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"More Tons, Less Energy, and Reduced Total Costs via Enzymatic Deinking"

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OVERVIEW

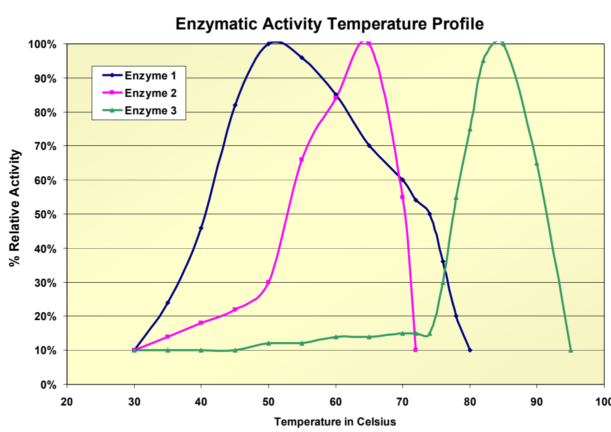
Enzymatic Deinking Overview

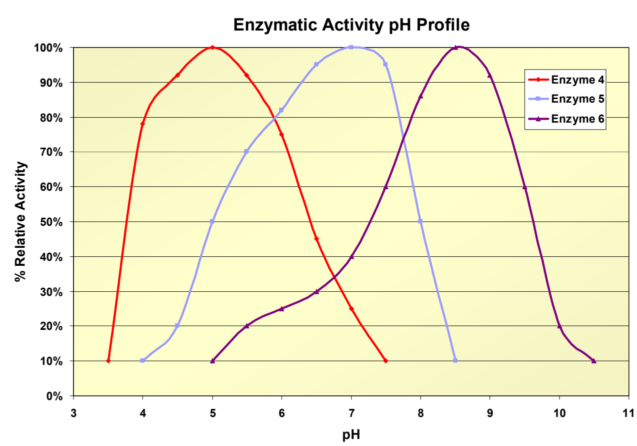
Enzymatic treatments of pulp fibers are a natural solution for improving papermaking. In nature, cellulosic modification, and ultimately degradation, is driven almost entirely by enzymatic mechanisms. While industrial enzymes have only been available for several decades, their activities have been present for millions of years.

Enzymes are uniquely-shaped molecules comprised of chains of amino acids. It is their individual composition and their morphology that create their particular activity. Our bodies have billions of enzymes regulating most cell functions ranging from initial fertilization, to digestion, to energy production, to growth. Perhaps the most well-known enzyme function in humans is the role of lactase in enabling us to digest the lactose in milk sugar. Without sufficient lactase, people are lactose-intolerant, and they cannot properly digest dairy products.

Recent discoveries of new enzyme varieties have led to a step function increase in the breadth of industrial enzymes, each with their own substrate affinity, their own mechanism, and their own operating properties with respect to temperature, pH, kinetics, and other factors. Industrial enzymology has truly become an applied science of our times.

Consequently, in order to obtain the maximum desired benefits from an enzyme treatment and avoid undesired effects, enzymes should be selected carefully such that the proper blend of synergistic materials can best be employed. The approach taken by the studies covered in this paper is to develop a blend of enzymes based on four key factors: the wastepaper furnish being treated, the deink plant equipment and water circuits, the key temperature, pH, and retention time conditions, and the desired outcome from the enzymatic treatment. Indeed, no two mills are alike, nor are their objectives, nor should be their enzyme treatments.





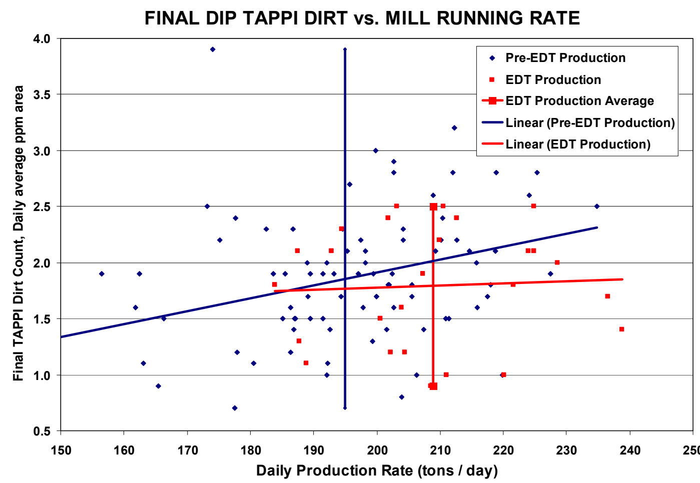
While the benefits from different treatments in tissue/towel production span many areas, typical goals are to enhance ink detachment and removal, degrade wastepaper, control stickies, increase mill throughput, improve sheet physical properties, and reduce energy. Though these benefits can be interrelated in cause and effect, two of them will be discussed in this paper: improving tonnage output and energy reduction.

