# Performance or Sustainability? No need to choose when it comes to enzymes in Paper Packaging

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The use of enzymes in the pulp and paper industry is increasing rapidly. Applications include pulp bleaching, stickies and pitch control, starch conversion, and most recently fiber modification. As enzyme products are derived from renewable resources, the application of enzymes contributes greatly to sustainable production practices. Based on their specific targeted effect, enzymes have fewer unwanted additional side effects as compared to many traditional chemicals.

However, in contrast to traditional chemistries where the normal practice is "plug and adjust," the application of enzymes in these complex industrial environments requires a foundational understanding of the physio-chemical properties of fibers, the biochemistry of the enzymes and an understanding of the physical/mechanical system that they will be applied in. Replacing conventional chemistries with enzyme-based technology, when possible, is a more sustainable strategy for any industry, and a variety of benefits can be achieved when enzymes are used in the manufacture of pulp and paper, when compared to conventional chemistries.

## Introduction

In an increasingly competitive market, you must control costs if you want to survive and prosper. The fiber-based packaging industry is striving to remain competitive and profitable while meeting the increasing demands of their customers for stronger and lighter product, while replacing plastic-based packaging. The industry is expected to continue to grow with the boom from e-commerce sites. On the other hand, the market is driven by the fact that retailers and shippers are demanding board that is stronger and lighter due to customer demand.

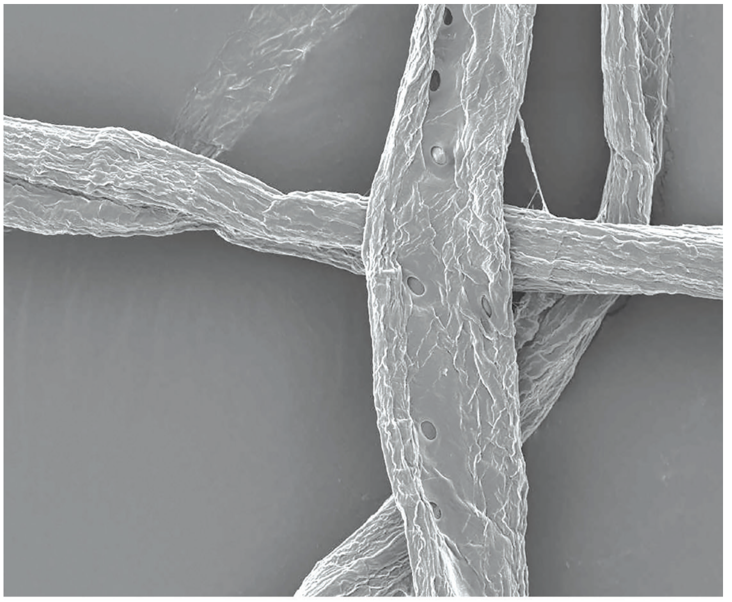
This environment is creating many pressures for the packaging industry: the need to increase strength with a lower basis weight, lower total operation costs, increase production, increase yield, and reduce energy and fiber consumption. Additional sustainability and regulatory pressures combined with increasing competition from plastic-based packaging create an even more dynamic and competitive market.

To meet market demands most mills are using the following costly levers in order to achieve strength targets: polymeric/starch solutions, adding basis weight, reducing speed, more refining, and fiber quality management. All these strategies work but are used to the point of diminishing return which increases cost and introduces instability to the process. Some of these approaches also limit your mill's ability to increase production. Some require more chemicals overall, which will impact system stability and cost.

