Turning the page to profitability

How biotechnology can set up paper mills for long-term competitiveness

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INTRODUCTION:

Over the past couple of years, an unpredictable and highly volatile economy, and a variety of changing conditions across the globe have put unprecedented pressure on many businesses. The pulp and paper industry is no exception. In fact, a number of factors have combined to make it particularly hard for mills to remain competitive.

The lockdowns during the COVID-19 pandemic resulted in a huge rise in online sales, with a 43% increase in 2020 alone[1]. This rapid increase in e-commerce drove a huge demand for papermakers in the corrugated packaging segment, a demand that is becoming even more pronounced as growing environmental concerns are resulting in higher taxes and penalties on plastics. During the same time period, the tissue and towel segment also saw a sharp rise in demand, while printing and writing struggled to deal with shifting market trends as their segment continued to decline. All of these changes caused materials shortages across the industry and higher raw material prices.

And, as some paper mills struggle to come to grips with these challenges, rising operating expenses have strained their bottom line to the breaking point. In 2022, the energy cost required to run a mill can be equal to or even greater than the full sale price of paperboard a year ago. As a result, many paper mills have shut down operations entirely, putting pressure on those that remain to find ways to increase production while still maintaining a profit margin, remaining competitive, and improving their environmental profile.

Mechanical and chemical optimization no longer hold the answers

The most obvious answer to increasing margins and producing more is to optimize efficiency. However, conventional optimization methods have their limits and, in some cases, are no longer viable due to sustainability concerns.

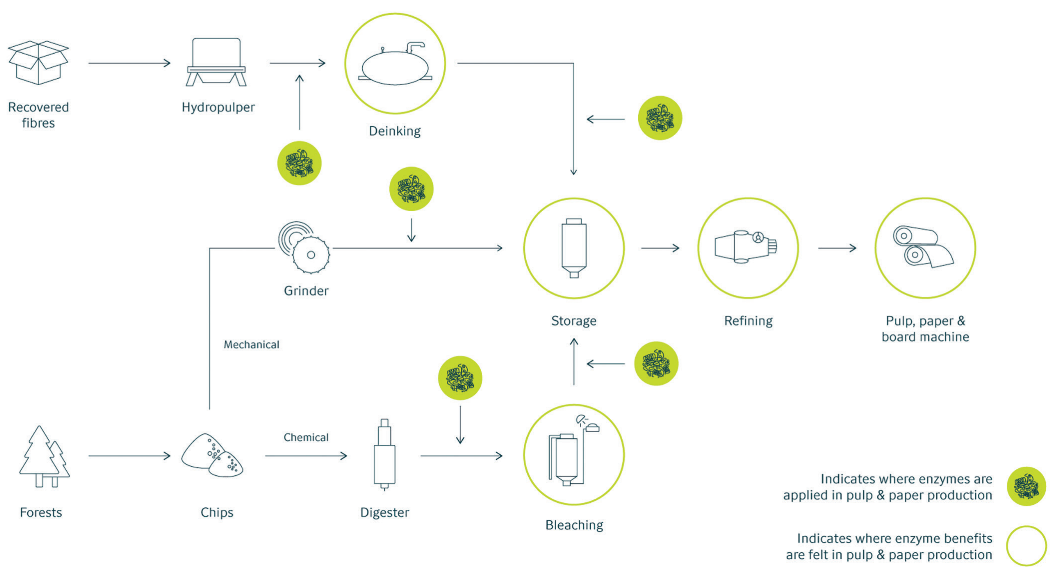
For most paper mills, the efficiency of mechanical optimization of existing equipment has plateaued. Efficiency can only be improved so far when the fundamental capacity and processes remain the same. Focusing on mechanical improvements also is costly in terms of CAPEX spending. Rather than improving margins, this creates a vicious cycle where future growth opportunities are compromised by marginal short-term gains. Carving out cost savings becomes increasingly difficult.

Chemical optimization methods used in papermaking — dewatering and retention aids, strength additives, and debonders, for example — have limits to their effectiveness as well. Additionally, stricter environmental regulations — like the European Green Deal — and uncertain fate under the Chemical Strategy for Sustainability (CSS), mean that mills are increasingly forced to abandon conventional chemical treatments with high CO_2 footprint in favor of more sustainable solutions.

