Sustainable Textile Chemistry

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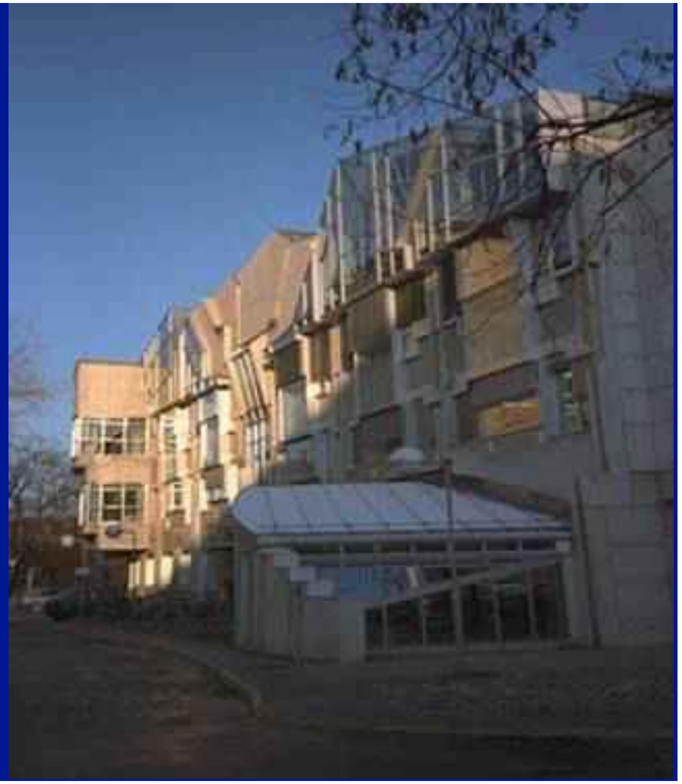
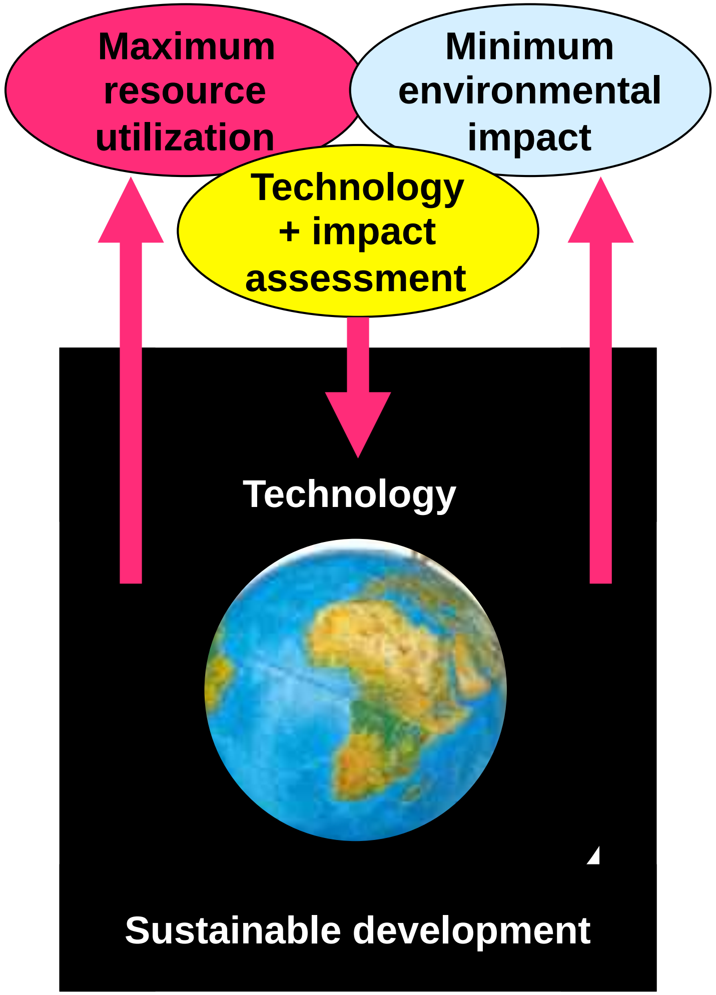


Graz

- Just 820 km from Stresa
- Academic environment
  - 4 Universities in Graz
  - 60k students out of 250k inhabitants
  - Graz University of Technology
  - Faculty Chemical Engineering and Biotechnology

Sustainable Textile Chemistry

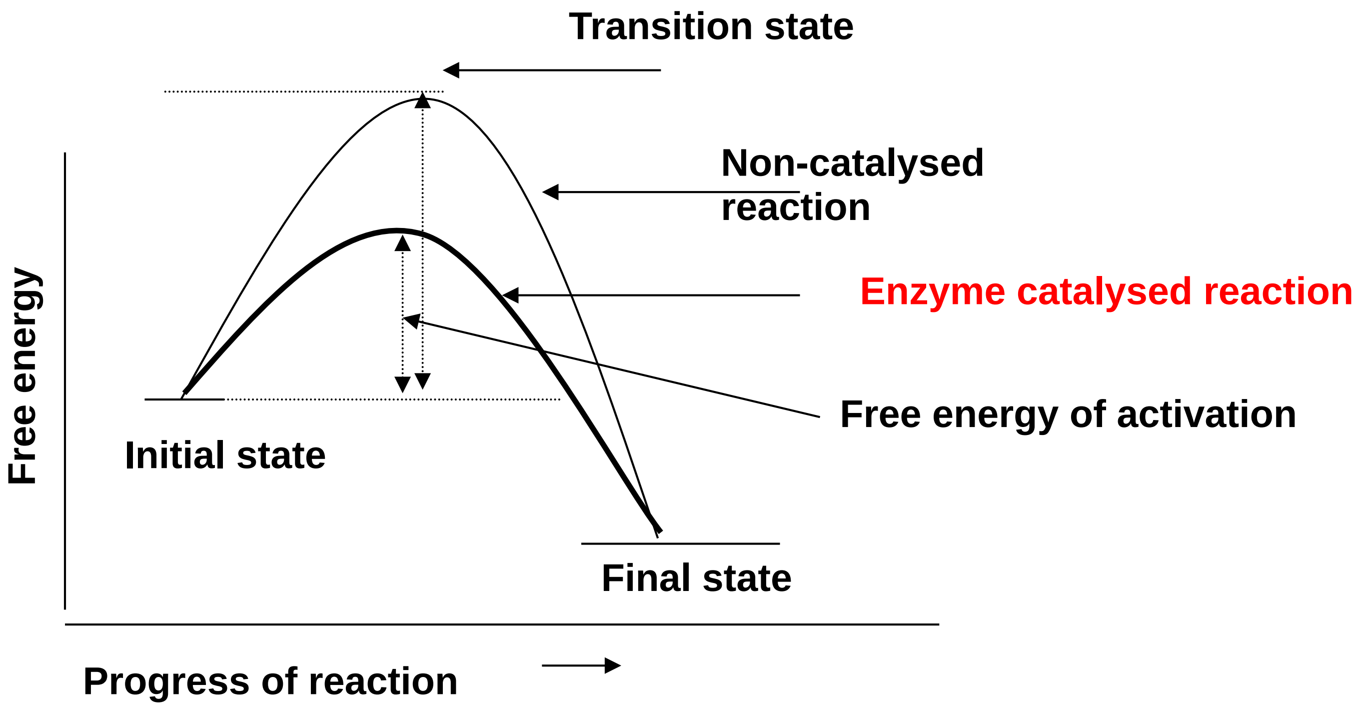
Longer lifetime
Higher functionality
Higher fastness
Covalent bonds
…..



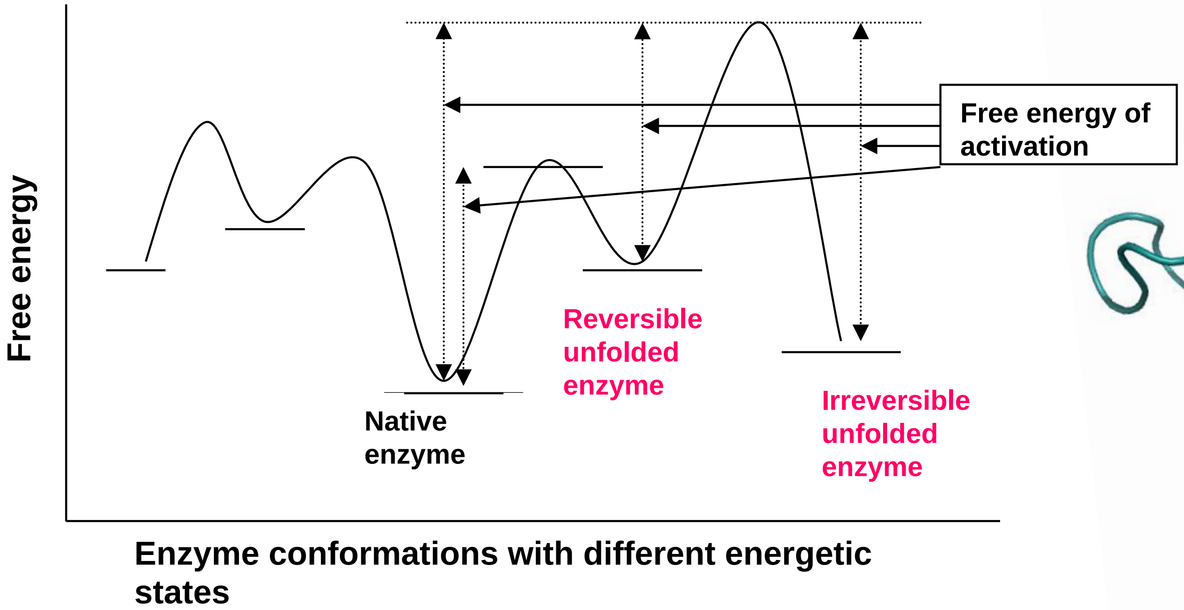
Why using enzymes?

