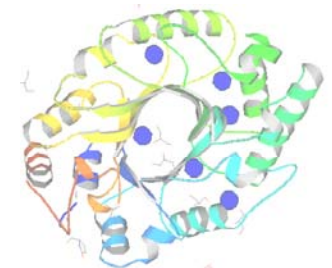


# Enzyme Applications in Pulp and Paper: An Introduction to Applications

Dr. Richard Venditti

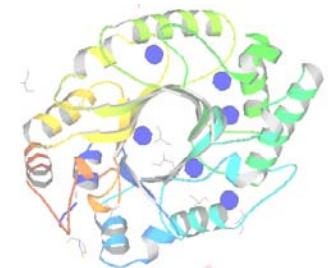
Associate Professor - Director of Graduate Programs  
Department of Wood and Paper Science  
Biltmore Hall Room 1204  
Raleigh NC 27695-8005  
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Email: richard\_venditti@ncsu.edu



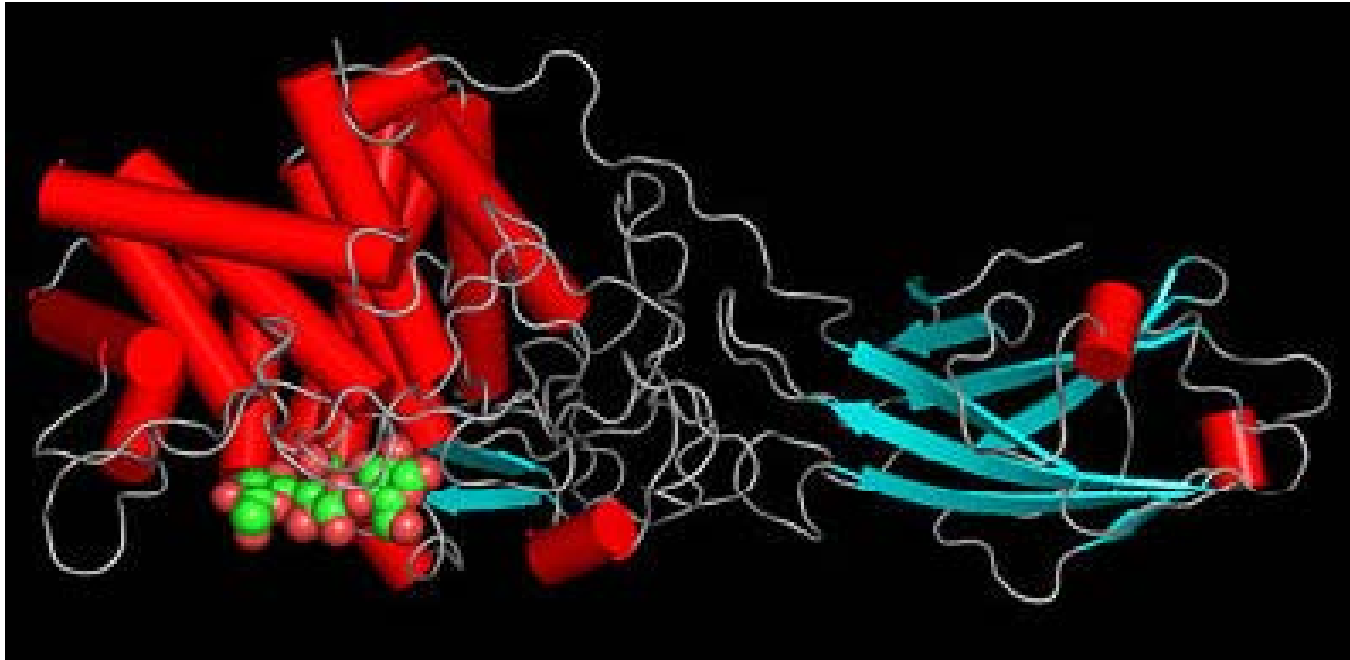
Endo-Beta 1,4 Xylanase

# Enzymes

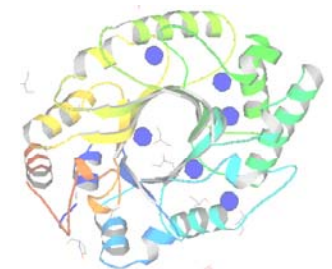
- Are proteins that catalyze chemical reactions
- Biological cells need enzymes to perform needed functions
- The starting molecules that enzymes process are called substrates and these are converted to products



Endo-Beta 1,4 Xylanase



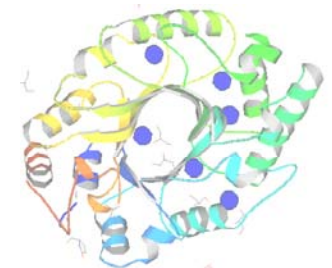
Cellulase enzyme which acts on cellulose substrate to make product of glucose.



Endo-Beta 1,4 Xylanase

# Enzymes

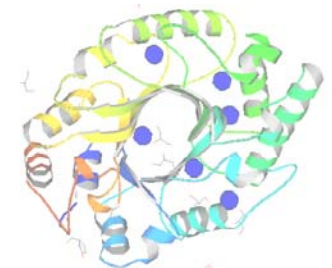
- Are extremely selective for specific substrates
- Activity affected by inhibitors, pH, temperature, concentration of substrate
- Commercial enzyme products are typically mixtures of different enzymes, the enzymes often complement the activity of one another



Endo-Beta 1,4 Xylanase

# Types of Enzymes in Pulp and Paper and Respective Substrates

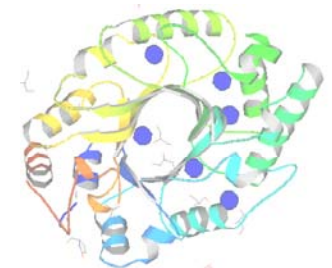
- Amylase --- starch
- Cellulase --- cellulose fibers
- Protease --- proteins
- Hemicellulases(Xylanase) ---hemicellulose
- Lipase --- glycerol backbone, pitch
- Esterase --- esters, stickies
- Pectinase --- pectins



