Bright Idea: Enzymes Enhance Bleachability of Pulp for Papermaking

Enzymatic pre-bleaching with xylanase is an easy way to reduce chemical costs and achieve higher quality in a more environmentally friendly fashion

Just the Facts About Pulp Bleachability

By Ali R. Esteghlalian, Ph.D. Industrial enzymes have a wide array of applications in the chemical industry. Examples include textile wet processing, fructose and ethanol production from corn, food and fruit juice production, and the pulp and paper industry. Enzymes are also added to a number of household products, such as laundry and dishwashing detergents, in order to enhance product efficacy and applicability. Enzymes can be simply described as non-living proteins or organic chemicals that exist in all living organisms and are produced to perform specific biochemical functions of a catalytic nature that are essential to the survival of the host. These "bio-catalysts" are designed by nature to either carry out the synthesis of different chemical compounds essential for the proper functioning of the organism and/or to facilitate the breakdown or alteration of such chemicals under a variety of environmental and physiological conditions. One of the advantages of enzymes as a "treatment aid" in many industrial or household applications is their substrate specificity &#151 or the enzyme's ability to target only one compound and not degrade other components. Amylase, for example, is a starch-degrading enzyme that is used for multiple applications. In the corn wet milling process, amylase is used to convert cornstarch to dextrins, or smaller sugar units. In the textile industry, it is used to degrade and remove starch that has been applied to the cotton yarn as a lubricant in the weaving process. In household detergents, amylase enzyme targets and removes the starchy soils and food stains (potato, pasta, etc.) from dishware and garments. The specificity of amylase for starch allows this enzyme to effectively degrade starchy material without damaging the fabric to which it is applied or the sugar stream produced from the starchy grains.

The pulp and paper industry is a mature sector of the chemical industry that remains critically important for many countries and regions of the world including the U.S. The paper industry has been searching for new and innovative solutions to reduce its operating costs and make paper production operations more profitable. Such process improvement solutions will have a better chance of being adopted by the industry if they can provide additional environmental benefits and allow the industry to comply with stringent environmental regulations and meet the public demand for protection of natural resources. T he papermaking process illustrates an example of this need. In a papermaking plant, the multi-stage chemical bleaching process comes after the pulping operation and is used to remove the residual lignin from the unbleached pulp to increase its whiteness and make it suitable for the production of papers for printing and writing. The bleaching operation uses chemicals such as chlorine dioxide, caustic soda, and hydrogen peroxide to oxidize and extract lignin from pulp. Accessibility of lignin to the bleaching chemicals is a key determinant of bleaching efficiency, and any treatment that can enhance this efficiency and subsequently reduce bleaching chemical requirements will be of great interest to the pulp and paper industry. The use of xylan-degrading enzyme products, or xylanases, for pre-bleaching of pulp prior to the actual multi-stage bleaching operations has been in use since the early '90s. Xylanases are a widely known group of hydrolytic enzymes that can degrade xylan, a component of the hemicellulose fraction of plant cell walls, and can enhance pulp bleachability. Pulps made from both softwood (coniferous) and hardwood (deciduous) trees contain xylan chains that, along with cellulose, lignin, and other hetero-polysaccharides, form the multi-layer fibrous structure of the pulp. When applied to the unbleached pulp, the xylanases in certain commercial enzyme products cleave and partially degrade the xylan fraction and enhance the accessibility of the lignin to lignin-oxidizing chemicals such as chlorine dioxide. In a laboratory test or in the actual mill process, the positive effect of xylanase pre-bleaching is manifested as a reduction in the amount of chlorine dioxide required to bleach the pulp to a certain degree of whiteness (brightness).

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Xylanase-based enzyme products developed specifically for the pulp pre-bleaching application provide the pulp and paper industry with multiple options for improving process economics and/or the quality of their products. These include the following: 1. Xylanase pre-bleaching reduces the required chlorine dioxide charge, thereby providing dollar savings on bleaching chemicals. 2. In cases where the mill has limitations in terms of chlorine dioxide availability, xylanase pre-bleaching allows the mill to maintain throughput and/or enhance productivity by decreasing the total requirement for chlorine dioxide. 3. Xylanase pre-bleaching allows a bleach plant to increase the final brightness level, and thus the product value/price, without having to increase chemical charge in the bleaching process. 4. In cases where environmental regulations limit the mill's capacity to generate chlorine dioxide (to maintain chlorate ion concentrations under predefined limits), the use of a pre-bleaching enzyme allows the mill to bleach more pulp (higher productivity) without having to produce additional chlorine dioxide. Enzymatic pre-bleaching of pulp with xylanase prior to the first stage of a bleaching operation is a relatively easy application and, if basic application requirements are fulfilled, can have a positive and measurable effect on the process. For an effective pre-bleaching reaction to occur, the enzyme product has to be thoroughly mixed with the pulp to ensure uniform distribution of the enzyme product within the pulp mass. While the required pre-bleaching reaction time is relatively short (15-30 minutes), longer incubation times (hours) do not produce any undesirable results. Depending on the nature of the enzyme product, the pH of the pulp stream has to be adjusted so as to avoid enzyme inactivation. Certain enzyme products are from thermophilic origins and can withstand temperatures up to or even exceeding 80&#176C. It is often required to make some pH adjustments on the pulp before the enzyme is added and mixed in because, in the process, the pulp stream remains alkaline even after multiple stages of washing. Enzymatic pre-bleaching with xylanase is an easy-to-implement process option that can help the industry reduce chemical costs, achieve higher throughput levels, and produce products of higher quality in a more environmentally friendly fashion. *Dr. Ali R. Esteghlalian is a senior scientist with the Industrial Enzyme Applications at Diversa Corp. in San Diego, CA. He has degrees in chemical engineering and bioengineering. His postdoctoral studies were conducted at the University of Georgia's biological engineering department and with the University of British Columbia's forest products biotechnology. He has been involved in experimental research related to the enzymatic treatment and bioconversion of lignocellulosics for more than 10 years. Supported by a grant from the National Renewable Energy Laboratory, he developed a unifying kinetic model to describe the acid-mediated depolymerization of hemicellulose fraction in several lignocellulosic feedstocks (corn stover, poplar wood, and switchgrass). At UBC, Dr. Esteghlalian studied the kinetics and interactions between cellulolytic enzymes (cellulases) and cellulosic substrates such as softwood- and hardwood-derived pulp and steam-exploded wood. At Diversa Corp., he currently conducts and leads enzyme applications research and contributes to the development of new bioproducts for various carbohydrate-based industries and applications such as pulp and paper, textile processing, and oil and gas well stimulation operations. He can be reached at 858-526-5108 or aesteghlalian@diversa.com.*