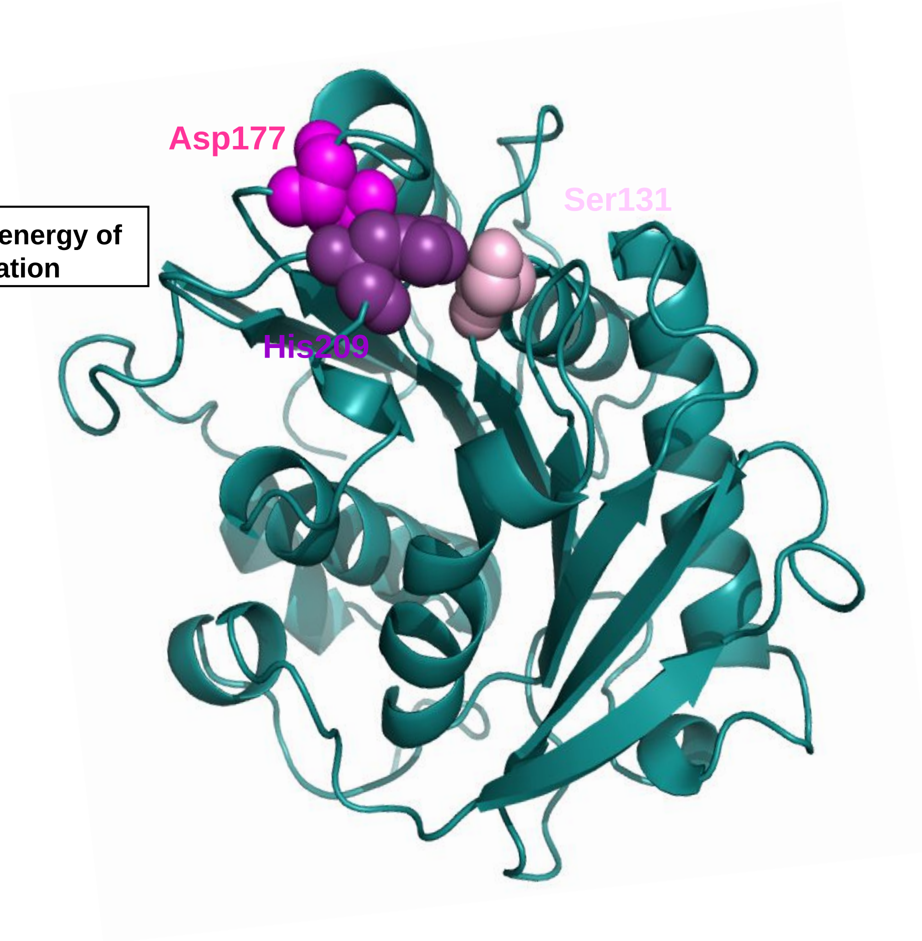
- Enzymes are highly specific biocatalysts
  - Only catalyse certain transformations while leaving other material intact
- Avoids use of hazard chemicals
  - Enzymes work under “mild” conditions
- Enzymes are fully biodegradable
  - since they are proteins
  - Used only in catalytical amounts

Enzyme catalysis



Handling of Enzymes: Denaturation





Enzyme inactivation

- pH / temperature
- Chemical modification: Reduction/Oxidation
- Surfactant
- Chelator
- Shear force
- Protease activity

Potential of enzymes in textile processing

Established
Commercial
In vitro

Cellulose / flax / viscose

- **Desizing:** Amylase, Lipase
- **Scouring:** Retting of flax (Microbes), pectinase
- **Bleaching:** Laccase, peroxidase
- **Catalase** (between Bleaching and Dyeing)
- **Dyeing:** Laccase, peroxidase, Azo reductase; Enzym. dyeing
- **Finishing:** Stone washing: Cellulase, Laccase, protease (back stain); Biofinshing: Cellulase removal of fibrils and pills

Wool

- Scouring (Xylanase, pectinase, etc)
- Enzym. dyeing
- Modified protease, Transglutaminase

Silk

- Degumming
- Functionalisation

Synthetics

- polyesterase, Antipilling, Hydrophilisation

History & current status

- 200 M€ Enzymes in Textile processing
  - Amylase for low- or high-temperature desizing
  - Cellulase for fabric finishes

- Commercial but rarely used
  - Pectinases for bioscouring
  - Catalases to clean up bleach baths
  - Proteases for wool treatment
  - Polyesterases

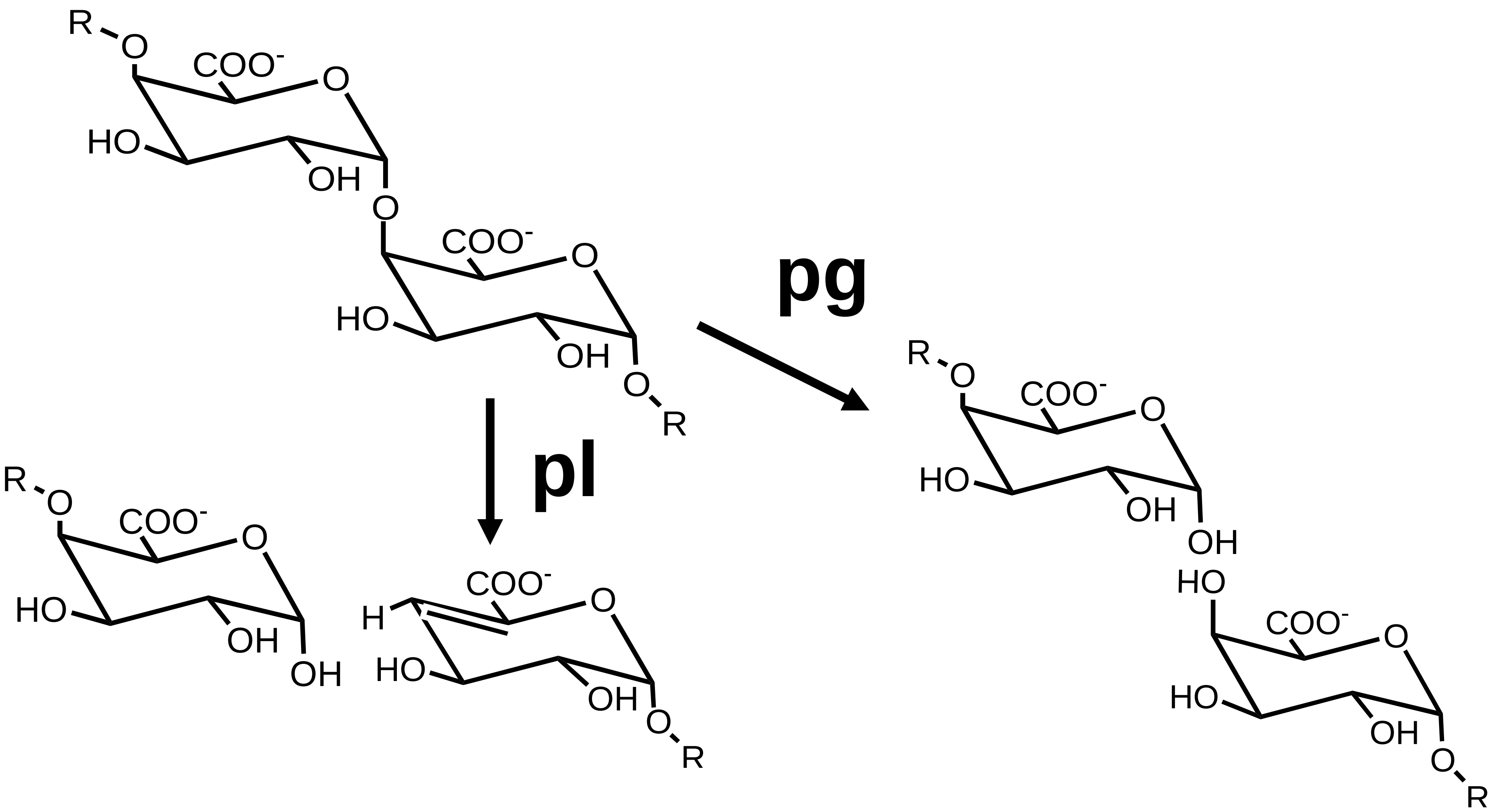
- Recent commercial developments (past 15 years)
  - > 61 EU-RTD projects (CORDIS)
  - > 1500 Scientific publications (sci-finder)

Bioscouring

- Scouring
  - Provide high and even wettability to fabrics
    - Important for dyeing
  - Removal of the non-cellulosic natural matter
    - fats, waxes, pectins and proteins

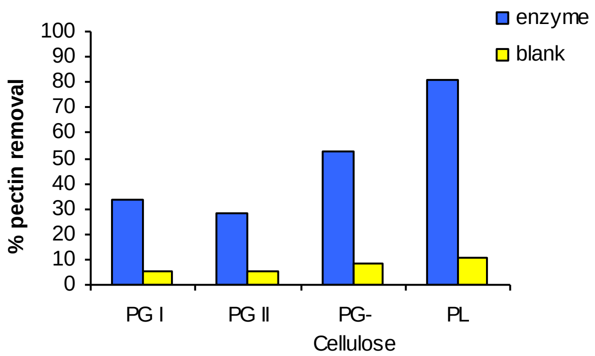
- Potential of Enzymes
  - Savings in chemicals (alkalinity)
  - Reduction of strength loss
  - Reduction of COD loads

Polygalacturonase and Pectate Lyase



Bioscouring : Status

- Endo-acting PGs more effective



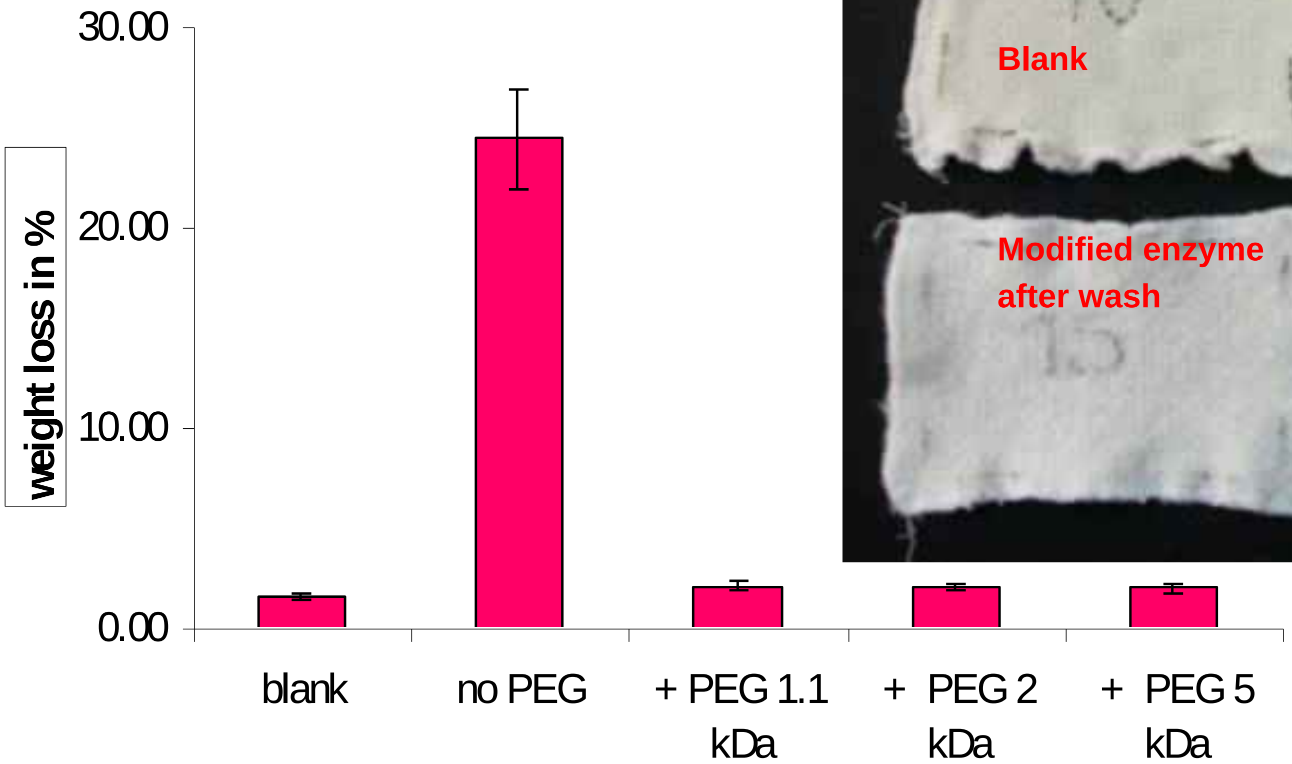
- Low-temperature wax removal with
  cutinase or
  cutinase-CBD increases hydrolytic rate of pectinase