Endo-Beta 1,4 Xylanase

# Enzyme Applications in Pulp and Paper

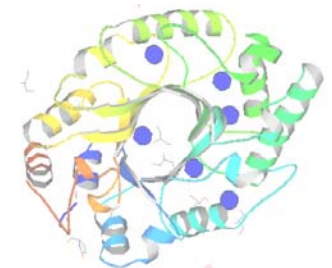
- Treat starches for paper applications
- Enhanced bleaching
- **Treatment for pitch**
- Enhanced deinking
- **Treatment for stickies in paper recycling**
- Removal of fines
- **Reduce refining energy**
- Cleans white water systems
- **Improve softness in tissue**
- Clean outs



Endo-Beta 1,4 Xylanase

# Starch Conversion for Surface Coatings

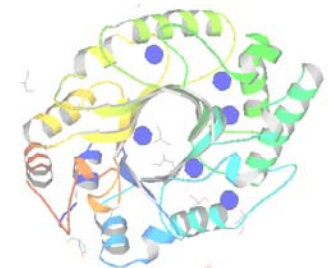
- Amylases are used to cleave starch molecules to reduce the viscosity
- Used for surface sizing and for starch in coatings
- Not used for dry strength agent additive



Endo-Beta 1,4 Xylanase

# Bleaching

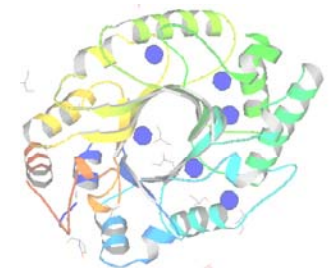
- Hemicellulases (xylanases) are used to cleave hemicelluloses in fiber, making the bleaching process more effective
- May be able to reduce bleaching chemicals by up to 30%
- Can improve brightness



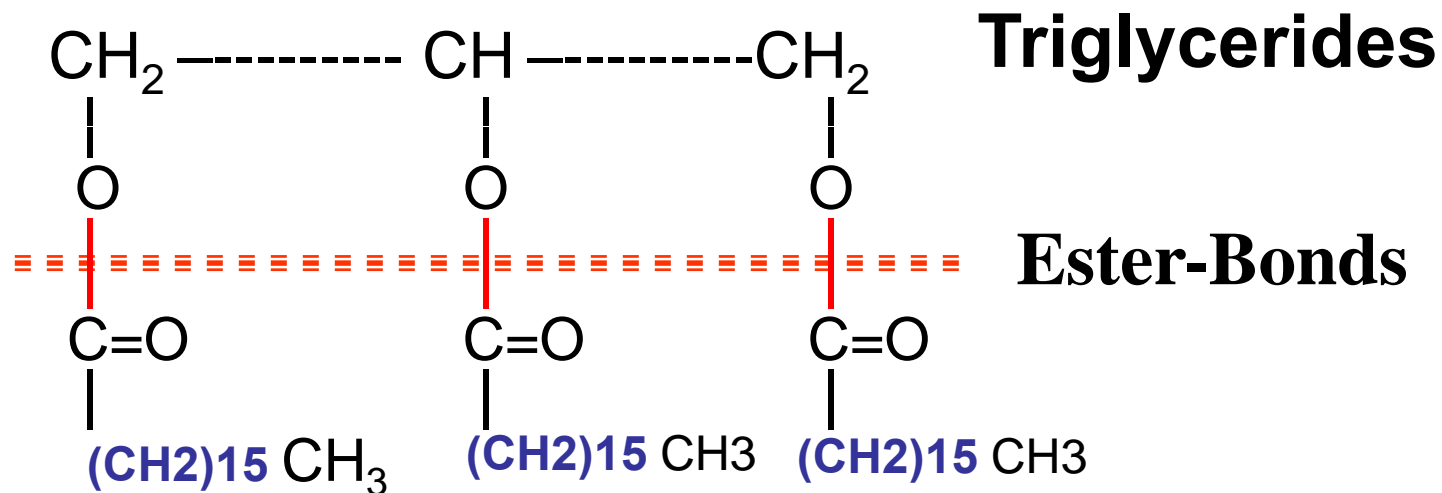
Endo-Beta 1,4 Xylanase

# Pitch treatment

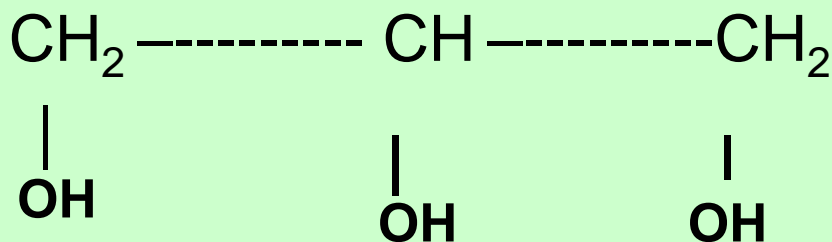
- Lipases used to control pitch in pulping processes
- Converts tri-glycerides to fatty acids which are more stable in water, won't deposit as much



Endo-Beta 1,4 Xylanase

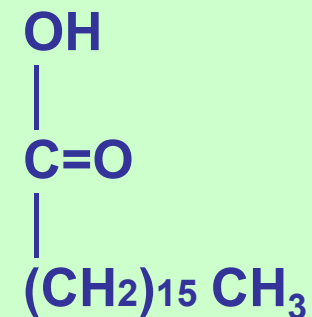


**glycerol**



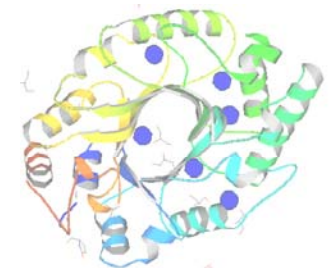
**Fatty acids**

+



# Deinking

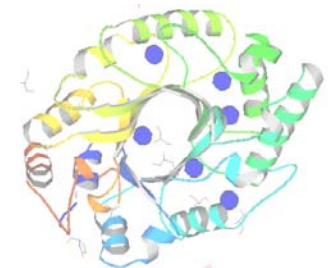
- Paper recycling inks and stickies attach to fibers at the surface of the fibers, stuck to microfibrils
- Cellulase and hemicellulase enzymes hydrolyze these microfibrils, releasing the adhesives
- Enzyme assisted DI reported to remove 30-60% more toners
- Enzyme assisted DI reported to improve brightness by 4-5 points