The power of enzymes: finding answers in nature

As paper mills look for ways to take on the increasingly difficult questions of improving cost-effectiveness and increasing sustainability, many are turning to biotechnology for answers.

Enzymes are proteins found in nature that are produced by every living organism that act as catalysts to speed up chemical reactions.



In humans, plants, and animals, they play a key role in a wide variety of life-sustaining functions, including metabolic processes like respiration and digestion. In industry, enzymes have been used for centuries as catalysts in a broad range of applications. Because they are highly selective as to their function, they produce fewer side reactions, require fewer reprocessing and purification operations, and produce less pollution and effluents, enzymes have become cost-effective, biodegradable, environmentally friendly solution for synthetic processes at an industrial scale.

Every type of enzyme is a unique chain of amino acids that has evolved to perform a single catalytic activity on a specific substrate — sort of a natural lock and key mechanism. The enzyme's unique three-dimensional structure seeks out a substrate molecule with a complimentary geometric shape. During the enzymatic reaction, the substrate binds to the active site of the enzyme, converted to a reaction product, and released. Most enzymatic reaction rates are millions of times faster than those of chemical or metal catalyzed reactions. And, like any catalyst, enzymes aren't consumed by the reactions. The enzymes remain intact after the reaction and moves on to react with more substrate molecules. That´s why only a very small amount of enzyme is needed to produce the desired result and deliver value.

Thanks to modern technology, it is now possible to develop robust enzymes to fit the needs of specific industries like household care, food and beverages, agriculture, animal production, biofuels, and textiles. And it stands to reason that this natural approach to adding value should apply to an industry that is as deeply rooted in nature as pulp and paper.

An enzymatic approach to paper mill optimization

Using enzymes in pulp and paper mills isn't new. They have been recognized as having great potential to save on chemical and energy use and add value to a number of pulp and paper products. Improvements in production efficiency with enzymes are now used on an industrial scale in the industry, as additional ground-breaking biotechnology research continues with the aim of replacing different conventional pulp and paper processes with more sustainable and efficient solutions.

Historically, multi - enzyme "cocktails" have been tested and used in pulp and paper for decades with varying results. These applications were explored and tested before the technology was developed to make well-defined, single-enzyme products. Although they can produce measurable benefits in some instances, this shotgun approach has potential drawbacks. The most abundant and important component of papermaking fibers is cellulose. The goal of enzymatic fiber modification using cellulolytic enzymes, or cellulases, is to add value to the fibers while preserving fiber yield.

Cellulases, are produced by fungi, protozoans, and certain bacteria. In nature, they aid in the decomposition of plant matter. Different types of cellulases can break down cellulose molecules into simple sugars (monosaccharides) and other sugar molecules in a concerted manner. This saccharification process is a critical step in the production of biofuels. Cellulases can also be used to modify fiber in the pulp and papermaking process.

However , the use of multi-enzyme cocktails to produce this degree of action on cellulose in papermaking fiber can produce undesirable results. A problem that only gets worse with crude enzymes that are not refined to a sufficient level to meet pulp and paper needs. What is required is a level of technology that is designed and standardized for the production of high-quality cellulase-based products.

The use of cellulases to modify paper fiber requires the use of carefully selected molecules that add value to the fiber while also preserving its integrity. Multi-component cellulolytic enzymes are more difficult to control and can do both harm and good to the fibers. Additionally, when using multiple enzymes, there's often no way to fully ensure that enzymes aren't present in the final product.

The alternative is a more targeted, "rifle" approach based on mono-component enzyme products. Modern biotechnology allows the production of single-enzyme products that produce a more controlled modification of fibers and other components in papermaking.

Targeted enzymatic treatment can deliver potential benefits across the entire pulp and paper process, with minimal risk of the adverse effects sometimes experienced with multi-component treatments. These include improvements to deinking, bleach boosting, deposit control, and starch modification. But some of the most pronounced benefits in terms of boosting production and getting the most paper and board possible from every tree come from using enzymes in fiber modification.