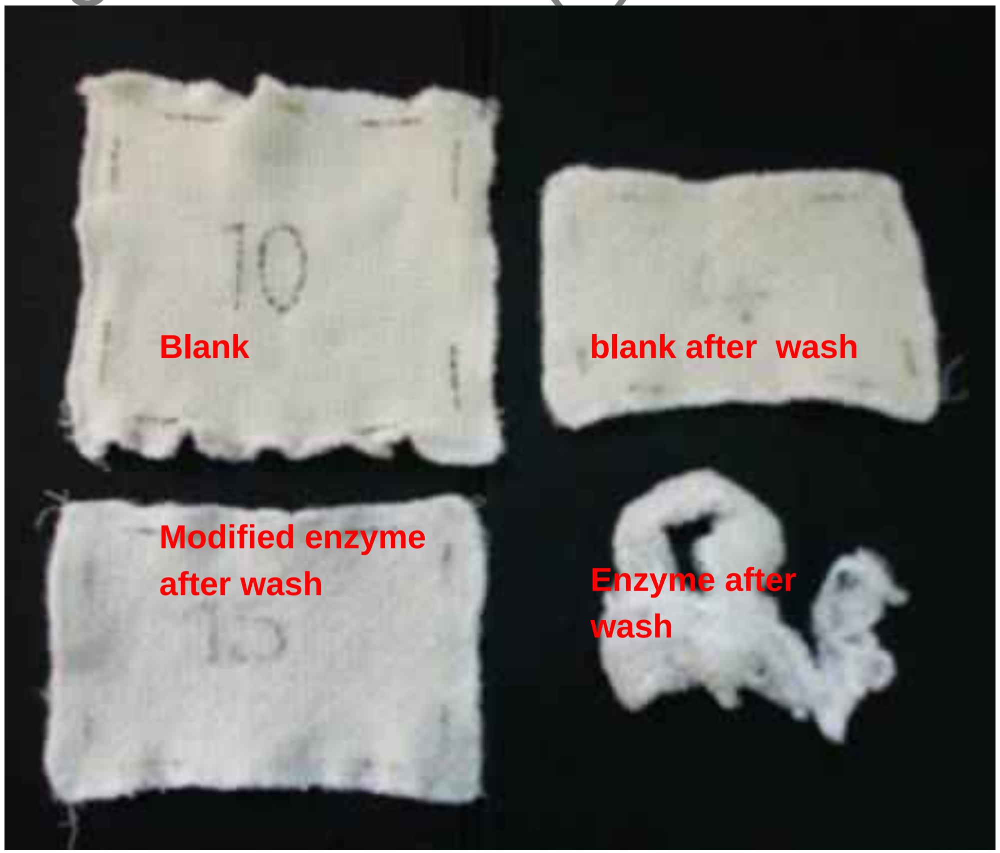
- Potential combination with biobleaching

Schnitzhofer,W., et al. Enzyme Microbial Technol. 40, 1739-1747
Klug-Santner,B.G., et al. J. Biotechnol. 121, 390-401
Agrawal et al. Enzyme Microbial Technol. 42,473-482
Held et al. Environ. Chem. Lett. 3, 74-77.
etc.

Commercial status: enzyme available

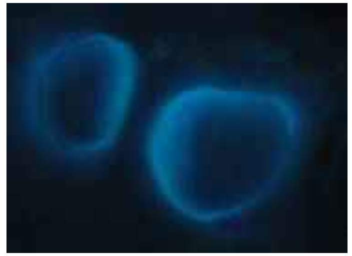
Wool antishrinking treatment (1)



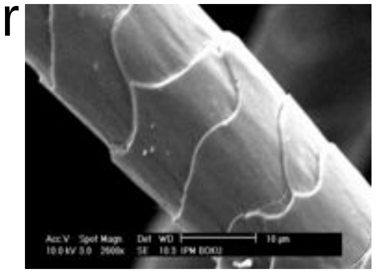


- Weight loss decreased and Shrinkage reduced

Wool antishrinking treatment (2)

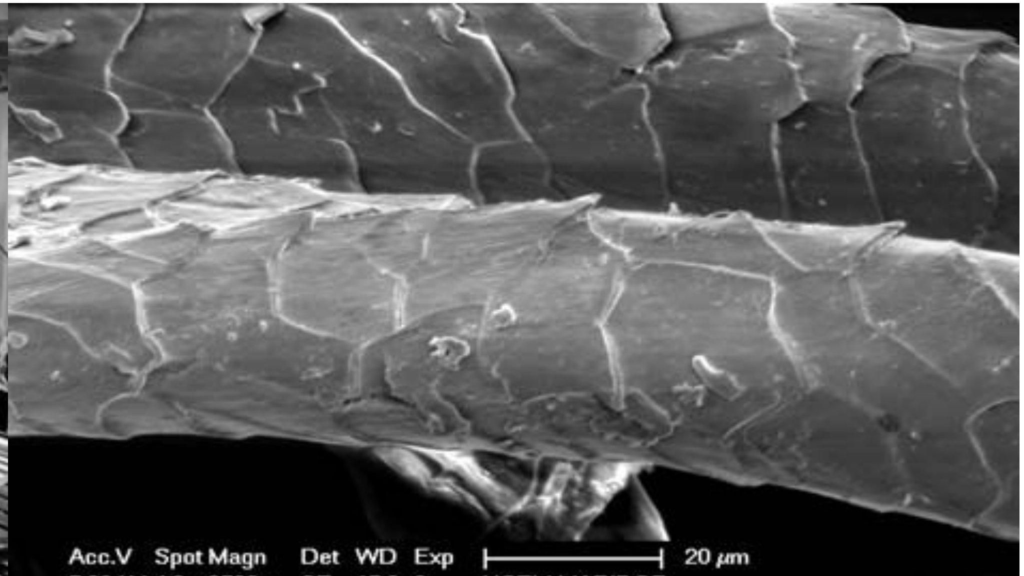


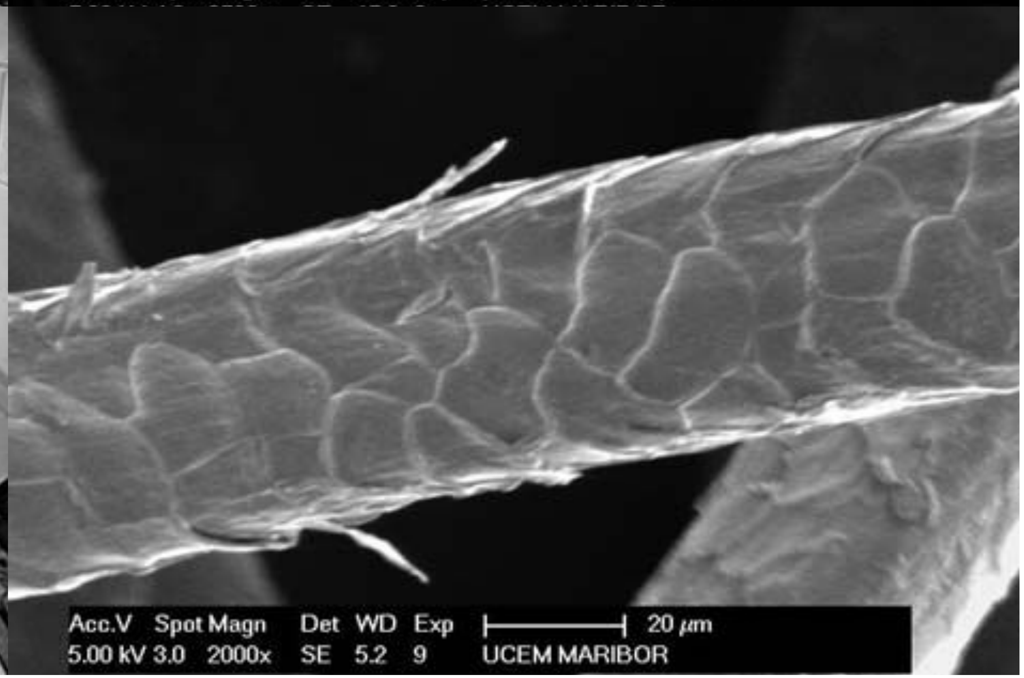
- Status
  - Process established for chemically modified enzymes
  - Gentically modified enzymes available
  - IPR-protected
  - Pilot-trials with industry