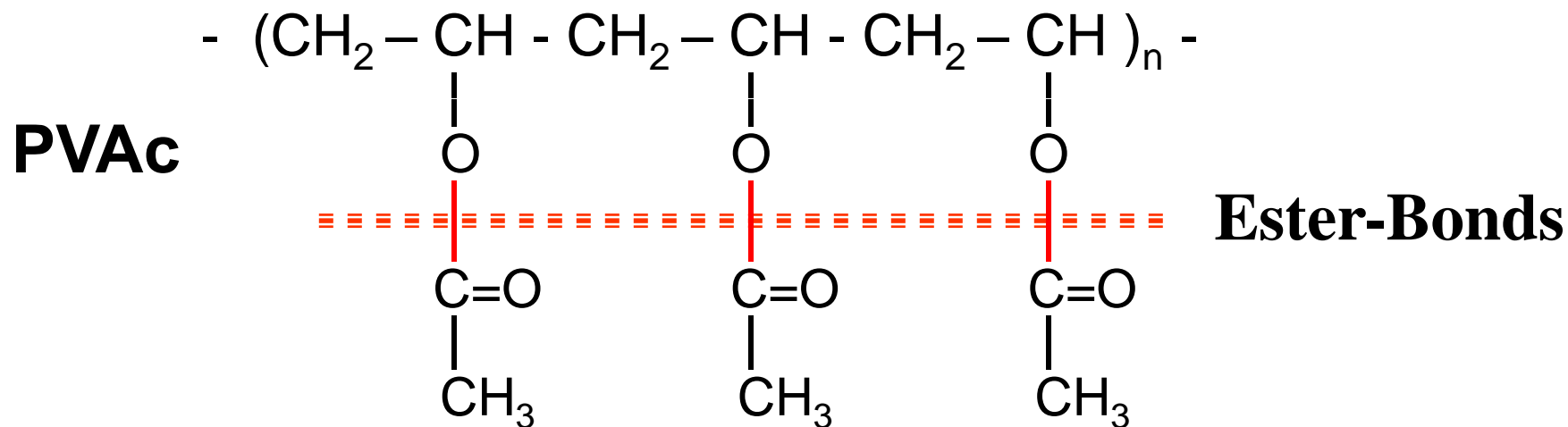
Endo-Beta 1,4 Xylanase

# Enzymes as stickies treatment

- Esterases used to break ester bonds in polymers used in toners and adhesives
- Improved paper cleanliness
- Less deposits, less clean up on PM
- Can be used as substitute for talc or solvent based dispersants

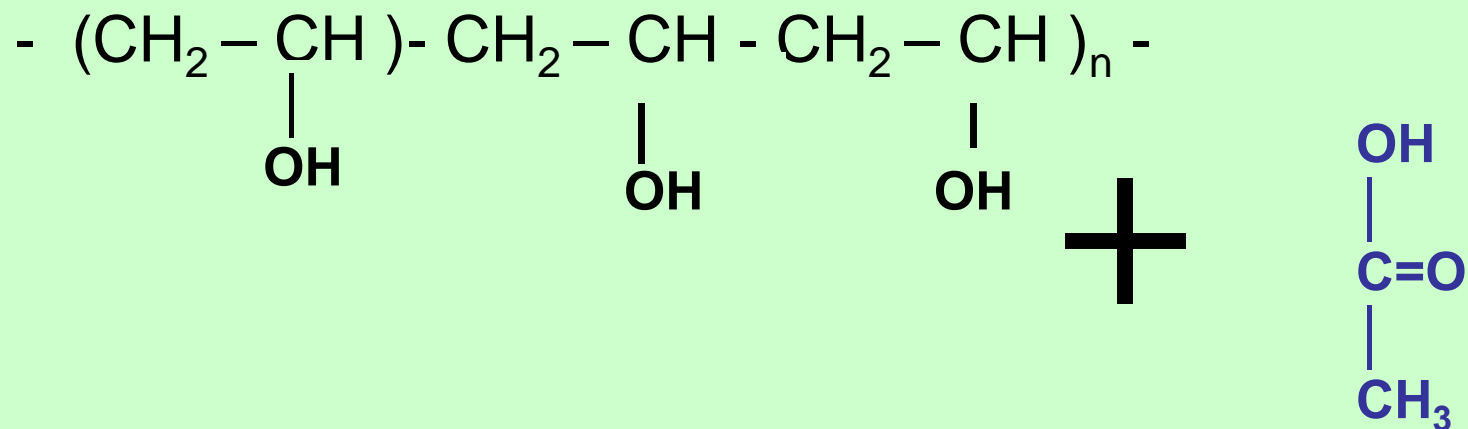


Endo-Beta 1,4 Xylanase

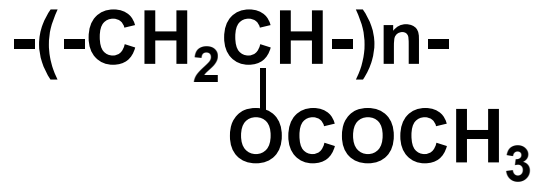


**PVA Alcohol**

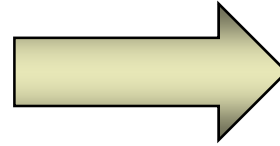
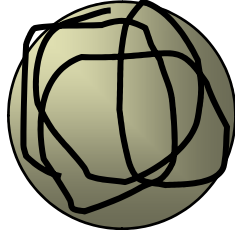
**Acetic acid**



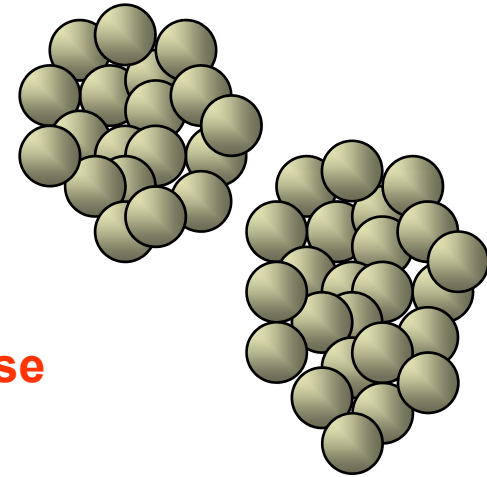
**polyvinyl acetate**



Hydrophobic  
Surface

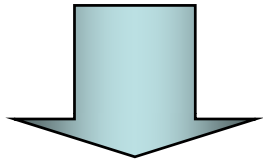


**without Esterase**

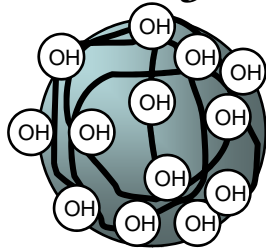
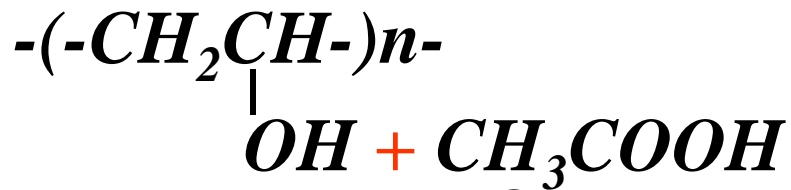