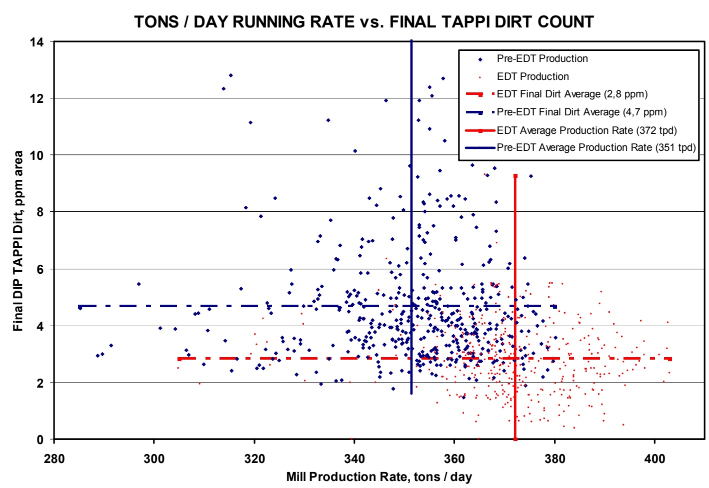
The Value of Producing More Tons

Mills can make more money by increasing revenues and by decreasing costs. Oftentimes the former gets a lot less attention than the latter. A mill can increase revenues through many actions, but producing more tons or *better* tons can have a significant effect. For a given amount of uptime, increased output can generally be achieved through faster running (liters of stock/minute) at the same consistencies or similar running rate at a higher consistency stock. Though sometimes a mill has a purely mechanical pumping limitation, many times it can pump faster and/or at slightly increased consistencies.

A common issue is that quality suffers with either faster running or higher consistency running. The quality decrease in either instance is due to stock receiving less treatment time in key stages or being processed as thicker stock. Treatment time is a well-known factor in deinking efficacy across stages such as flotation, cleaning, and bleaching. On the other hand, higher consistency processing can be highly detrimental to quality in screening, cleaning, flotation, and washing. Studies of mills comparing tons per day running rate with deinked pulp quality have shown a clear, inverse relationship.

<u>Maintaining High Quality at Higher Tonnage Rates</u>
Enzymatic deinking has been used successfully to debottleneck mills such that the penalties of faster running rates are minimized or pushed out to higher tonnage thresholds. In two different mill applications where final deinked pulp quality was the constraint to output, enzymatic deinking enabled production to increase 6% to 10% beyond what was formerly the maximum while achieving similar or superior quality standards. The primary enzymatic mechanism that explains the benefits provided is improved ink detachment. With ink and stickies free from the fiber, dirt and stickies removal stages can still perform their function well even if given less time or a higher consistency stock.





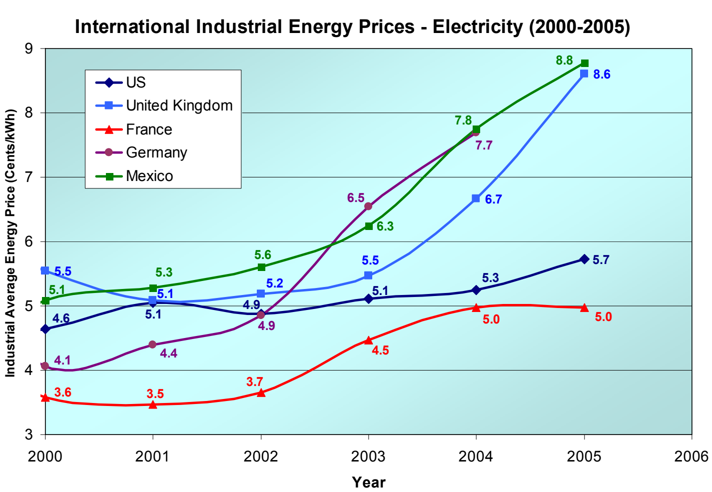
The economics of higher production can be quite valuable. Many costs commonly thought as "variable" with production rates are actually "semi-fixed." The relevant economics for consideration are those related to the extra tons produced. At these production levels, for example, many such costs only increase 5% for a 10% boost in output. This means the impact to the mill's bottom line from such production gains can be surprisingly attractive, more so than the mill's usual financial accounting might indicate from a usual "gross margin" analysis.