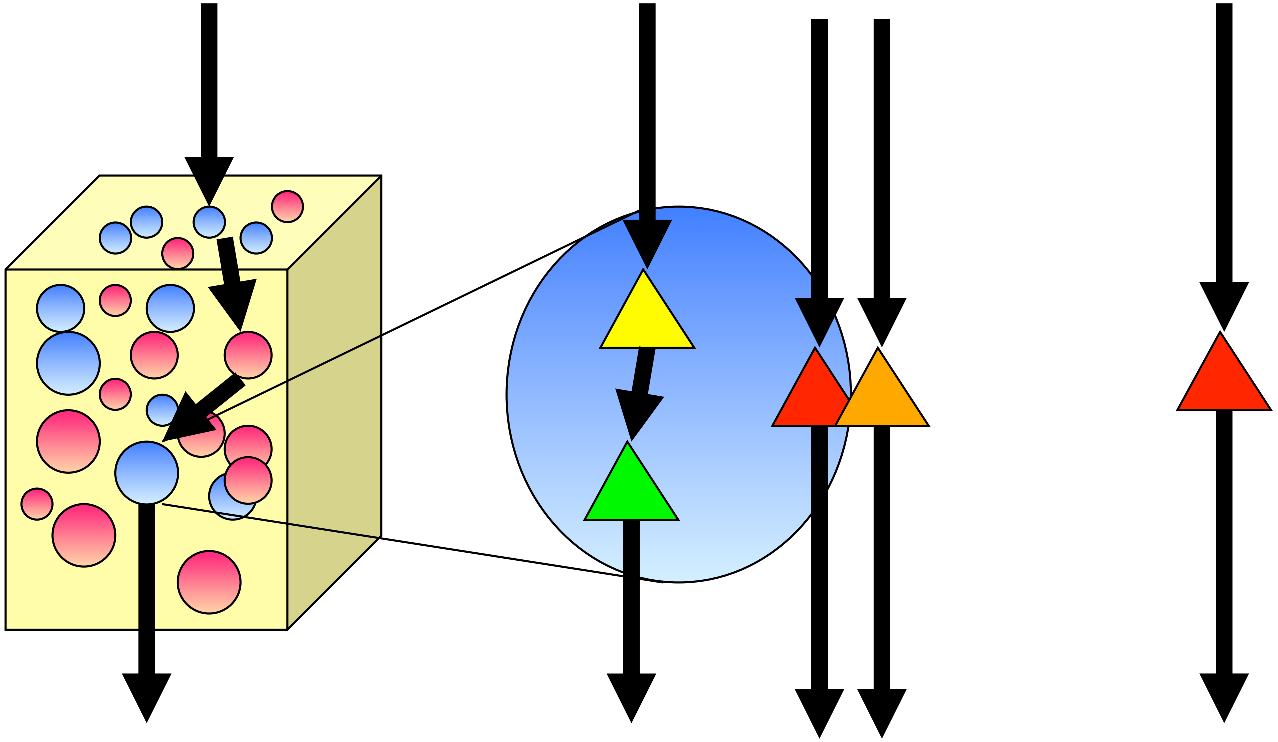
- Implementation
  - Niche-market
  - Large amounts of enzymes required for industrial trials
  - big investment (relative to market) for enzyme producer
  - Marketing: bio-product?

Wool antishrinking treatment (3)