**Agglomerates of PVAc**

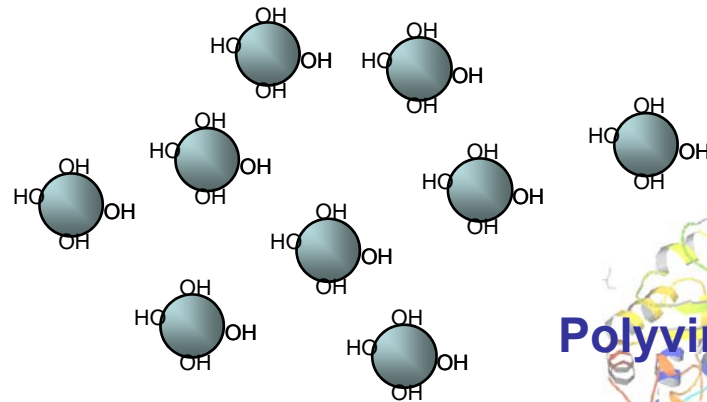
**with Esterase**



*polyvinyl alcohol + acetic acid*



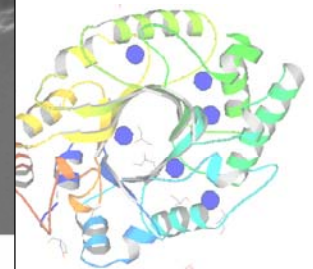
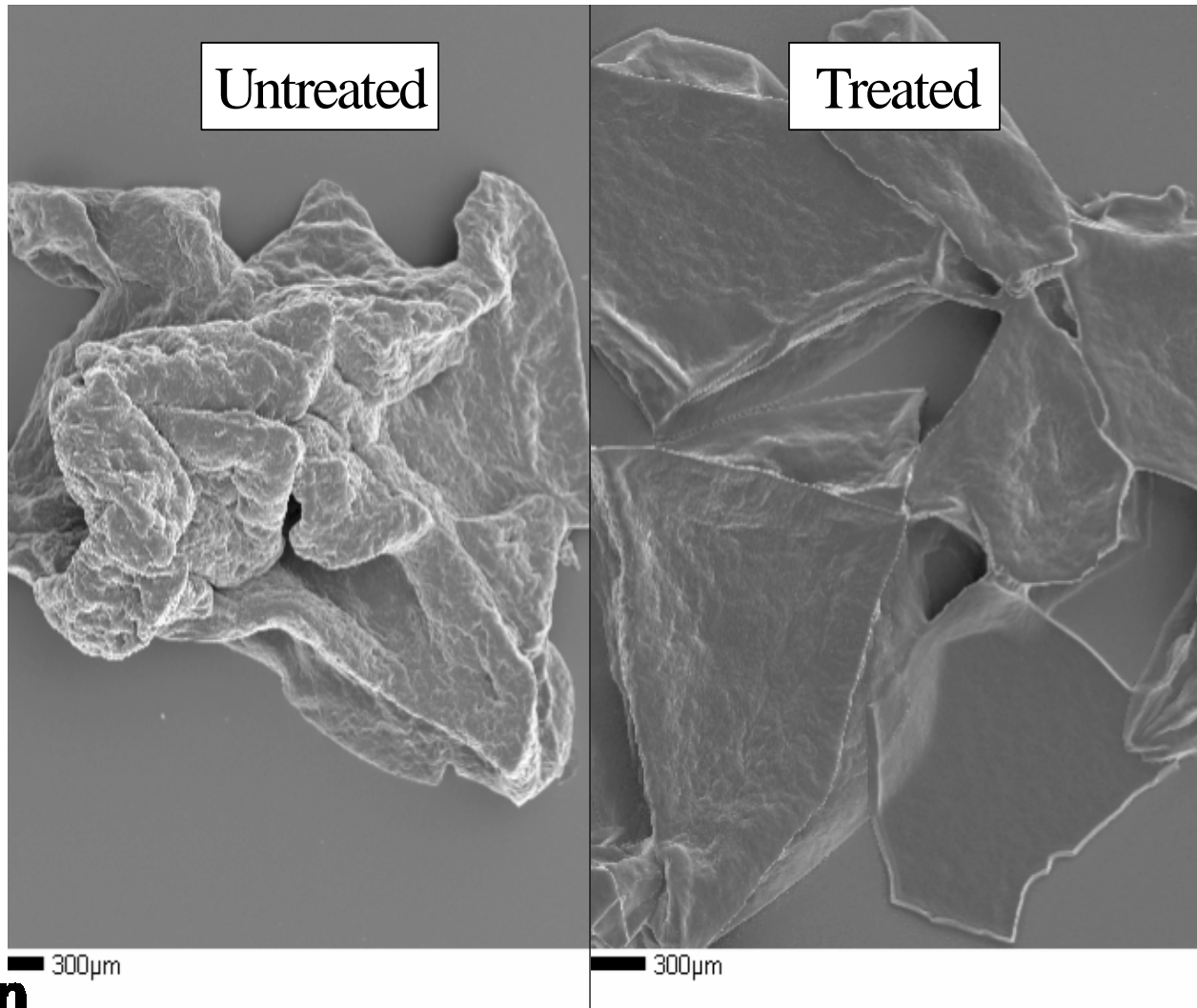
**Hydrophilic**



