofuranose-(xylose)_{16-17} xylose).

While H. kurnsawa has studied the same subject and concluded the small amounts of arabinose were present in the hemicellulose. Except xylose and arabinose, he also insisted that small amounts of dextran (glucosan) may be simultaneously present.

However, the hemicellulose A and B of the Formosan bamboo, contain 75%, and 85%, of pentosans, respectively and those chief components are apparently xylose. Except xylans, writer has confirmed the simultaneous presence of small amount of arabinose, and dextran (glucosan) in the hemicelluloses.

The above results is very interesting and found out that the hemicelluloses of the
bamboo are very resemble that of the bagasse.

Furthermore, this results coincided with the results of the study of pentosan of the culms of Madake by S. Ogrí, except the fact that in the components of the hemicellulose of the culms of the bamboo, there is a glucose unit.

As mentioned above, although the hemicelluloses contain A and B fraction corresponding the hemicellulose A and B of O'Dwyer's procedure, but not separated. Consequently, it is quite difficult to conclude now that whether the glucosans in the hemicellulose were derived from cellulosan origin or not.

The hydrolysis of the hemicelluloses were carried out under pressure treatment, so that whether the uronic acid in the hemicelluloses were decomposed during the processes or not is quite in question, but still it is interesting that the uronic acid is not present in the hemicelluloses of the culms of the Formosan bamboo.

As for the chemical reaction which occurs in the hexose in the plant tissues it was assumed that first the \( \text{CH}_2\text{OH} \) group of the molecule was attacked to convert the carboxyl group by partial oxidation in forming glycuronic acid which was secondarily transformed into \( 1(+) \) xylose by the splitting-off of \( \text{CO}_2 \) from the molecule.

\[
\begin{align*}
\text{CHO}-\text{C}-\text{C}-\text{C}-\text{C}-\text{CH}_2\text{OH} \rightarrow & \quad \text{CHO}-\text{C}-\text{C}-\text{C}-\text{C}-\text{COOH} \\
\text{CHO}-\text{C}-\text{C}-\text{C}-\text{CH}_2\text{OH}+\text{CO}_2 \rightarrow & \quad \text{CHO}-\text{C}-\text{C}-\text{C}-\text{COOH} \\
\end{align*}
\]

Thus, \( 1(+) \) xylose in the plant resulted from \( \text{d-glucose} \), and glycuronic acid stands as an intermediate state in this transformation.

The fact which has been mentioned by many chemists that \( \text{d-glucose} \) and galactose have almost always been found in nature with \( 1(+) \) xylose and \( 1(+) \) arabinose should account for the formation of the pentoses by the metabolic changes of the hexoses in plants.

Moreover, it is a noteworthy fact that glycuronic acid, which was described as an intermediate product of glucose metabolism in nature, was isolated from the expressed juice of the shoots. Confirmation of this substance was made by determining the rotary power of its lactone, m. p. 160-9\(^\circ\) \([\alpha]\)\(^{20}\) = 18.64-1.6\(^\circ\) and also by transformation into the barium salt of phynyl hydrazone, m. p. 192\(^\circ\) and hydrazone, m. p. 181\(^\circ\).

Consequently, the results also confirmed the view that although the relatively large amounts of hexoses, glycuronic acid, are present in the shoots of bamboo, the contents are gradually reduce in accordance with its growth and in the culms of the bamboo, only pentoses are predominantly present.
SUMMARY

According to the procedure of Norris and Preece, after removal of crude pectins by hot water, 0.5% ammonium oxalate treatment, the hemicellulose A of Formosan bamboo (Sinocalanus Latiforus Munre) was extracted by 4% NaOH solution. The above residue was further extracted with 10% NaOH solution and obtained the hemicellulose B.

1. The hemicellulose A has ash contents 5.07% \( [\alpha]^{25} = -78.2 \degree \) while the hemicellulose B has ash contents 3.98% \( [\alpha]^{25} = -89.2 \degree \).

2. The hemicelluloses compose of two fractions corresponding to O’Dwer’s hemicellulose A and B.

3. From the hydrolyzates of hemicellulose A and B, d-xylose was isolated by crystallization. The prismatic crystals melted at 142-145\( \degree \), \( [\alpha]^{25} = +19.6 \degree \) (after 70 min).

Calcium bromoxylonates were prepared.