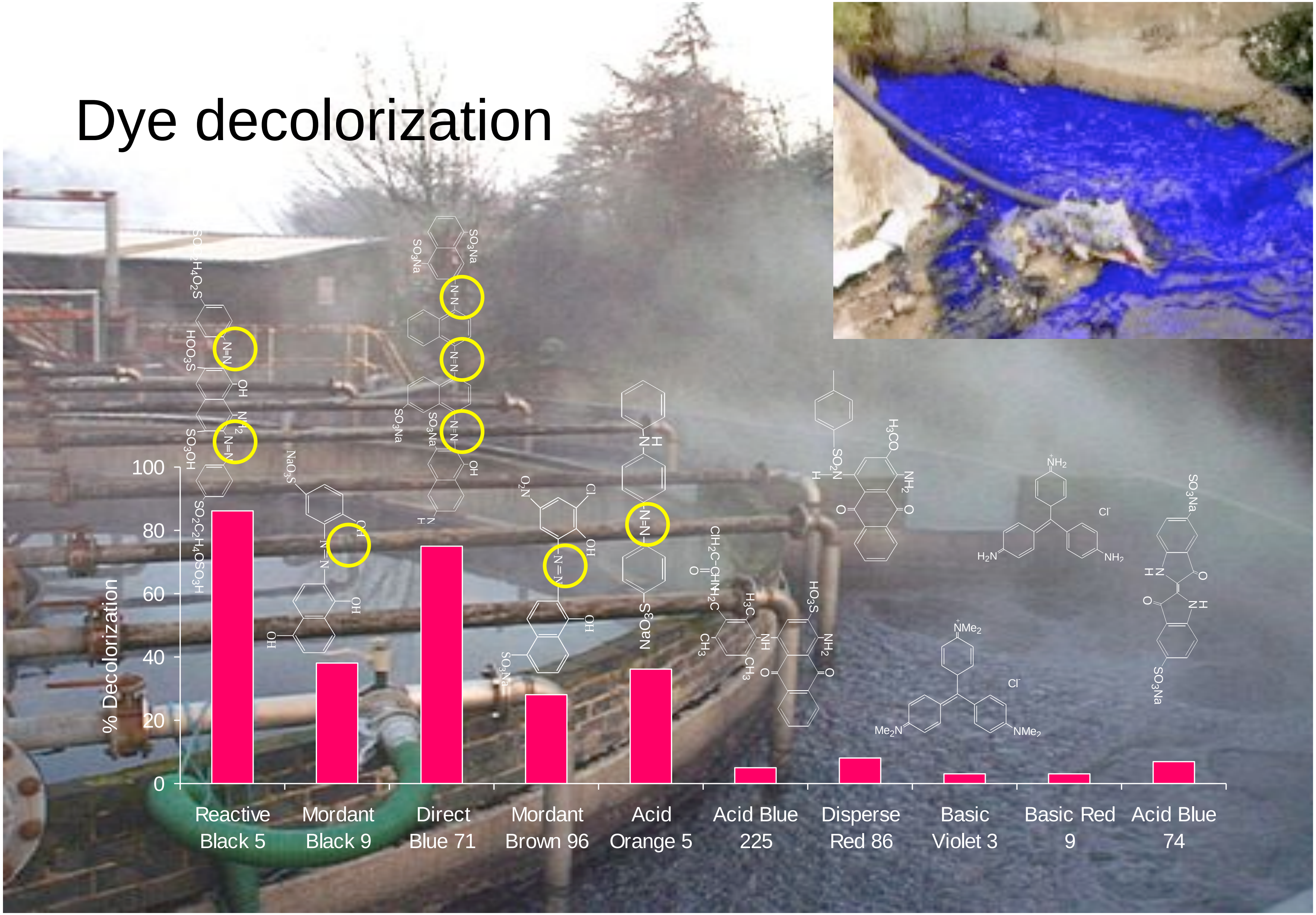




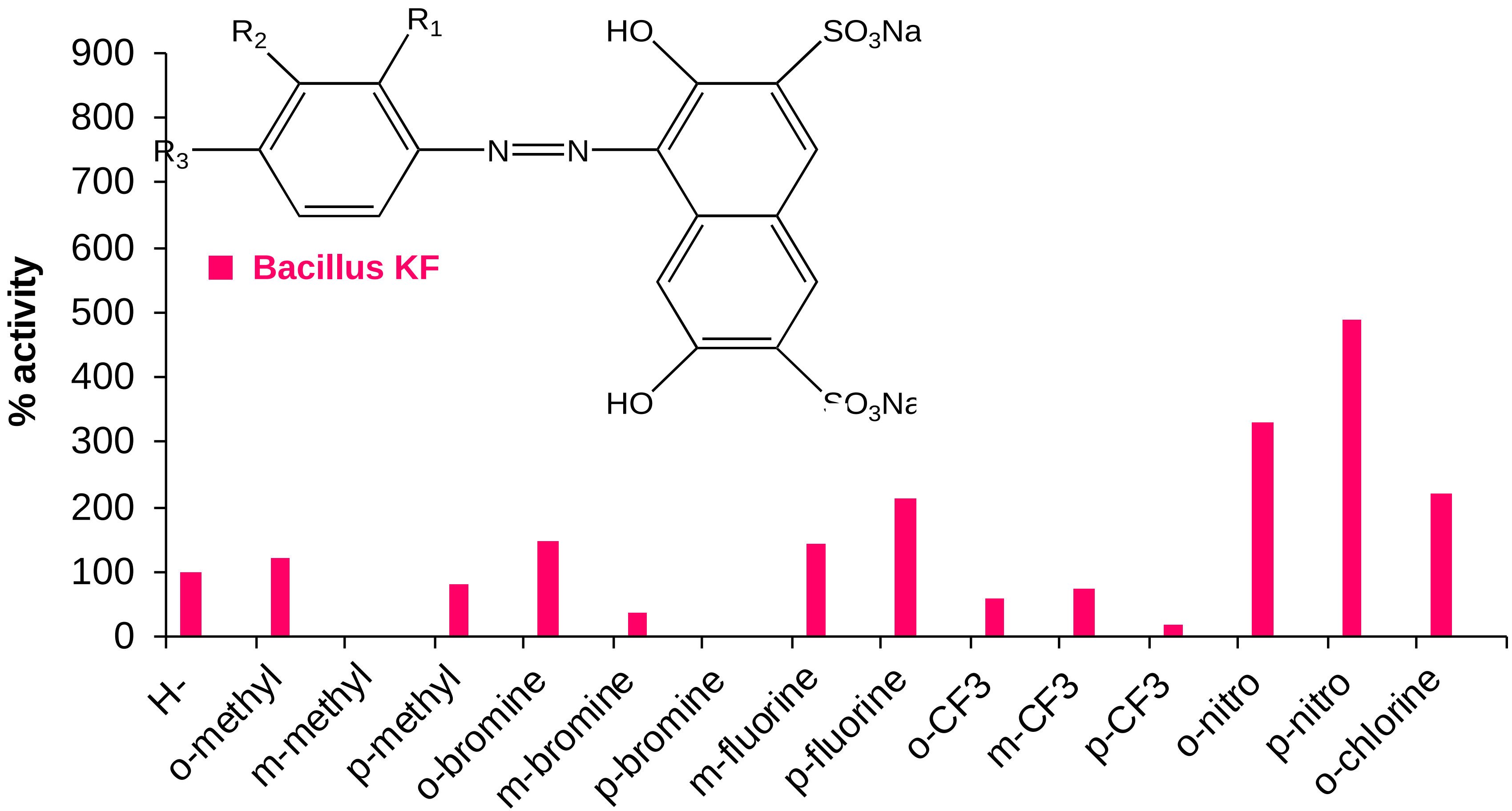
Effluent treatment



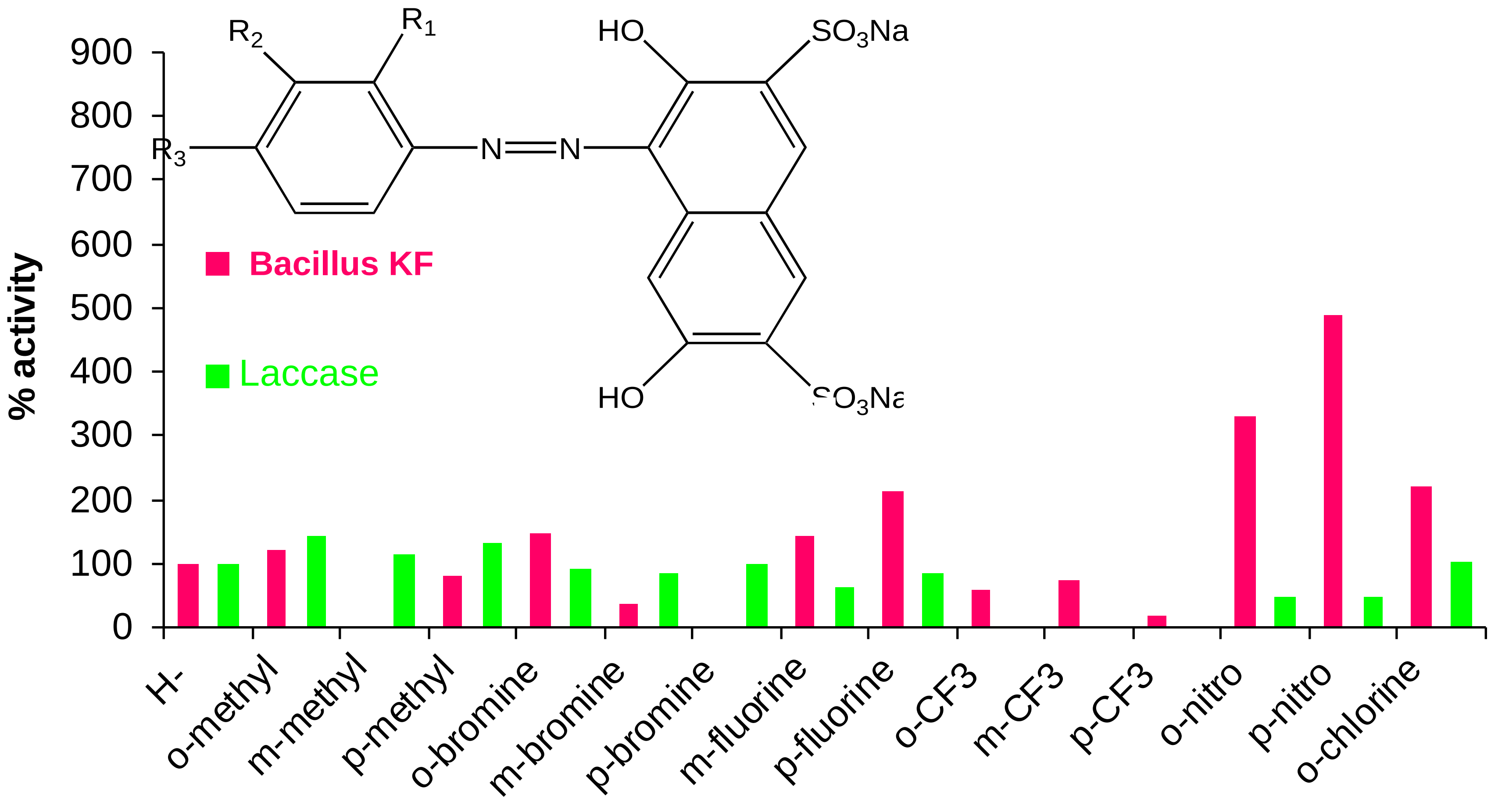
Dye decolorization



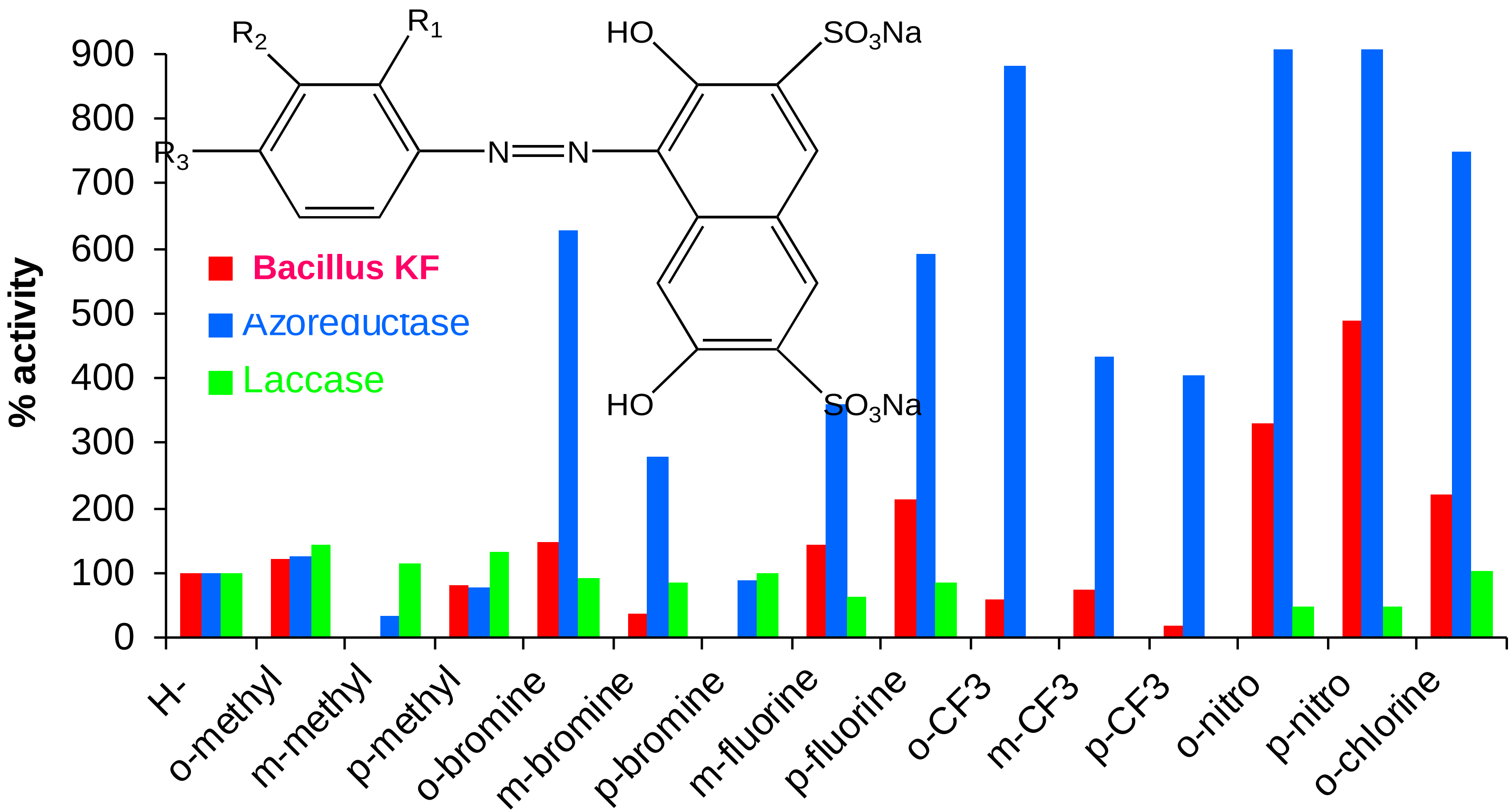
Oxidation/reduction of azo compounds



Oxidation/reduction of azo compounds

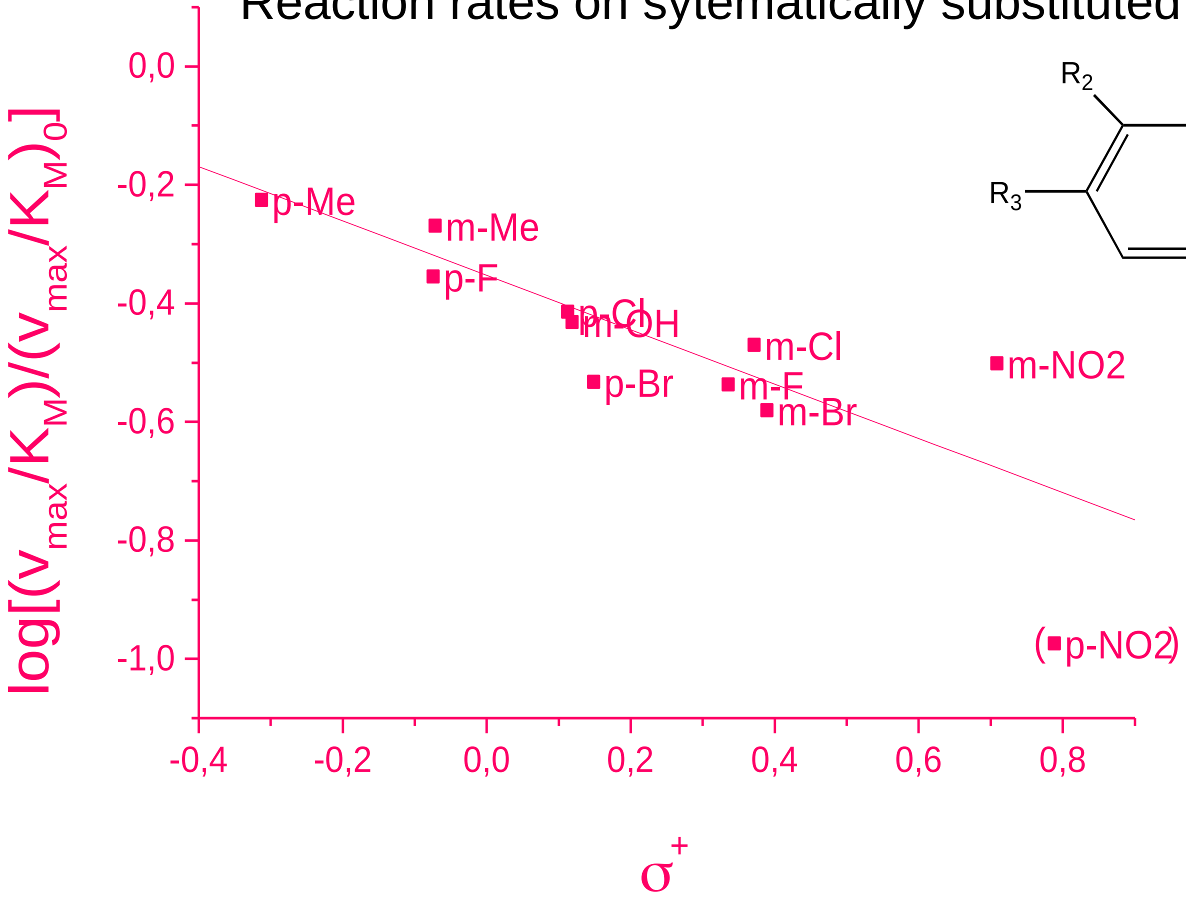


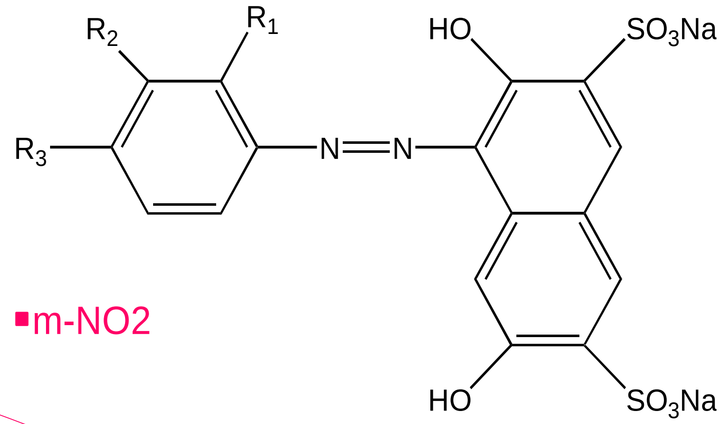
Oxidation/reduction of azo compounds



Predicting enzyme substrate specificities

Reaction rates on sytematically substituted model substrates





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Kandelbauer,A., Erlacher,A., Cavaco-Paulo,A., Gübitz,G.M., 2004. Biocat. Biotrans. 22, 331-339