**Polyvinyl alcohol**

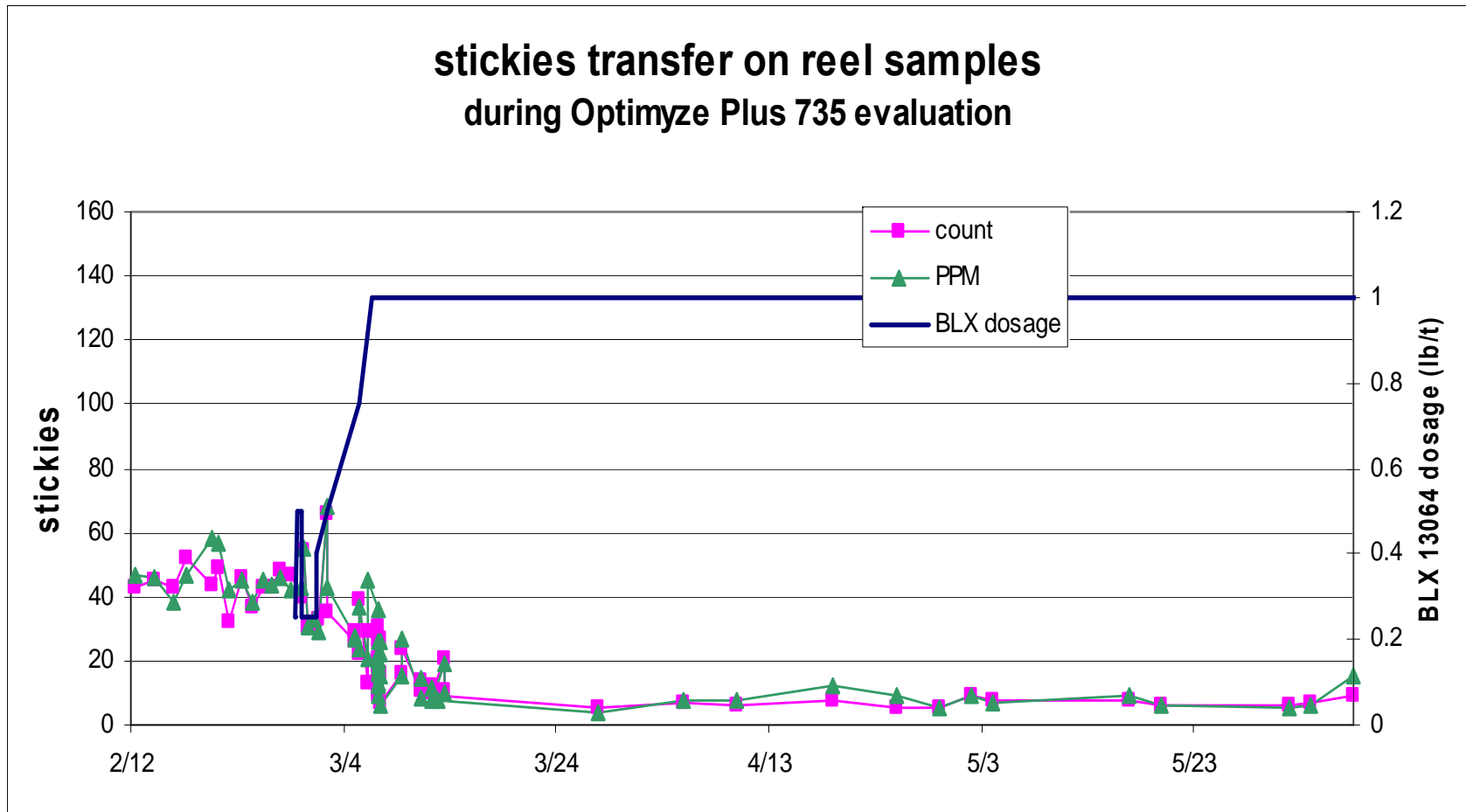
Endo-Beta 1,4 Xylanase

# Electron micrographs



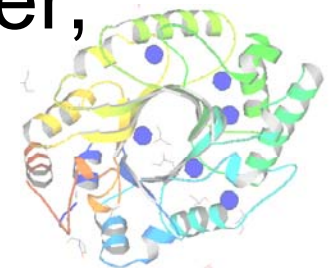
eta 1,4 Xylanase

# Optimize Plus 735 trial data



# Caustic replacement: neutral deinking for newsprint deinking

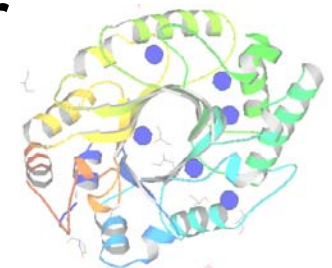
- Caustic is used in pulping recycled fibers to swell fibers, improving paper making potential
- Cellulase enzymes can be used in conjunction with or as a substitute for the caustic to swell fibers
- Neutral deinking has some advantages including less COD in the white water, lower costs



Endo-Beta 1,4 Xylanase

# Decrease energy in refining

- Cellulase enzymes cause partial depolymerization of cellulose and swelling of fibers, more flexible fibers
- Reduction of fines
- Improves efficiency of refining, can decrease energy consumption or obtain improved strength at higher freeness
- Often better runnability or less dryer energy required

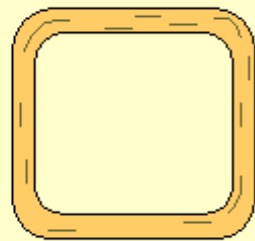


Endo-Beta 1,4 Xylanase

# Fibrillation

## Fibrillation

Delamination of cell wall



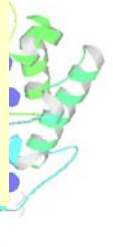
Native  
shape



Refining

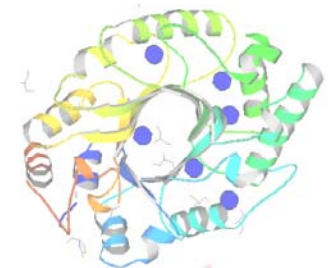


Delamination  
& microfibrils



# Fiber Modification

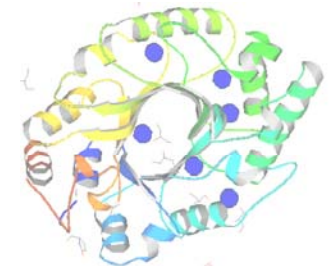
- Enzymes can assist this de-lamination process
- Conditions fiber for refining
- Reduces refining energy
- Changes the refining curve
- Old rules do not apply
- Laboratory Testing