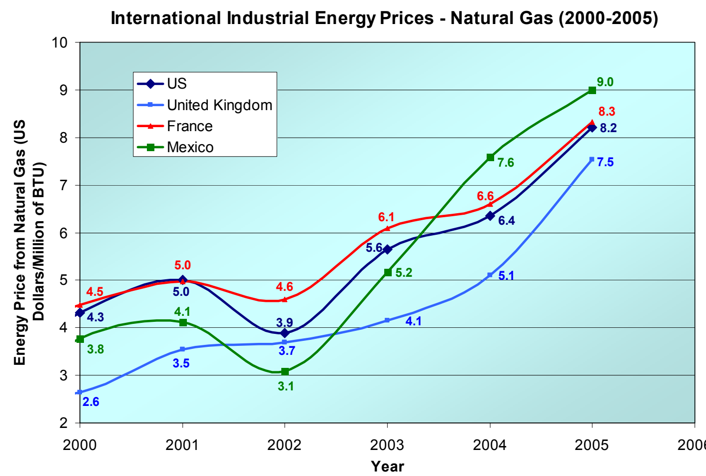
Replace Virgin Pulp with High-Quality Deinked Pulp

Alternatively, some mills leverage enzymatic deinking to make better tons instead of more tons. Average dirt count reductions of 50% have enabled mills to capture or secure better market positions than would otherwise have been possible. Some mills leverage higher quality DIP and greater tons produced with enzymatic deinking to reduce alternate pulp use. Particularly in today's market, the replacement of virgin with high quality deinked pulp can be financially very interesting.

Energy Reduction Opportunities

Energy costs are high, and high on everyone's mind. Global supply/demand factors and environmental concerns have created significant increases in the costs of all forms of energy: natural gas, oil stocks, coal, and purchased power. While new technologies are being explored to mitigate this rise, few analyses predict cheaper energy in the future.





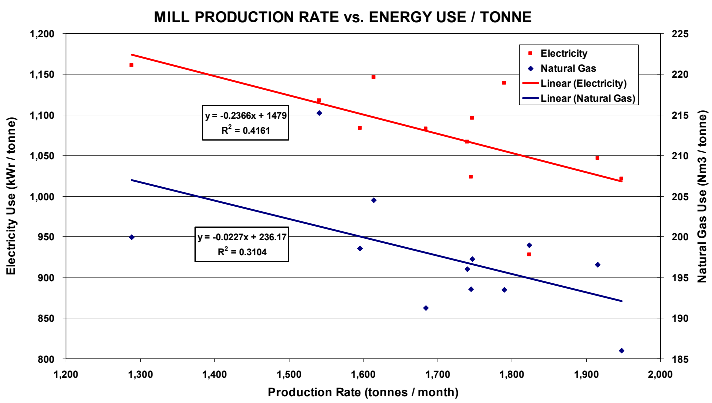
Unlike some virgin pulping processes such as chemical pulp production, deinked pulp production and machine operation are strong net users of energy. Integrated deink plant and tissue machine energy costs vary considerably, but total costs of all energy forms which can exceed € 170-200 per final tissue ton are not uncommon. For some mills this is twice the cost compared to just 5 years ago. It is also possible energy usage will attain a new relevance if industry carbon tracking from energy consumption becomes a trend. Reducing energy use has therefore become a top goal for most paper companies and mills.

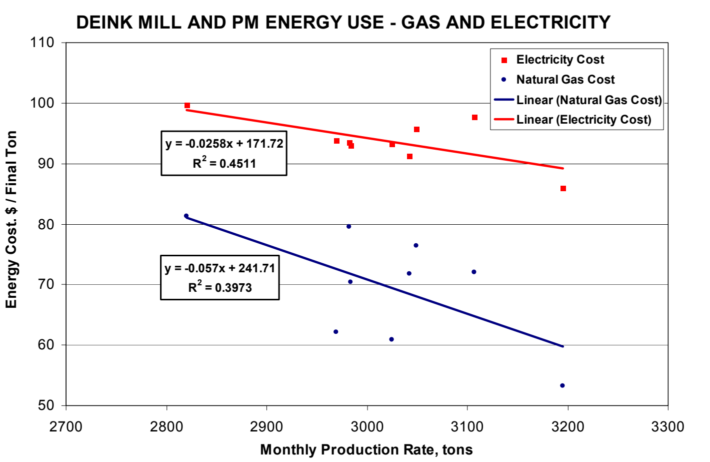
The use of enzymes, a natural "green science" for deinking, has been employed with a variety of strategies to reduce energy costs, both in the deink plant and on the machine. This paper discusses five such strategies to reduce energy costs per ton: increased tonnage output, enhanced pulper defiberisation, reduced dispersion, reduced refining, and reduced drying energy.