Surface functionalisation of synthetics

- Synthetic polymers
  - PAN, PAT, PA, PP
  - Hydrophobic
  - Difficulties in finishing

- Surface modification
  - Low fasteness
  - Chemical process require harsh conditions
  - Damage of materials (e.g. 15 % weight loss for PET finishing)
  - Polymer bulk properties changed
  - Plasma treatment

- Enzymatic processes
  - Act only on surface
  - Mild conditions
  - Highly specific

Enzymatic surface hydrophilisation of PET

Technical materials: PVC coated PET

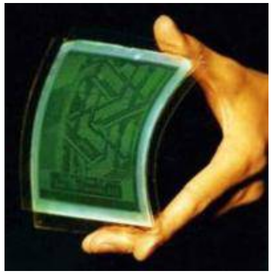
80 % reduction of adhesives needed

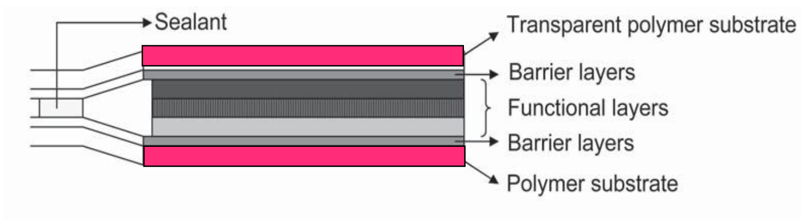
Functional sportswear

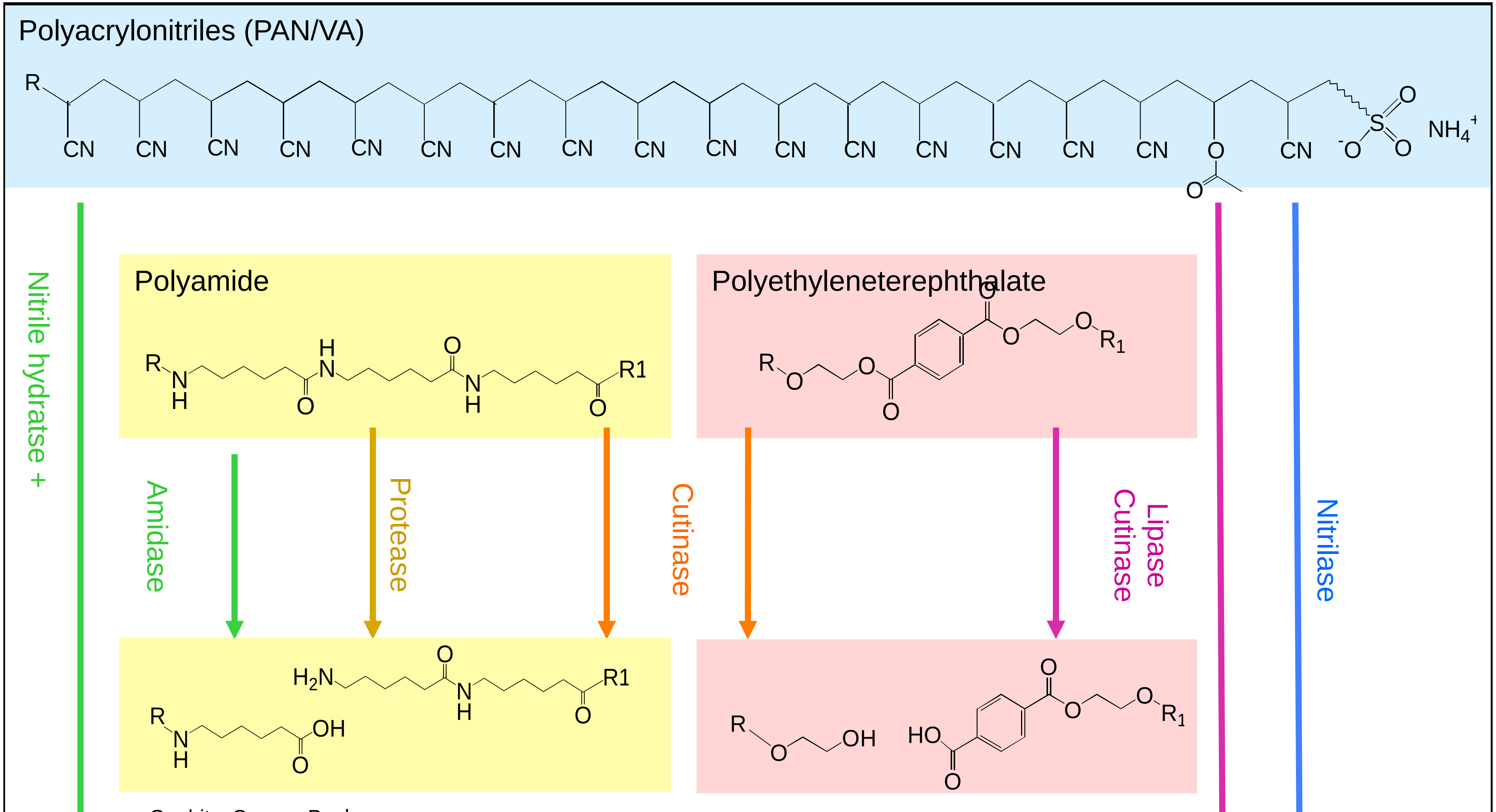
Enhanced:
Breathability
Moisture uptake
Antistatic behavior
Reduced pilling
Handle
Finishing fastness

Flexible electronic devices

Enhanced bonding to PET







Guebitz, Cavaco Paulo,
Trends in Biotechnology 2008

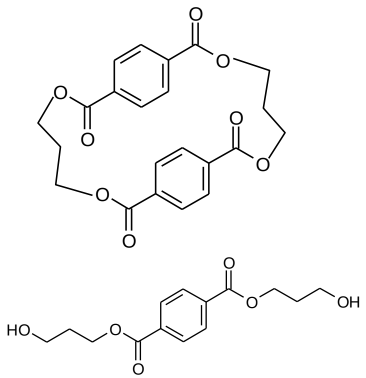
PET-hydrolases: mechanistics

Enzymes: ***Thermobifida fusca, Beauveria brongniartii, etc.***

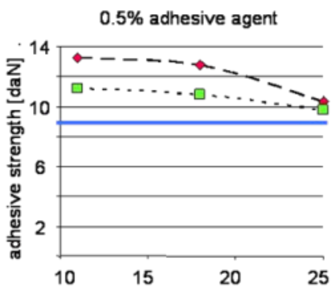
Applications: Textiles, PVC-Coating, Electronics, etc.

Polyesterases act endo-wise on PAT (XPS, MALDI, SEM)
Enzymes from different origin different substrate specificities

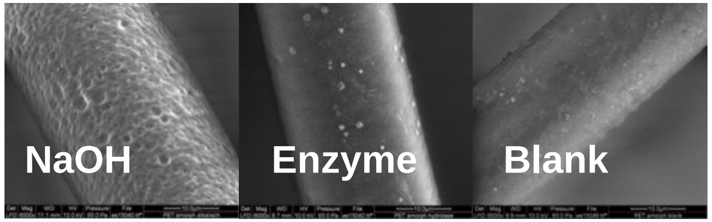
LC-MS (ion-trap)