Endo-Beta 1,4 Xylanase

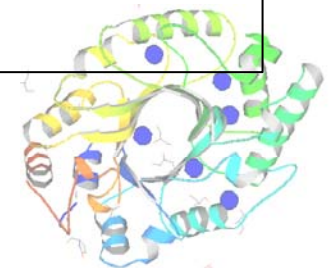
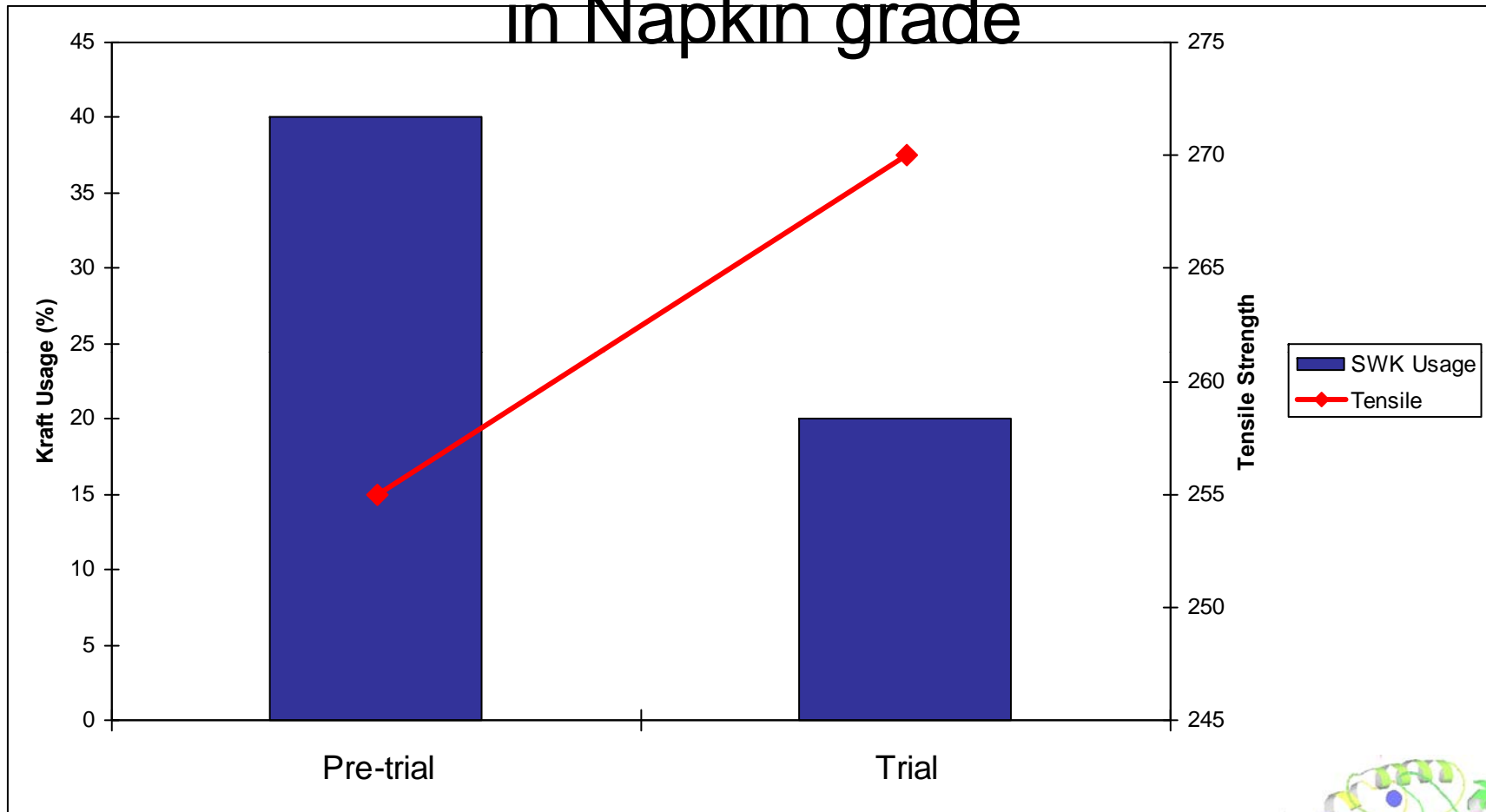
# Case History

- **MILL:** Quebec
- **FIBER:** Recycled/Softwood Kraft
- **GRADE:** Napkin
- **GOAL:** Increase tensile strength to middle of specification, reduce kraft fiber usage
- **METHODS:** Treated MOW stock at the pulper with 0.5 to 1.0 kg/tonne BZM 2545, about 3 hours of contact time