Energy Reduction from Increased Tonnage Output

As noted earlier in this paper, enzymatic deinking has helped mills increase production rates while maintaining good deinked pulp quality, overcoming the challenges resulting from running faster or at higher consistencies. One major benefit of increased tonnage is the reduction in specific energy cost per ton produced. While energy is commonly regarded as a "variable" cost, it is actually only partially variable and is “semi-fixed” at higher production levels. A fully variable cost would increase 1% with each 1% increase in output.

Analyses of total energy costs in mills have shown a rather significant decrease in average energy cost per ton as production rates increase. For example, in one study, for each 1% increase in production natural gas usage increased 0.79% and electricity usage increased only 0.62%. In another study, increases in production from already high levels amounted to almost no increase in energy cost, meaning within that range energy consumption had become essentially a fixed cost.

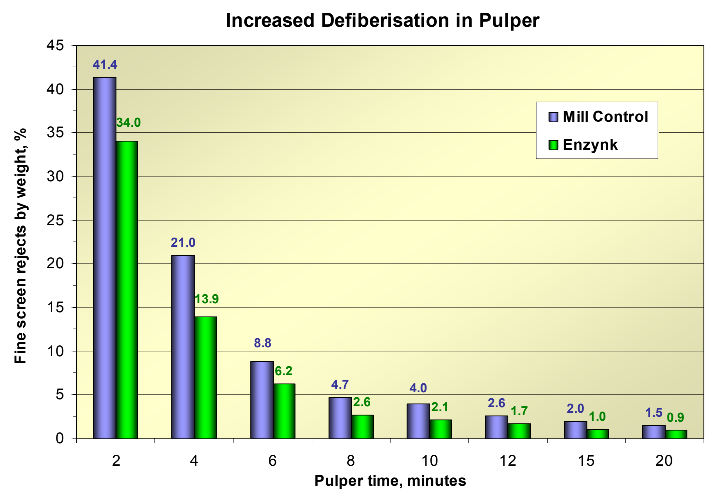




Of course, quality parameters are not the only bottleneck to increasing production; mechanical and operational issues can also be limiting. Enzymatic strategies have also focused on fiber modification to enhance drainage and increase machine output. In one application where drainage in a dewatering screw was a limitation, an enzyme treatment was developed to successfully de-bottleneck this stage.

<u>Enhanced Defiberisation</u>

Pulping is one of the most energy-intensive stages in a deink plant. Pulping has several goals which include not only a separation of the fibers, but also the detachment of ink particles and other contaminants from the fibers to enable follow-on deink plant equipment to operate effectively and at as high a fiber yield as possible. Enzymatic treatments have been developed to leverage the action of the pulper in breaking down the fiber matrix. Mill scale-ups of this approach have helped mills reduce pulping times, and hence energy. In one application, high consistency pulping time was reduced by 23%, from 22 minutes to 17 minutes. This method can also increase the running rate for mills that are bottlenecked at the pulper.