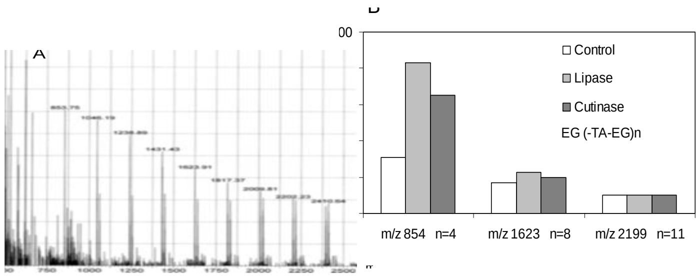
Coating



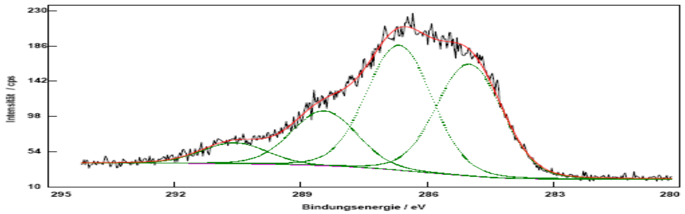
SEM



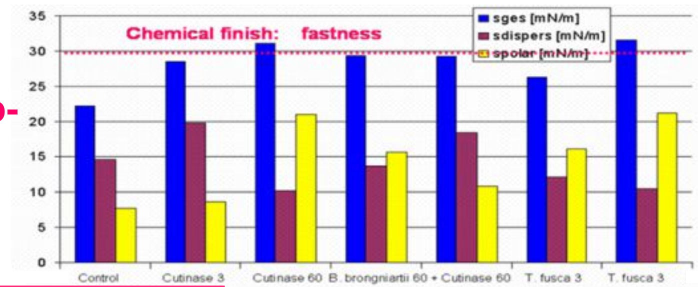
MALDI



XPS



Tensio-metry



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Fischer-Colbrie,et al. 2004. Biocat. Biotrans. 22, 341-346.
Heumann et al. 2006. J. Biochem. Biophys. Meth. 39, 89–99
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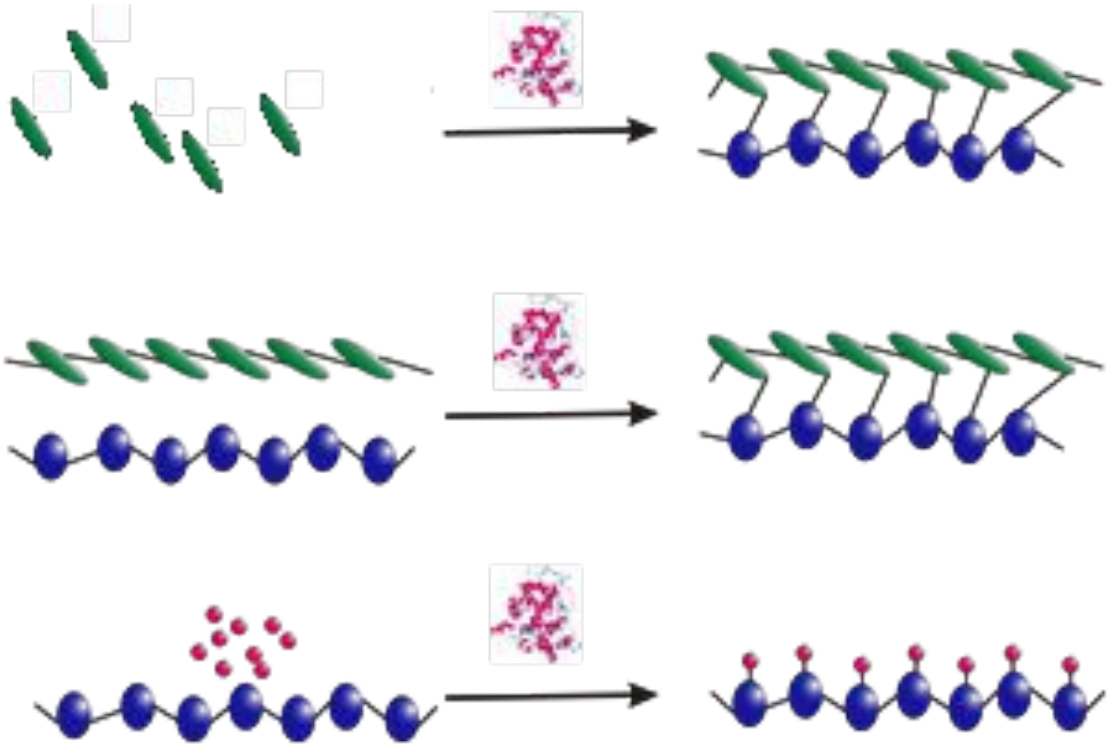
Coating, grafting and crosslinking



Coating

Flax with phenolics *(Schroeder et al)*
polyamide with phenolics *(Heumann et al)*
polyester with siloxanes *(Eberl et al)*

Crosslinking

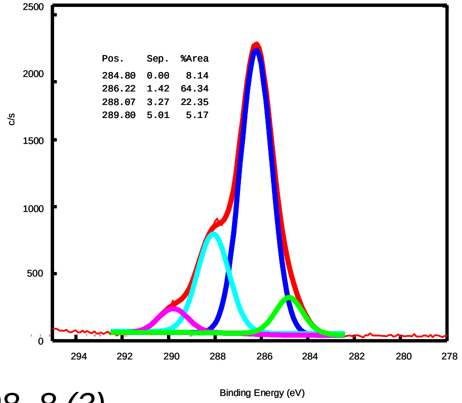
Fibres

Grafting

Flax & fluorophenols *(Kudanga et al)*
proteins *(Jus et al)*

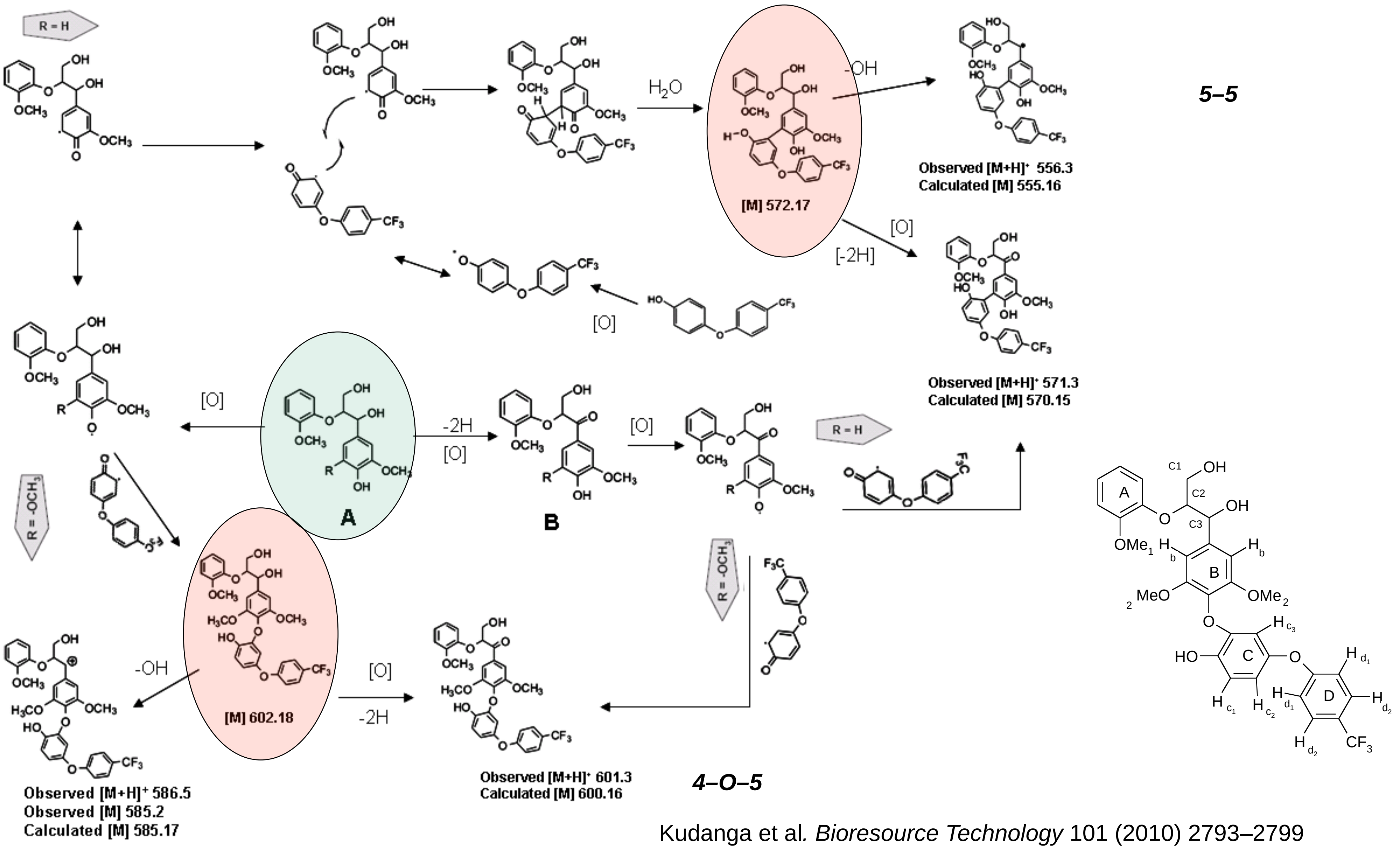
Grafting / coating flax

	antibacterial activities			
phenol	**on fibers**	**on fabrics**		**color**
hydroquinone	very good §$	very good §$		white
2-methoxy-5-nitrophenol	good *§$	good *§$		yellow
ferullic acid	very good §$	very good §$		orange
guaiacol	none	none		red
vanillin	none	none		greyish
methyl-3-hydroxy-4-methoxybenzoate	good §$	good §$		pale yellow
§*B. subtilis* $*S.aureus* **K. pneumoniae*				



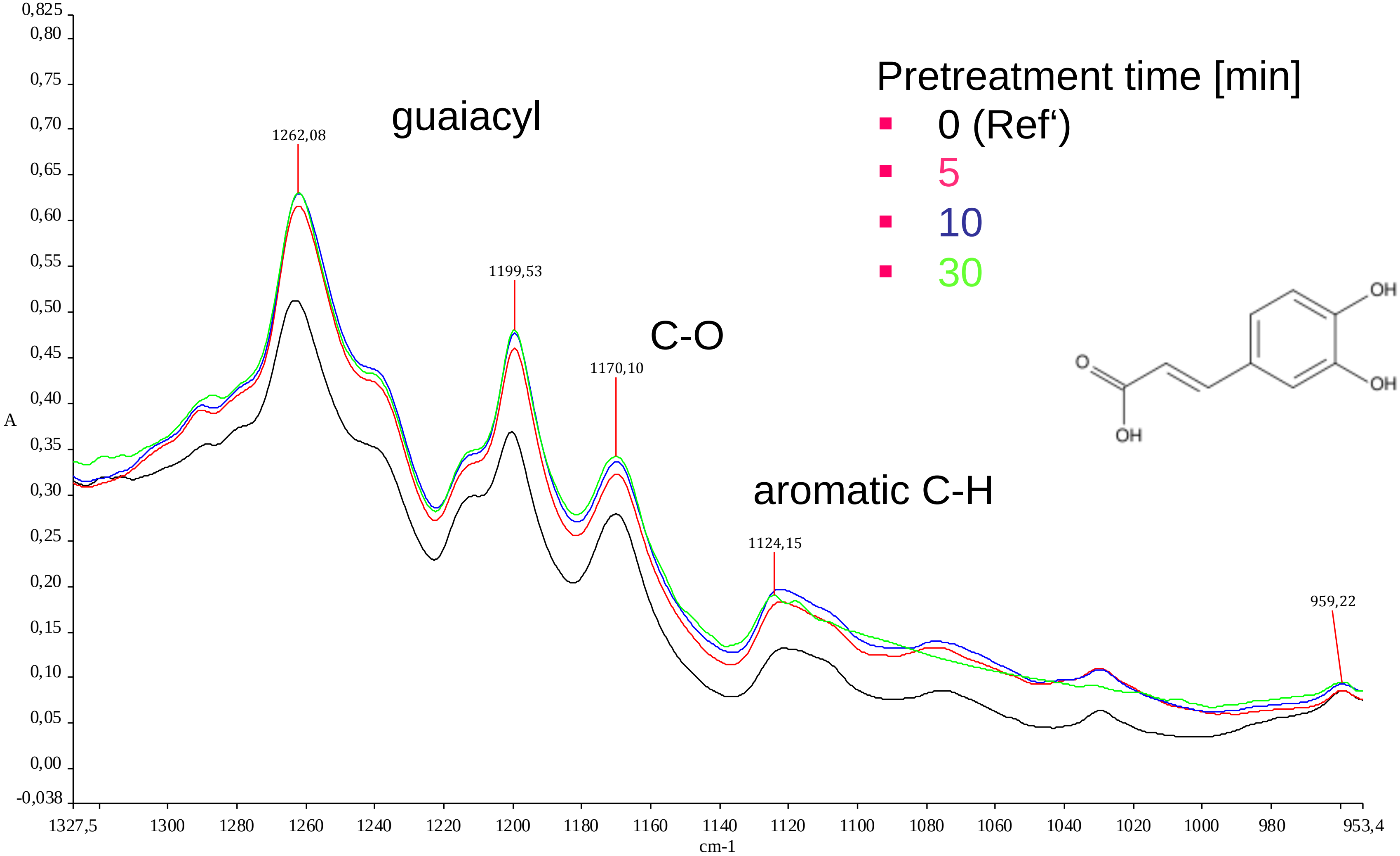
1 Schroeder,M. et al., 2007. Biotechnol. J. 2, 334-341. *2 S. Kim, et al.,, Eng. Life Sci. 2008, 8 (3),*