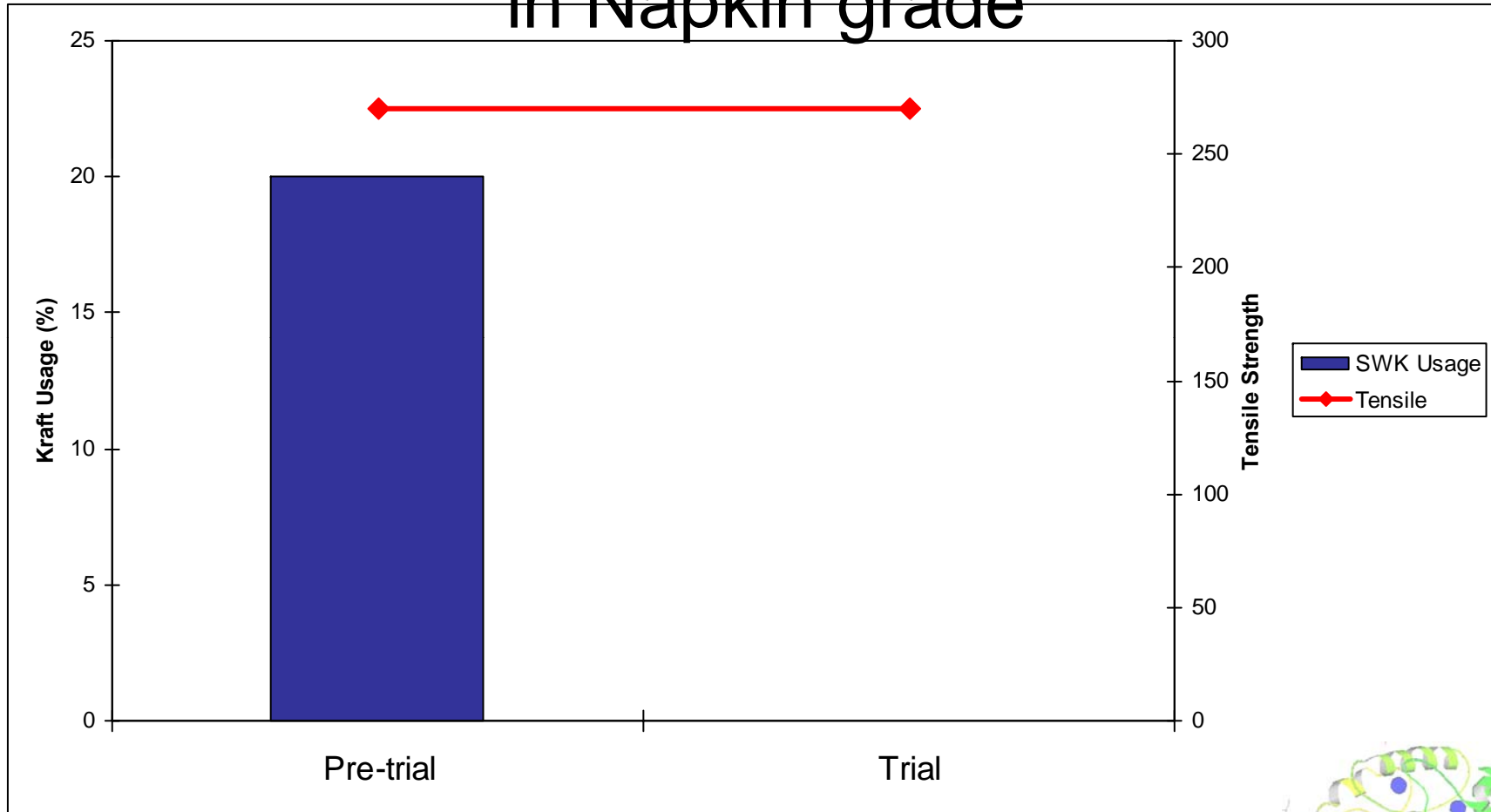
Endo-Beta 1,4 Xylanase

# Machine Trial of Buzyme 2545 in Napkin grade

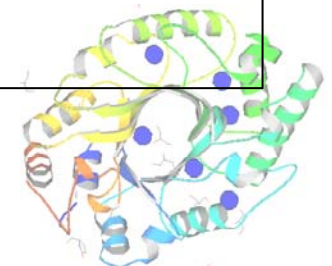


Endo-Beta 1,4 Xylanase

# Machine Trial of Buzyme 2545 in Napkin grade



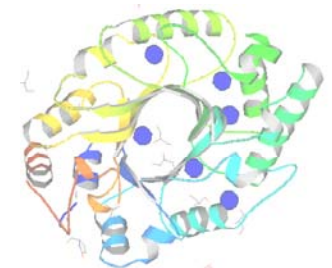
Refining energy reduced



Endo-Beta 1,4 Xylanase

## Results: Machine Trial of Buzyme 2545 in Napkin grade

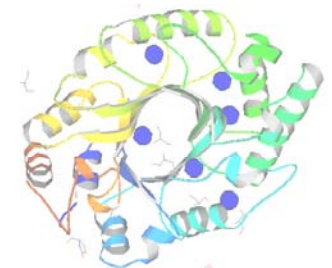
- Reduced kraft from 40% to 0% of furnish
- Increased tensile to a “comfortable” range
- Refining energy reduced 14%
- Drainage is better, but cannot take advantage of it, due to drive limitations



Endo-Beta 1,4 Xylanase

# Hydrolysis of fines

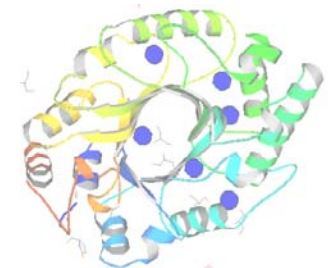
- Fines build up in water loop in PM and cause drainage, formation and paper properties problems
- Cellulase enzymes hydrolyze these fines, making them soluble, improving PM ops
- Can run PM faster (up to 10% faster in some cases?)



Endo-Beta 1,4 Xylanase

# Softness in tissue

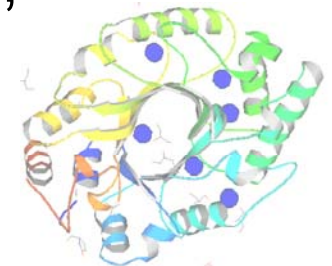
- Cellulase enzymes improve softness by hydrolyzing cellulose in fibers, creating weak spots in fibers, making fibers flexible
- Softness increases of up to 25%
- P&G has several patents, some donated to NCSU