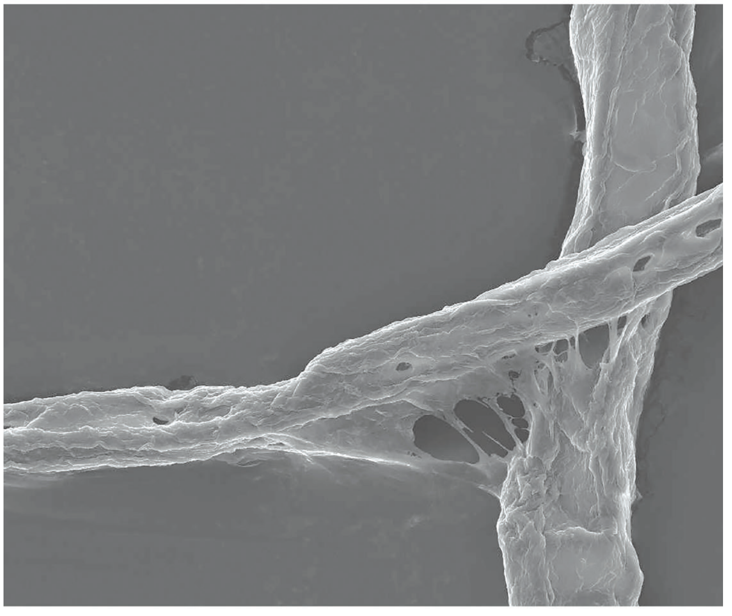
Enzyme use in the pulp and paper industry has been proposed for at least 30 years.[1] Early on it was suggested enzymes could be used in many diverse applications.[2] Many research articles have since described the theoretical application of enzymes in the pulp and paper industry, but enzymes have been surprisingly difficult to sell into this market. As efforts have continued and improved products have been developed, the use of enzyme-based technologies has become more common in this industry.

Major efforts supported by government and industry are in progress to find ways to convert wood and other lignocellulosic biomass into fuels and other usable chemicals.[3] In contrast, by carefully selecting enzymes and conditions, it is possible to limit the effects on a fiber. This supports fiber modification and conditioning rather than fiber degradation. Understanding the mechanism, mode of action, substrate specificity and reaction kinetics of cellulases is important when developing cellulase-based products.[4] Different species of wood, as well as the method of pulping (chemical, semi-chemical or mechanical process, or recycled) have a major impact on the surface chemistry of fibers and directly impact how different cellulases will attach and act on the fiber.[5,6]

In addition to the species of wood and the chemical composition of the fiber, a very important aspect of most enzyme treatments includes the mechanical refining of the fiber after enzymatic treatment.[7] Once cellulases are introduced into a slurry of fibers, they immediately initiate partial cellulose hydrolysis on the surface of the fiber. Consequently, the fiber responds more readily to mechanical refining, and this results in faster fiber collapse and fibrillation. This in turn generates increased surface area, improving the ability to hydrogen bond, and thus is correlated to sheet strength properties. The development of fibers is shown in **Figure 1**. Optimizing enzyme treatment and mechanical refining is critical to achieving the appropriate return on investment when applying enzymes for fiber modification.[8]