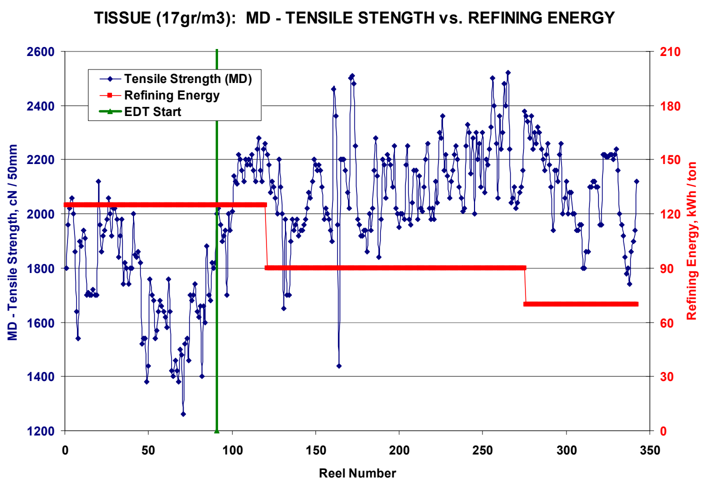


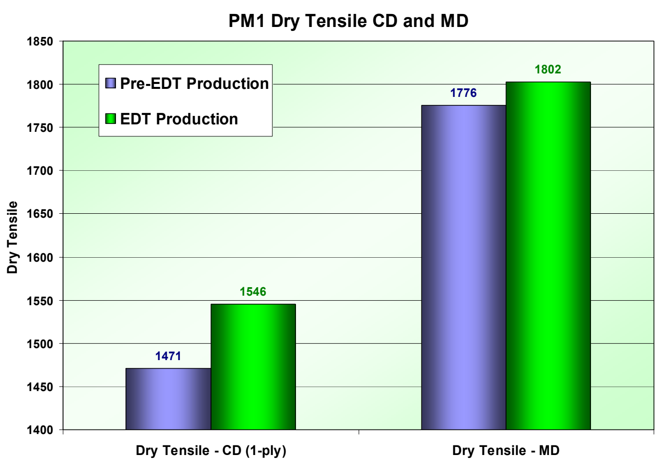
<u>Less Dispersion Energy</u>

Dispersion can be a highly effective stage in which to significantly reduce visible dirt counts. A key objective of enzymatic deinking in most mills is to enhance the detachment and removal of inks across screening, cleaning, flotation, and washing. In instances where dirt reductions can be sufficiently improved across these stages to attain suitable final quality, the disperger energy may be reduced or in some cases eliminated. Even in situations where the disperger is needed for the mixing of bleaching chemicals, mills have adjusted the gaps and the equipment operation such that significant energy reductions are realised while still attaining good bleach chemistry mixing.

Reduced Refining

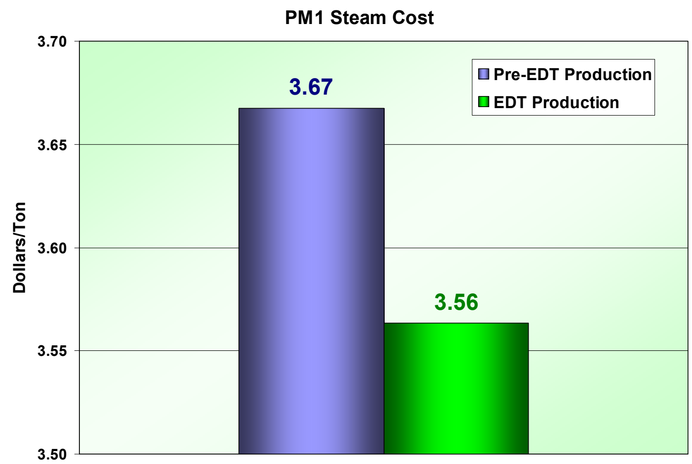
Final tissue sheet strength is an important driver for the level of refining energy imparted to the stock. Certain enzymatic treatments have been found to "clean" fibers such that more hydrogen bonding sites present themselves to provide strength in the sheet. In mill applications where strength enhancement was a goal, sheet strength increases from 5% to 13% were attained. While mills leverage these increases in different ways, a common strategy is to decrease refining energy such that the same sheet strength is achieved. For example, one mill reduced refining from 125 KWh/ton to the 70-90 KWh/ton range and still achieved the desired final sheet properties.





More Efficient Drying

Dewatering and drying dynamics are key determinants in the rate of machine operation and ultimate energy use per ton. Enzymatic treatments can enhance the drain-ability of stock on the paper machine. Certain treatments have enabled the steam to escape more readily and have reduced drying energy per ton. While the mechanisms of enhanced drying are still being explored, the benefits are being profitably realised at mill scale.



Altogether, energy reductions leveraging the five strategies outlined in this paper can be considerable. Mills using such enzymatic approaches have been able to reduce total energy usage by over € 10 per tissue ton. In targeted development programmes, these energy savings have been realised in conjunction with other benefits such as improvements in dirt, brightness, and stickies control.

Summary and Conclusions

The use of enzymatic treatments in the production of recycled and virgin tissue is a new and growing field that offers much to maximize value for tissue and towel production in a challenging marketplace. Many hundreds of enzymes are now used in industry and the number of potential treatments is growing daily. In pursuing the technology, it is important to ensure the right factors are considered in choosing the optimal treatment blend. In a successful application, the benefits can be considerable and can help re-orient the direction of the mill. Whether the objective of mill management is to increase production, reduce total energy consumed, or degrade to less costly furnishes, enzymatic treatments can be effective in increasing a mill's bottom line profitability.