U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

THE CHEMISTRY OF WOOD IN RELATION TO PRESENT AND POSSIBLE USE

By E. C. SHERRARD
Principal Chemist

June, 1933

THE CHEMISTRY OF WOOD IN RELATION TO PRESENT AND POSSIBLE USE

By

E. C. SHERRARD, Principal Chemist

The principal uses of wood have always been constructional and mechanical. There are, however, many uses of wood in which it plays the part of a chemical raw material. While such uses, even including the production of pulp and paper, bulk much smaller in aggregate consumption than the constructional use, they constitute a field of continuing interest to the forester and lumberman by reason of their present importance to industry and the possibilities of larger utilization which they offer in certain lines of future development.

Wood, in itself, is not a chemical integer; in other words, it might better be considered as a mixture of materials, most of them radically different from each other. Among the components of wood are to be found extraneous materials such as resins, gums, sugar-like materials, tannins, and acids, which are simply deposited in the wood and may be removed by means of inert solvents, such as water or alcohol. A second constituent is cellulose which, together with other kindred materials, goes to make up the cell wall. A third component is lignin, which acts as an incrusting material around the cell wall and largely forms that part of the wood known as the middle lamella. It is distinct from the cellulose mentioned above.

No general means can be devised for utilizing the first group, the extraneous materials, because these materials differ in every species. Woods grown in temperate climates do not contain the extremely valuable medicinals, dyes, or other materials which have made a few of the tropical species famous. Certain species of American woods, however, do produce extractives that are industrially useful. Perhaps the best example is that of the resin and turpentine found in longleaf pine. A process for the extraction of these materials, first by the removal of the turpentine by steam distillation and then the solution of the resin in gasoline, has been devised and now occupies a position of industrial importance. While the products differ somewhat from the turpentine and rosin obtained from the living tree, they have definite uses and have considerably added to our supply of naval stores.

The tannins also constitute a present source of valuable materials. Only a few trees either in the wood or bark produce in sufficient quantity the quality of tannin needed for tanning the chief industrial leathers. Tannins from different species differ considerably among themselves and some produce highly desirable qualities in the finished leather, such as different degrees of softness, color, and strength. The future market for tannin is not especially promising, since chemical tannins have been developed that are cheaper and produce acceptable grades of leather. Certain leathers are, however, still dependent upon particular types of tannins, and from all indications we shall always be dependent upon tannins from trees or plants for the manufacture of special leathers.

Many other less well-known products are obtained from wood extractives and occupy a definite position in commerce, although the demand for them may be quite easily satisfied. Among these are the extractive from cascara bark and the galactan from western larch. The latter product is an interesting one and eventually should give rise to at least a small industry. Galactan, upon oxidation, gives rise to mucic acid, a product which is well adapted for use in baking powders, soft drinks, effervescent salts, and in other uses where an assimilable organic acid is needed in the preparation of foods. Other woods contain characteristic dyes, volatile oils, and aromatic substances which finds use in textile, perfume, and pharmaceutical industries.

There are extractives in most woods which, although not the source of chemical products as such, are nevertheless extremely important to the service that wood renders, since they impart such desirable properties as color and resistance to decay and to the action of corrosive agents. For example, a phenolic compound occurring in western red cedar has been found to be as highly toxic toward the fungus Fomes annosus as mercuric chloride. Even the mechanical properties of a wood may be enhanced by the extractives present in it. Obviously, a working knowledge of the effects of extractives on wood behavior is of practical value to those who must select wood for specific uses.

Chemically, the most interesting component of wood at the present time is the cellulose -- the material that makes up the greater part of the various elements of wood. It is the most interesting because it has received the most attention, both scientifically and industrially, and more is known of its properties than of any of the other constituents of wood.

Several chemical processes have been developed by means of which the noncellulosic material surrounding the cell wall may be removed, leaving the cellulose in the form of short fibers or pulp. This cellulose, although closely related to the simple sugar, glucose, because of the complexity of its molecular structure is extremely stable; and because of its stability and the matting qualities of the fibers, it constitutes our most valuable papermaking material. The generally used pulping processes are wasteful in that during the manufacture of the fibers a considerable quantity of material closely related to the cellulose proper, but less stable to pulping reagents, is lost. Paper chemists have recently developed a semichemical process that utilizes less vigorous reagents together with a mechanical treatment for the disintegration of the fibers which overcomes this loss to a certain extent and even utilizes a fraction of the noncellulosic material. The problem now confronting them is to bleach this product and render it suitable for the manufacture of high-grade papers.