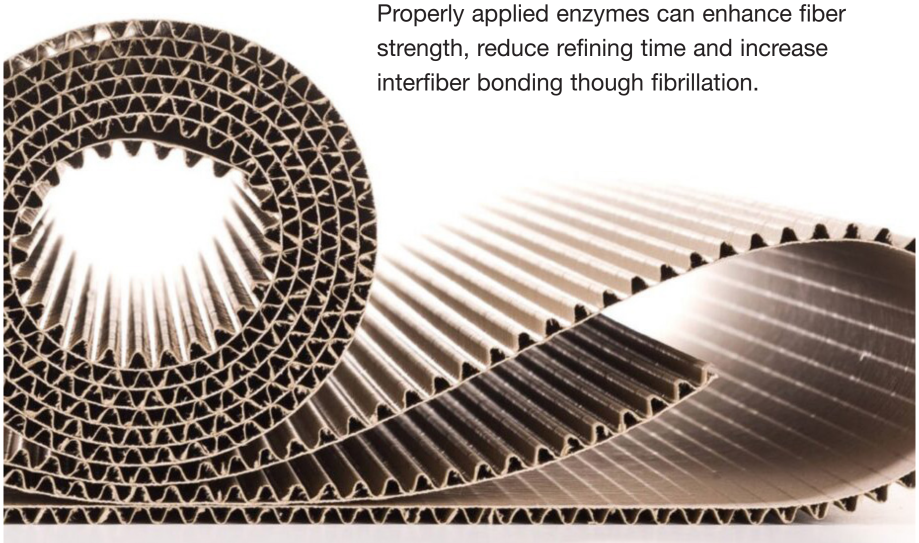


**Refined & Treated with Maximyze® (SEM 500X)**



**Refined & Untreated (SEM 500X)**

**Figure 1.** Photomicrographs of wood pulp fibers (500x) showing the bonding between individual fibers. The strength in a sheet of paper is created by hydrogen bonds at the point of intimate contact. In both cases the fibers were subjected to the identical level of refining energy. But in the case of B, the fibers were treated with cellulase prior to mechanical refining. The action of the enzyme makes the fiber more responsive to the mechanical treatment, increasing the creation of fibrils on the surface, in turn strengthening the bond between the fibers (Buckman unpublished results).



Properly applied enzymes can enhance fiber strength, reduce refining time and increase interfiber bonding though fibrillation.

Mechanical refining of pulp fibers entails more than simply grinding them. Where significant energy is required to develop sheet strength properties, there may be significant cutting of the fibers. This will decrease the average fiber length, and thereby reduce sheet strength properties.

Mechanical refining can also result in the formation of fragments (fines), which will hinder the draining of water from the fiber web and slow down production. The specific refiner plates, refiner plate wear, the energy applied, the amount of recirculation, and many other factors impact the correct development of the fiber for the characteristics required for each grade of paper.[9] Properly applied enzymes can enhance fiber strength, reduce refining time and increase interfiber bonding though fibrillation. The main challenge in using enzymes to enhance fiber bonding is to increase fibrillation. Enzymes used to modify the fiber do on a molecular level what mechanical refining does on a macro level. These enzymes break bonds in the cellulose chain, thus weakening the surface of the fiber and resulting in the same effects, collapse and fibrillation, that mechanical refining does. In cases where the recycled fiber quality is very poor, such that any additional mechanical refining will only serve to impede drainage on very short fibers, enzymatic treatment will still help the papermaker. The proper application of select enzyme formulations will serve to provide fiber conditioning and boost drainage without the need for aggressive mechanical refining.

In summary, the commercial application of enzymes in the pulp and paper industry requires a foundational understanding of the physio-chemistry properties of fibers, the biochemistry of enzymes and an understanding of the physical/mechanical system that they are applied in.

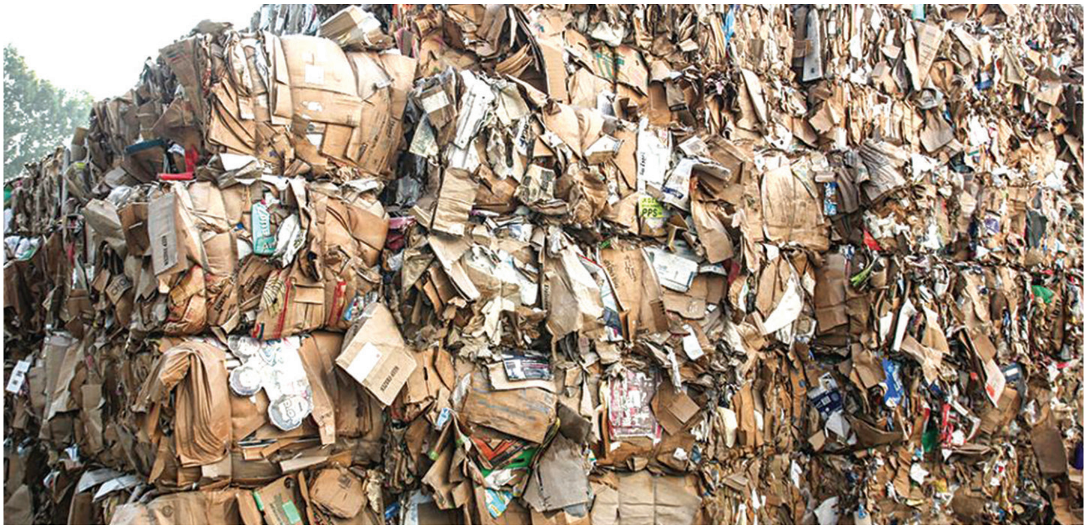
## Application

Maximyze® fiber modification enzymatic technology utilizes simple feeding systems. The product is typically fed with simple addition pumps. In some cases, post-dilution addition with either fresh water or clarified whitewater can improve mixing and product effectiveness. In paper machines with multiple plies we typically add the product to all plies at an equal dosage. However, every system is different and sometimes dosing strategy for each ply is necessary.

