MYCOLOGY ANSWERS

HOW CAN FUNGI MAKE PAPER MANUFACTURING PROCESSES MORE ENVIRONMENTALLY FRIENDLY?

Wood is the raw material of the paper industry. Wood fibres from logs or chips must first be separated by pulping and some components are removed chemically. The resulting pulp must then be bleached before being formed into sheets. Large volumes of toxic chemicals are generated in the process. However, naturally occuring wood degrading fungi (mainly ascomycetes and basidiomycetes) attack and grow through woody substates very efficiently. The enzymes produced by these fungi degrade structural components, gradually weakening and bleaching the wood. Great research interest is now focused on the possibilities of harnessing such fungal activities with a view to reducing the amounts of chemicals used in paper processing.

Wood is composed of varying amounts of cellulose (β,1-4 linked polymers of D-glucose), hemicelluloses (polymers of 5- and 6-carbon sugars, including xylans and mannans) and lignins (highly complex and variable polymers of phenyl propane). Softwoods (coniferous wood) are usually preferred in paper manufacturing because the fibres are longer than in hardwoods (deciduous wood), although hardwoods are increasingly being used for paper production. The chemical composition of the lignins differs in the two types and also varies with the species of tree from which they are derived. It is the lignin component which provides the mechanical barrier against microbial attack for the intact plant.

For paper-making the lignin must be separated and removed from the wood with minimal release of the other components. Chemical pulping methods (the kraft process) use solutions of sodium sulphite and sodium hydroxide to dissolve the lignin, leaving behind hemicelluloses and cellulose fibres in a brown pulp which must then be chemically bleached using chlorine and alkaline extraction processes, although modern systems now make increasing use of chlorine dioxide to brighten pulps.

Chemical treatments give rise to pulps with higher strength fibres than mechanical pulping systems. However, mechanical methods are cheaper and can now be used effectively although these pulps require considerably more bleaching. After chlorination, toxic chlorinated organic compounds (total organic chlorines TOCl, and absorbable organic halogens AOX) must be discharged from the manufacturing plants. Legislation now controls the release of such bleach waters, in efforts to protect the environment. Less environmentally damaging procedures are now under development.

Under natural conditions wood is degraded by a combination of microbial species. The white rot fungi (basidiomycetes) selectively remove lignin, phenolics and some polysaccharides from woody substrates. Some species are extremely efficient in removing lignin. Mycelium spreads quickly over the surface of wood chips digesting cavities in the cell walls and attacking the lignin component. *Trametes versicolor* (L.:Fr.) Pilat, *Phlebia tremellosa* (Schrad.:Fr.) Nakas. & Burds., *Heterobasidion annosum* (Fr.) Bref. and *Ceriporiopsis subvermispora* (Pil.) Gilbn. & Ryv. remove lignin effectively from various wood sources and screening programmes are underway to find other potential fungal candidates for industrial use.

Biopulping is now under development using fungi to produce delignified pulps. Very good success has been achieved with *Phanerochaete chrysosporium* Burdsal which is easily manipulated in culture. It is likely that methods combining fungal degradation with mechanical and/or chemical pulping, now on trial, will soon become viable. Biopulping is very energy efficient and gives rise to useful pulps with good fibre strength.

The action of fungal enzymes on the wood fibres is such that component molecules are exposed more efficiently than by chemical treatments. *Phanerochaete chrysosporium* pulps require less chlorine for subsequent bleaching. *Trametes ver-*

sicolor has been shown to give rise to hardwood pulps with increased brightness which can be further bleached using chlorine dioxide alone, removing the need for chlorination. The main drawback to biopulping systems at present is that fungi degrade lignin very slowly and therefore it is a lengthy process.

The use of crude enzymes derived from fungi is also under investigation. Enzymes derived from *Aspergillus awamori* Nakazawa and *Trametes versicolor* have been shown to enhance the efficiency of delignification processes. Lignin peroxidase from *Phanerochaete chrysosporium* has been tested with limited success although better results have been achieved with some specific xylanases. After treatment with fungal enzymes bleaching chemicals can gain better access to remaining lignin molecules and so lower volumes of chemicals are required for subsequent processing. Additionally, the escape of liberated lignins from the other wood components is facilitated.

It is therefore likely that the actions of wood degrading fungi will have direct, or indirect, effects on the efficiency of the paper making industry as well as improving the environmental impact of the present process.

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