Other partially solved problems confronting paper chemists are the bleaching of pulps without attendant losses or weakening of the fiber; a survey of the more important commercial species of wood in various regions of the country, since pulps made from different woods may differ widely in both chemical and mechanical properties; the conversion of pulp into a transparent waterproof wrapping sheet without the intermediate treatments now necessary; the development of an inexpensive method of molding or forming waterproof containers such as milk bottles and food containers; the forming of the fibers into sheets or articles approaching textiles in character; and the production of a pulp from wood that will withstand aging without becoming colored or brittle.

As regards the less stable portion of the cell-wall material in the pulp, aside from efforts that have been made to retain at least a part of it, little attention has been given to this most interesting group of carbohydrates. It constitutes almost 40 per cent of the total carbohydrate portion of the wood, and it differs from its more stable relative in containing pentose sugars and uronic acids instead of glucose alone. Because of its inability to withstand the action of pulping chemicals, most of it has been lost in the pulping liquors. Only recently has information as to the chemical character of this fraction of the wood become available, and there is hope that means of stabilizing it or of converting it into other useful products may be developed.

The quality of stability toward chemical reagents that cellulose possesses makes it valuable for other uses. It may be nitrated and thus converted into explosives, or its nitrate may be used for the manufacture of lacquers. By various other chemical treatments it may be dissolved and reprecipitated in the form of threads or sheets, resulting in a wide range of useful products, of which rayon and cellophane are well-known examples. While great strides have been made in manufacture of artificial threads, fabrics, sheets, and films, the field for future development is almost unlimited, and rapid advances should be made in the next few years. All of these methods depend upon the use of the isolated cellulose. Undoubtedly the time will come when chemists will succeed in converting the cellulose directly into cellulose products, thus eliminating the costly pulping process.

Because of their generally sugar-like composition, the cell-wall substances are readily susceptible to conversion into sugars; in fact, processes have been developed for the production of sugars from wood, usually as a step in the manufacture of alcohol. These processes are commercially feasible and only await the time when the world's production of sugar and waste molasses, the present source of industrial alcohol, is insufficient to supply our needs. Recent studies have also shown that both stable and unstable cellulose may be converted into acetic acid, lactic acid, and other commercially important solvents by bacterial fermentation.

Next to cellulose the most important constituent of wood is lignin, the material that surrounds the cellulose fibers and forms a continuous membrane throughout the wood. Our interest in the chemical nature of this substance has centered largely around our desire to get rid of it in the preparation of pulp. Through the development of empirical means, we have succeeded in finding methods of dissolving it and of liberating the cellulose fiber in the wood, but there our interest ceased. Lignin has always been considered a waste in the pulping process and as such discarded. Its chemical complexity seems to be even greater than that of cellulose, and because of the difficulties encountered in reducing it to simpler compounds its chemical characterization has been slow. As a consequence the development of methods of utilization will have to await the acquisition of more complete chemical knowledge. Fortunately, lignin reacts and is rendered soluble by reagents that do not dissolve the cellulose, such as alkali, sulphurous acid, and chlorine. The waste liquor resulting from the action of sulphurous acid is used to some extent for the manufacture of core and road binders and also to a limited extent in linoleum. There are good prospects of increasing its adhesive value through its reaction with aldehydes such as formaldehyde and furfural. Some progress has been made in the development of a plastic molding product from wood which is based upon a chemical treatment of the lignin. Since it comprises nearly one-fourth of the original wood, the need for methods for its utilization or recovery are self evident.

In all the foregoing cases our attention has been centered on the utilization of the individual components of the wood. From the utilization standpoint the paper would not be complete without some mention of wood distillation which, in its crude form of "charcoal burning," is one of the oldest industrial chemical processes of which we have record. Wood distillation processes operate on the whole of the wood, and the products obtained by means of it are, to a large extent, dependent upon the nature of the wood. Hardwoods, for instance, until the last few years, have been our main source of such important commodities as methyl alcohol, acetic acid, and acetone. Pitchy woods such as the southern pine have been our main source of wood turpentine and pine tar oils. The oils, tars, and pitches have also entered extensively into other industrial processes such as the flotation of ores, the compounding of rubber, and the manufacture of cordage, and they now show promise of becoming an important factor in petroleum technology. The distillation process is our only source of charcoal, a product whose importance can not be overestimated. Charcoal has always been used for the manufacture of black powder; it played an important part in the development of steel; it enters extensively into the clarification of industrial liquors, and it now promises to assume an important place in the purification of sewage.

In this brief discussion some of the more important aspects of the chemistry of wood and its chemical utilization, from the standpoint of present chemical knowledge, have been discussed. The field is almost unlimited and progress within the next few years will be very rapid.