Endo-Beta 1,4 Xylanase

# Case History

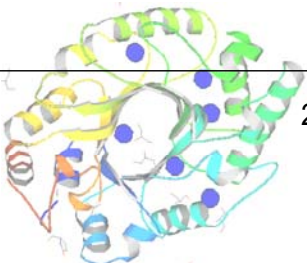
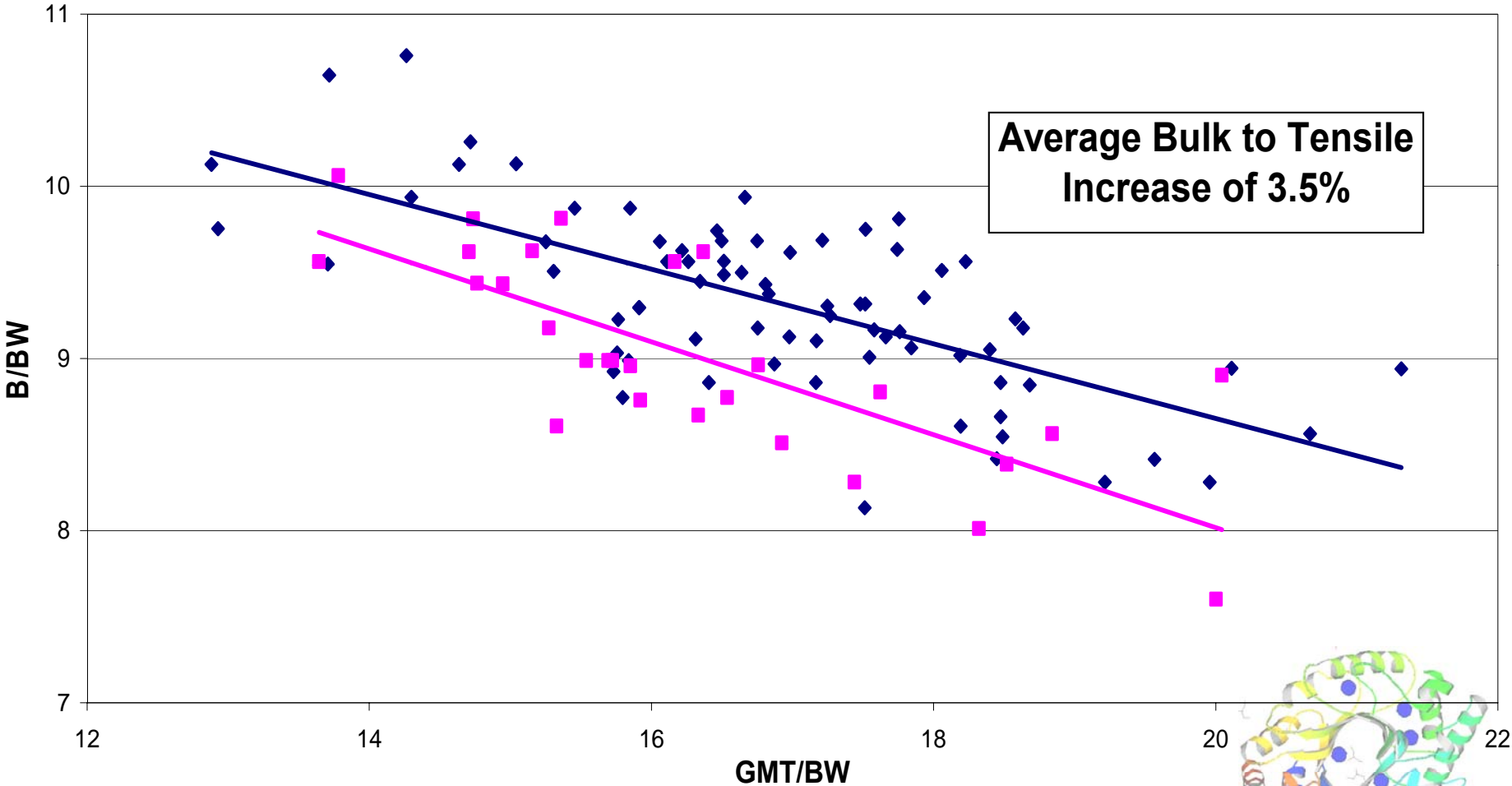
- **MILL:** Quebec
- **FIBER:** 95% SWD/5% Recycled Fiber
- **GRADE:** Premium Bath
- **GOAL:** Reduce refining energy, increase softness and bulk, maintain tensile
- **METHODS:** Treated stock at the pulper with 0.5 to 1.0 kg/tonne BZM 2545, about 3 hours of contact time



Endo-Beta 1,4 Xylanase

# Bulk vs. Tensile

## Buzyme 2535 vs. Glyoxylated Polyacrylamide



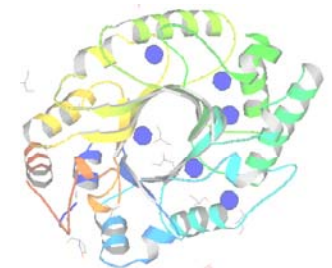
Endo-Beta 1,4 Xylanase



- ◆ Buzyme 2535
- ◆ Linear (Buzyme 2535)
- Glyoxylated PAM
- Linear (Glyoxylated PAM)

# Results

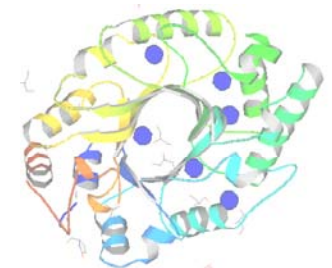
- Shut down refiners
- Maintained tensile
- Bulk/basis weight increased by avg. of 3.5%
- Able to reduce BWT due to increase in tensile
- Machine speed increase of 100 FPM, due to better drainage



Endo-Beta 1,4 Xylanase

# ROI for Fiber Modification

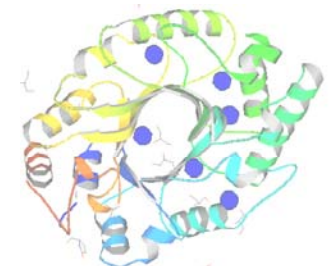
- Reduction in refiner energy
- Less fines generation
  - Better drainage
  - Softer feel
  - Less dusting
  - Cleaner white water
- Reduction in starch or CMC
- Fiber substitution
  - Could use more MOW, less virgin



Endo-Beta 1,4 Xylanase

# Improved biodegradability of pulp mill waste water

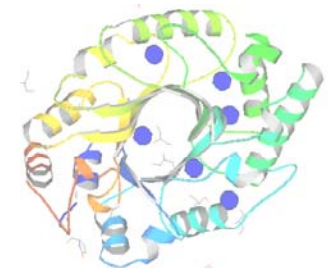
- Cellulases and Hemicellulases used to degrade cellulose and other high molecular weight polymers
- COD/BOD ratio of domestic sewage 2:1
- COD/BOD ratio of paper mill waste water up to 5:1
- Hydrolysis of cellulose fines by enzymes to lower molecular weight sugars that are more biodegradable



Endo-Beta 1,4 Xylanase

# Clean Ups / Boil Outs

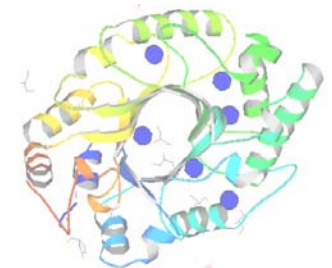
- Amylase to treat starch deposits in clean ups of starch preparation/application equipment
- Protease used as biodispersants or enzyme boil-outs, cleave protein molecules in deposits and solubilize deposits



Endo-Beta 1,4 Xylanase

# Summary

- Enzymes are green chemicals that can improve operations in pulp and paper
- Wide variety of enzymes, must be applied with understanding of how they work
- Several widely accepted applications, starch, bleaching, clean ups
- Future: high valued functionalized fibers, improved pulping, specialized paper properties, conversion of wastes to fermentable sugars.



Endo-Beta 1,4 Xylanase