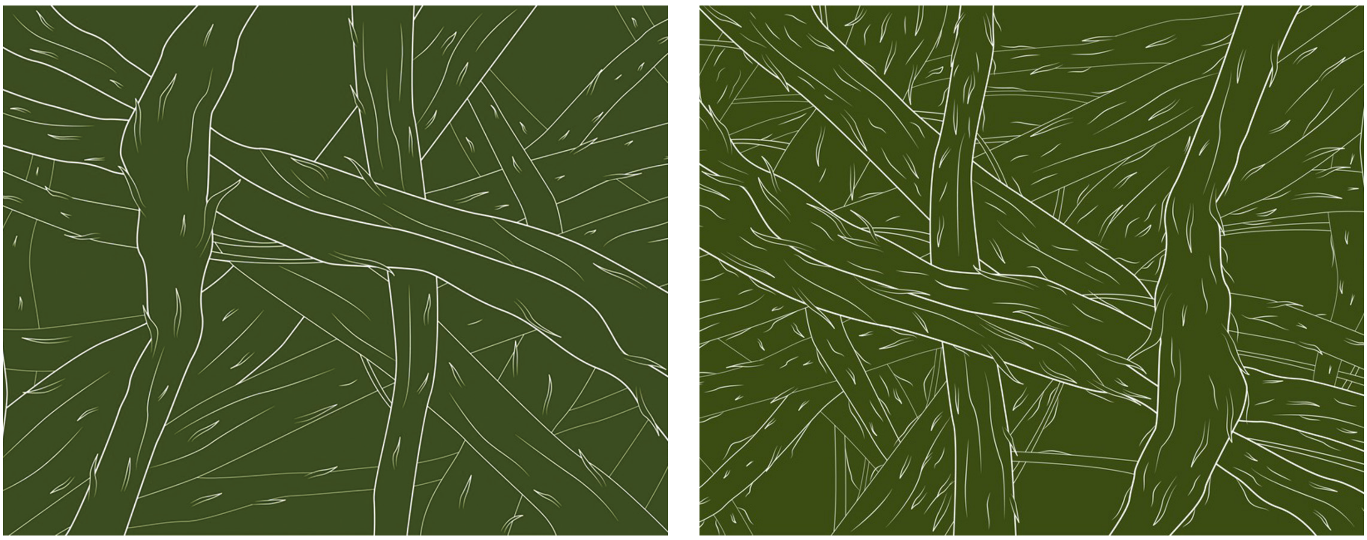


Figure 2a & 2b: before and after - "FiberCare® modifies the fiber surface and improves pulp fibrillation for more contact points and better bonding"

Enzymatic fiber modification is largely based on endoglucanases, which are cellulase enzymes. They act on paper fibers resulting in the formation of fine fibrils that increase inter-fiber bonding potential. This improves refinability and the strengthening potential of the fibers, which enhances paper and board's strength and structure.

The result is a significant improvement in paper and board structure and strength. Papermakers can take advantage of this in a number of ways — saving on fiber costs; reducing the amount of energy required for refining or drying; reducing the use of chemical strengthening agents; and producing a higher quality end product in a more sustainable manner. This process, which is already established practice in tissue and towel manufacturing, is being increasingly applied in the printing and packaging segments.

Implementing a plug-and-play solution

In a case study by Novozymes, one of the world leaders in bio innovation, a mono-component cellulase product was tested in a full-scale implementation in the printing and writing segment.

Industry experts performed an analysis to find the application point in the mill that would provide the greatest potential benefits. The trial was then implemented with minimal disruption and risk to mill operations.

The process was very straightforward, with no adjustments to existing mill operations and no CAPEX investment. All that was required was the enzyme product itself and dosing pumps to add the product to the application point.

Enzyme application experts provided guidance throughout the process and monitored conditions to ensure optimal results.

Economic—and environmental—sustainability for paper mills

The printing and writing case study overwhelmingly demonstrated the benefits of enzymatic fiber modification for the pulp and paper industry. The mill saw a significant ROI in terms of fiber savings, increased production, improved refining, and increased bandwidth and budget for new product development.

The paper mill reported a tensile strength increase of 16 percent and a 17 percent increase in internal bond strength. As a result, the solution delivered almost immediate short-term savings, cutting the energy required for refining by 50 percent.