The specific application point for Maximyze varies by system. Identifying the best application point is sometimes an iterative process. Several factors should be taken into consideration:

- Size of the stock preparation system in terms of time from the pulper to the headbox; some operations have one hour or less while others have as much as six hours. The correct application point needs to be close enough to the machine to allow for dosage adjustments with an appropriate response time. In most cases, the Maximyze addition point is one hour or less in time from the headbox, which varies depending on temperature and pH of the system.
- Degree of closure of the whitewater system and water locks: Some components in the third generation Maximyze do not bind to the fiber, meaning there is a cycle-up effect of Maximyze in the whitewater. The time to see the full effect of a Maximyze application varies depending on the size and degree of closure of the whitewater system.

The ideal addition point is one that provides excellent mixing, promoting intimate contact between Maximyze and the fiber. In most successful applications, Maximyze is fed to a pump suction, utilizing the pump impellor to thoroughly distribute the product throughout the entire stock stream. If refiners are utilized, feeding Maximyze to the refiner feed chest or the suction of the refiner feed pump has proven most effective in many applications.



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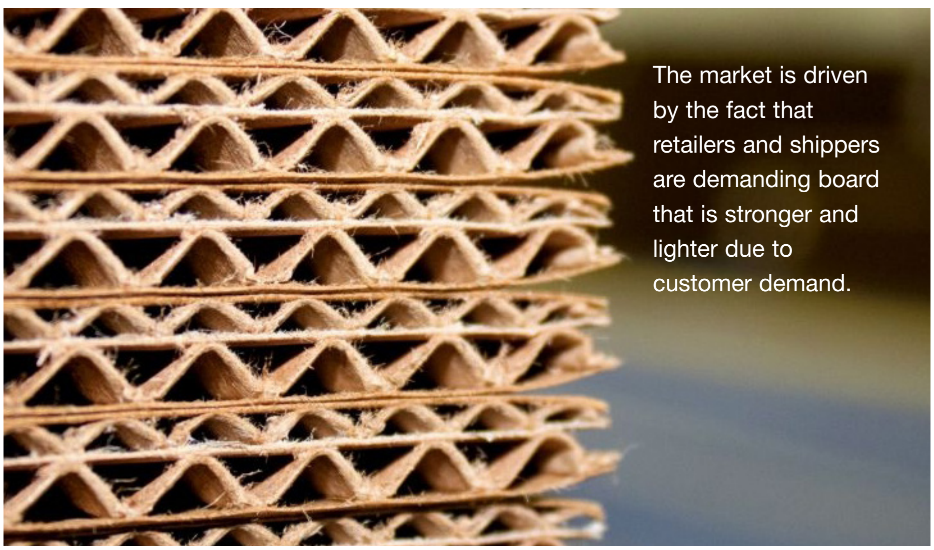
## Innovation in the Future

The application of enzymes in pulp and paper has increased significantly due to higher levels of applied knowledge and improves product stability gained in the past number of years. Continued focus on understanding the surface chemistry and evaluating new and novel enzymes or enzyme blends will result in more effective treatments and possibly allow the development of novel grades of paper. Buckman has focused on developing new screening techniques that can provide a greater understanding of how specific enzymes interact with the different cellulosic fibers and can accelerate the product development phase. This novel characterization technique, Fiberlytics™, provides a better understanding of what types of cellulose and hemicellulose are present on the surface of the fiber. This information, combined with the known activities of the enzymes, is critical to enzyme selection.As more research and new enzymes become commercially available, we will see the move to enzymatic applications that move beyond surface hydrolysis. This could include changes in charge density on the fiber surface, fiber functionalization and deeper integration with traditional chemistries. ■

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