Furthermore in the hydrolyzates of the hemicellulose A and B, except d-xylose, arabinoce and glucose seem to be present. This fact was further confirmed by paper partition chromatography.

However, the ketose tests (Seliwanoff, Pinoff etc.) were negative and could not find the presences of any other pentoses or hexoses in the hydrolyzates.

4. The hemicelluloses A and B may compose of either compound or mixture of 85% xylan with small amounts of araban and dextran. To clarify the structure of the hemicellulose of the Formosan bamboo, further study is necessary.

LITERATURE CITED

2. Biochemical studies on the bamboo, kyoto university, Japan. (1930)
   c. f. C. A. 42 13 4746i (1948)
   c. f. C. A. 49 17 68 (1949)
5. Arundicaria racemosa (1)
   c. f. C. A. 13 5 1738 (1949)
   c. f. C. A. 42 c 2102 (1948)
9. 小栗捨藏. 化学工業雑誌 34 939 (1931)
10. Schulze. E. Z. Physiol Chem. 16 387 (1892)
11. A. G. Norman. The biochemistry of cellulose and polyuronides, lignin, etc. (1937)
STUDY ON THE HEMICELLULOSE OF FORMOSAN BAMBOO (Sinocalanus Latiforus Munre)


15. O'Dwyer M. H. Biochem. J. 17 501 (1933)

18. Preece I. A. Biochem. J. 34 251 (1940)

28. Moore and Link J. Biol. Chem. 133 2 299 (1940)
29. Moore and Link J. Biol. Chem. 143 2 551 (1942)
30. Dimler and Link J. Biol. Chem. 150 2 345 (1943)
31. Louis E. Wise Tappe. 32 335-336 (1949)

38. Jame anr. Kerler. Holz. roh. u. Werkstoff. 3 2-7 (1940)

39. Jame and Schwab. Papier-Fabr. 37 57-59 (1939)
STUDY ON THE HEMICELLULOSE OF FORMOSAN BAMBOO (Sinocalanus Latiforus Munre)

42. Charles L. Smart and Royl. Whisher, Science. 110 713-714 (1949)
   c. f. C. A. 49 4243b (1950)
   c. f. C. A. 42 3171e (1948)
44. Untersuchungen uebcr die Aktivitaet der Pektinase. von der Eidgenossischen
   Technischen Hochschule in Zuerich zur Erlangung der wuerde eines Doktors derm
   Technischen Wissenschaften genehmigte Promotionsarbeit vorgelegt von Jon Matus,
   Seite 322 (1948)
45. 三浦伊八郎、西田町二. 木材化学 p. 682 (1943)
46. Lonis, E. Wise Wood Chemistry p. 616 (1944)
47. 右田伸彦. ヘルプ及製紙工業実験法 40-46 (1950)
48. 顏造便覧 74 (1930)
50. Schulze and Tollen Ann. 271 40 (1892)
關於臺灣之麻竹半纖維素之研究

楊晃華

據挪力斯 (Norris) 及普力斯 (Preece) 二人實驗手識，將台田產麻竹（採集地為台中縣竹山區鹿谷鄉秀韜村，國立台灣大學實驗林管理處清水溝營林區），以熱水 0.5% 草酸銀除去粗植物膠後，以 4% 荷性鈉鈉溶液浸出半纖維素 A，再將其殘渣用 10% 荷性鈉鈉溶液浸出，即得到半纖維素 B。

1. 半纖維素 A 含量灰分 5.02%，其 $\alpha$ 表為 -78.20°, 半纖維素 B 之灰分含量為 3.98% 而其 $\alpha$ 表即為 -89.2°。

2. 此半纖維素，即相當於歐地阿女士所講的半纖維素 A 及 B 二部分所組成。

3. 此半纖維素水解後，可得右旋木糖之結晶分離。此菱形結晶之熔點為 142-145°，其 $\alpha$ 表為 +19.6° (70 分鐘後)。此半纖維素 A 及 B 水解時，除得右旋木糖之外，可得阿刺伯糖。此事實以 ден紙界面層析及試驗（scliwanoff, pinoff etc）結果無反應，同時於水解物中並未發見其他五碳糖或六碳糖。

4. 此半纖維素 A 及 B 由 85% 木聚糖與少量阿刺伯糖及五葡萄聚糖之化合物或混合物所組成的。

若研究改洲產麻竹之半纖維素之構造，須更進一步之研究。