Coupling fluorophenols onto lignin moieties

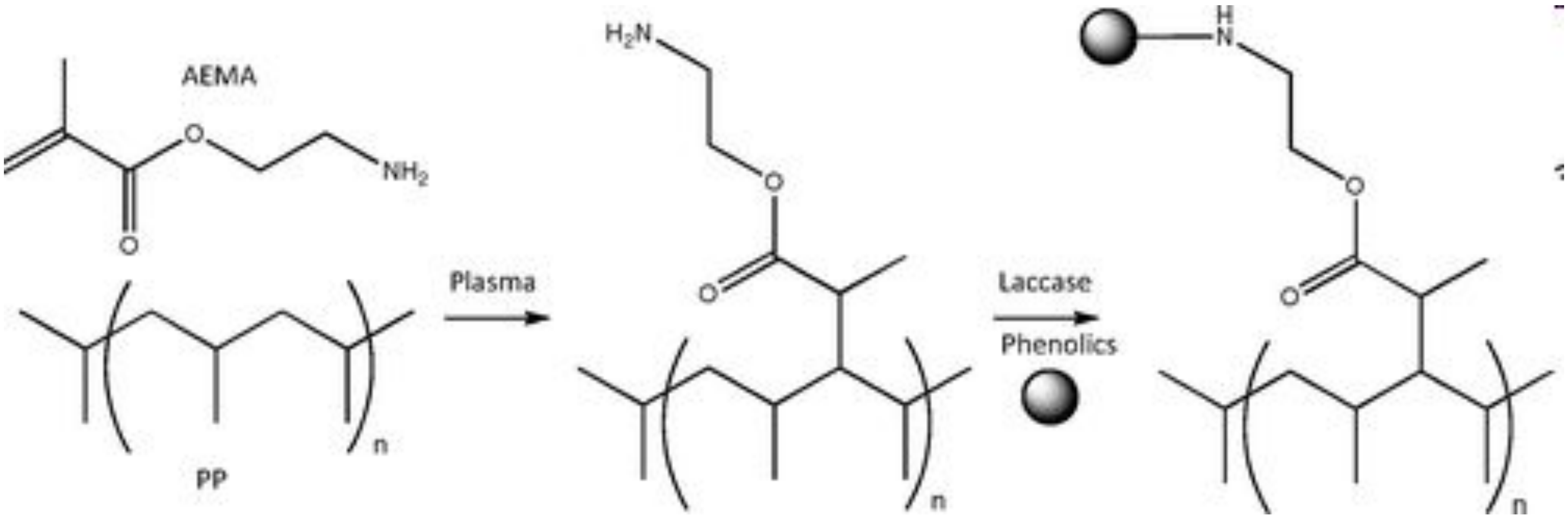


Kudanga et al. *Bioresource Technology* 101 (2010) 2793–2799

Coating of activated PA with caffeic acid



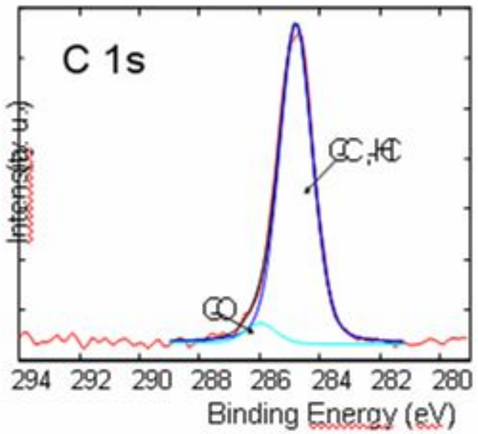
Amino functionalisation of PP

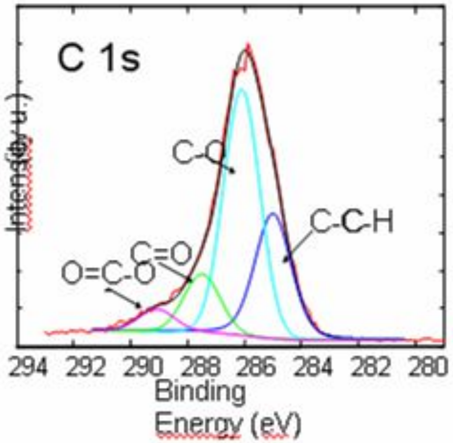


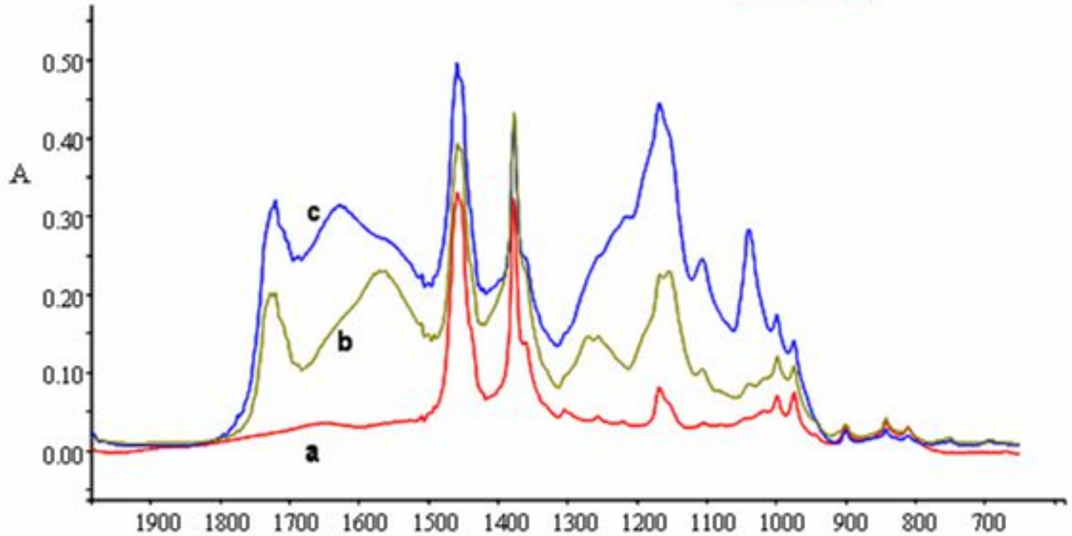
Schroeder et al.
Biomacromolecules, 2008, 9 (10), pp 2735–2741

UMaribor V. Kokol, Tectotessile, E. Fatarella

Phenol coating of polypropylene by oxidases





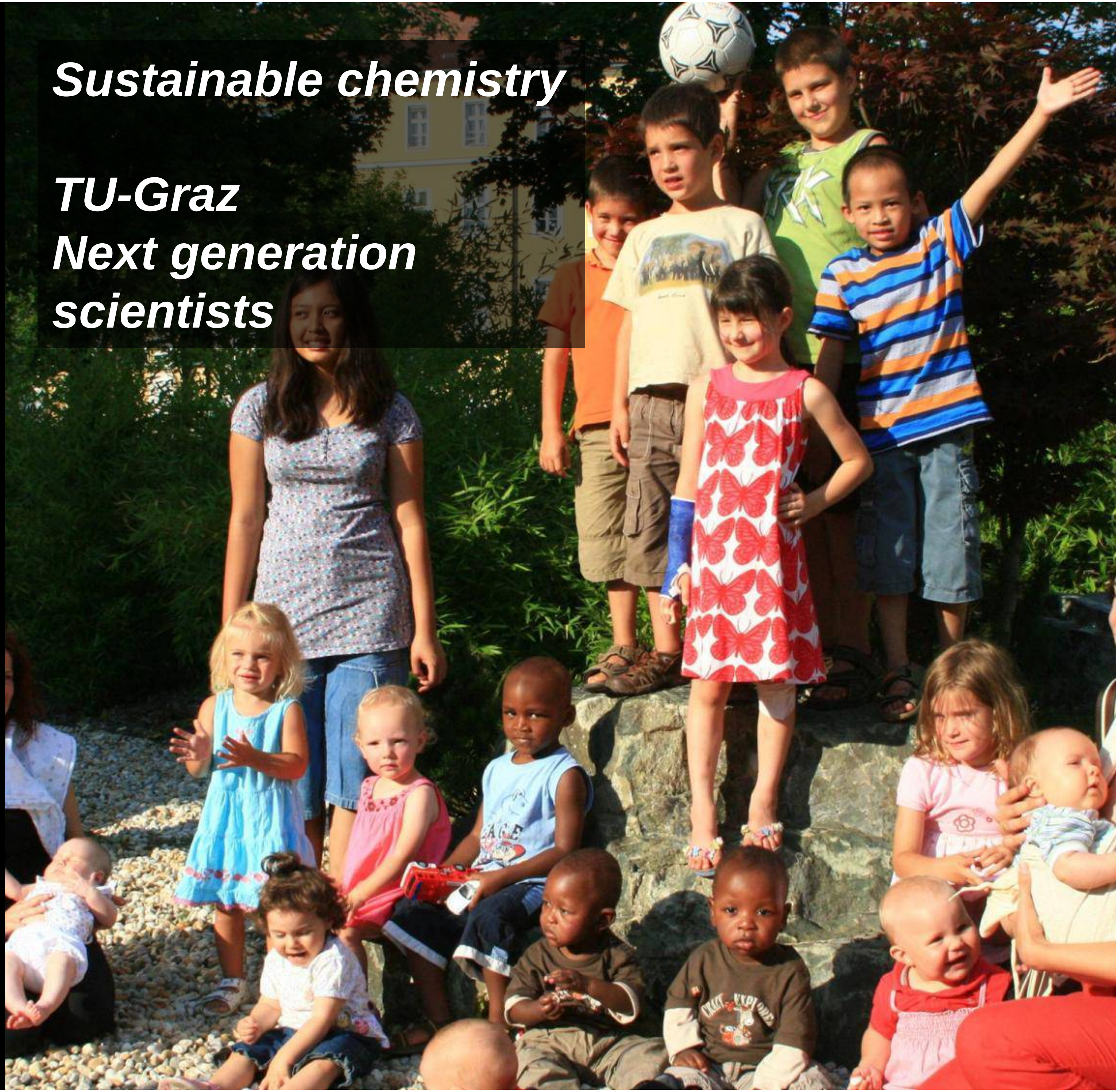


Schroeder, Kokol et al. Slo.PAT.2007

Conclusions

- Sustainable textile chemistry
  - Yes, enzymes can !
  - Special handling
  - Special price

- Biotech processes
  - Established/available
  - Bioscouring, Wool antrishrinking, Effluent treatment
  - The future: Targeted functionalisation


Sustainable chemistry
TU-Graz
Next generation
scientists