For a European paper mill that refines 200,000 tons per year (TPY) of bleached pulp with 80 percent hardwood and 20 percent softwood, this is an energy reduction of 20 kilowatt-hour per ton (kWh/t) and 45 kWh/t respectively, a total savings of 5,000 megawatt-hour (MWh)/year. Based on the 2021 average European Union energy cost of 0.1445 €/kWh, this represents a value of 3.5 €/ton or 720,000 €/year. That's the equivalent of importing about $130,000 USD less natural gas per year[2].

The mill in the case study also noted that, by shrinking their energy footprint, mono-component enzymatic fiber modification also significantly reduced the mills' environmental impact. The immediate effect is the ability to get the most out of every tree harvested by producing more from less. Lower refining energy and steam consumption resulted in an annual greenhouse gas reduction of 1,100 tons of carbon dioxide (CO_2)[3] — an effect equal to taking 470 cars off the road.

Expanding the application of enzymes to other stages of the pulp and paper process can potentially move mills even further toward their environmental goals by displacing or removing various chemicals in the pulp mill, bleach plant, and stock preparation. Additionally, enzymes used in the dewatering process can also allow mills to use more recycled materials and less virgin fiber by improving the dewaterability.

Getting the most from the mill…and from every tree

As growing demand, increasing costs, and tighter environmental regulations make even razor-thin margins nearly impossible to maintain, papermakers need to explore alternatives that move beyond the diminishing returns of traditional mechanical and chemical optimization methods.

With minimal operational adjustment and no additional CAPEX investment, paper mills can use enzymes to lower operating costs through significant energy savings in the refining process. They reduce materials cost by maximizing the papermaking potential from existing wood and pulp. And they potentially reduce or eliminate the cost of strengthening agents and other chemical products used throughout the papermaking process.

From an environmental standpoint, better utilization of existing fiber both reduces the pressure on forests and lowers the amount of wood or fiber needed for each ton of product. Additionally, adding strengthening potential to fibers with enzymes allows for the final product to be lighter without compromising strength. That means that, in addition to lowering the CO_2 output of the mill itself, enzymes contribute to lowering CO_2 in the transport sector in a time of rapid e-commerce growth. And, by reducing the need for chemicals, enzymes bring mills one step closer to meeting their sustainability goals. All without added investment in environmental initiatives.

A huge variety of industries worldwide — from agriculture, animal production, and biofuels to household care, textiles, baking, brewing, fermenting and pharmaceuticals — are already taking advantage of the added value, cost-savings and environmental advantages of enzymes. As they strive to make their margins in a world where demand is outstripping supply, enzymes offer a proven means by which pulp and paper manufacturers can meet demands in a cost-effective, sustainable way and regain a competitive edge.

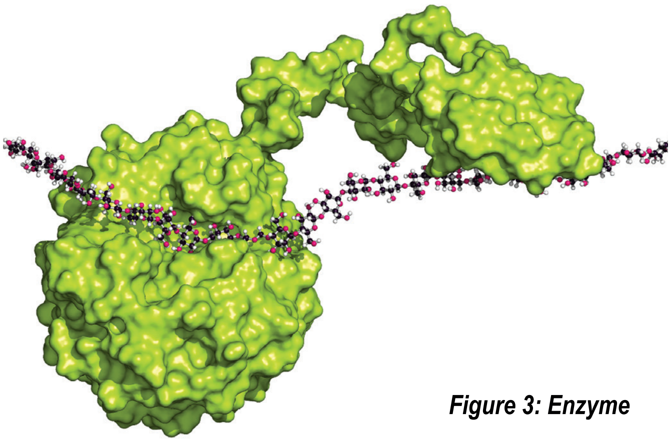


Figure 3: Enzyme

Notes

1. 2020 Annual retail Trade Survey (ARTS) Tables https://www.census.gov/programs-surveys/arts/data/tables.html
2. Based on a natural gas price of $7.84 USD/MMBtu (09/05/2022)
3. Based on the 2020 EU average of 230 grams of CO2/kWh grid mix, including the carbon footprint of the enzyme