Study of Enzymatic and Alkaline Surface Modification of Polyamide 6,6

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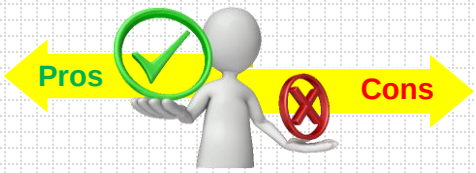
Contents

Polyamide 6,6



- High Strength
- Wrinkle and Abrasion Resistance
- Relatively Low cost
- Convenient Processing
- Tailorable Performance
- Easy Recycling
- Reduced Wearing Comfort
- Build-up of Electrostatic Charges
- Pilling Tendency
- Difficulties in Finishing
- Poor Soil Release Properties
- Poor Dyeability

Current Hydrophilization Methods

a) Physical methods
- Plasma Functionalization

b) Chemical methods
- Alkaline Treatment (NaOH)

c) Bio-technological methods
- Enzymatic Surface Modification of Textiles

Physical methods

❑ Plasma Functionalization

Advantage:

- **Clean & simple technique;**
- **Without use of water & chemicals**

Disadvantage:

- **Relatively High Cost**
- **Not Easy to control the process/Effectiveness**
- **Treatment not uniform**

Chemical methods

❑ Alkaline Treatment (NaOH)

Advantages(+):

+ High degree of improving hydrophilicity
+ Significant change of surface appearance and touch of treated fabric
+ Relatively low cost

Disadvantages(-):

- High chemical usage - Harsh process
- Significant fabric damage; weight and strength loss
- High water pollution (resulted from water consumption and chemical pollutants)
- Limited use for blends (Regenerated cellulose)

Bio-technological methods

❑ Enzymatic Surface Modification of Textiles

Advantages(+):

+ High Degree of Improving Hydrophilicity
+ Minimal Fiber Damage
+ Milder and Gentle Process
+ Relatively uniform performance
+ Less water pollution

Disadvantages(-):

- Relatively Expensive
- Sensitive to skin

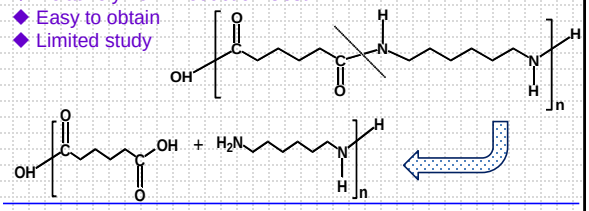
Current Hydrophilization Methods

Parameters	Methods		
	Plasma	Alkaline	Enzymatic
Degree of improving hydrophilicity	High	High	High
Processing cost	High	Low	High < Plasma
Water consumption	No	High	Relatively low
Chemical usage	No	High	Low
Waste water	No	High	Low
Elevated temperature	Low	High	Low
Fiber damage (Weight & Strength)	Low > Enzymatic	High	Low
Scalability/uniformity	Poor	Good	Good

Objective

The present work was undertaken with the aim to estimate the potential use of Subtilisin for treating Polyamide 6,6 fibers to find **an environmental friendly new method to improve its hydrophilicity.**

- Relatively Low Production Cost
- Easy to obtain
- Limited study



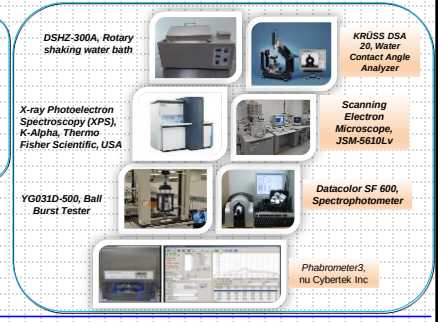
Experimental

Materials

- Polyamide 6,6 (PA 6,6) knitted fabric, 269 g/m²
- Industrial solution of Subtilisin (Savinase)
- Sodium Hydroxide (NaOH)

Equipments

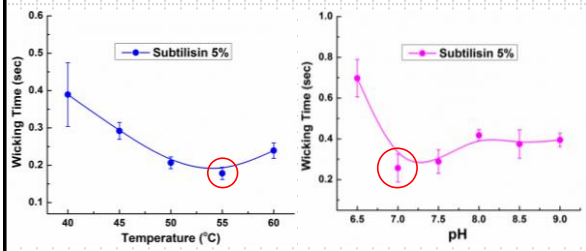
- *DSHZ-300A, Rotary shaking water bath*
- *KRÜSS DSA 20, Water Contact Angle Analyzer*
- *X-ray Photoelectron Spectroscopy (XPS), K-Alpha, Thermo Fisher Scientific, USA*
- *Scanning Electron Microscope, JSM-5610Lv*
- *YG031D-500, Ball Burst Tester*
- *Datacolor SF 600, Spectrophotometer*
- *Phabrometer3,* nu Cybertek Inc



Results and Discussions

Treatment Conditions - Wettability

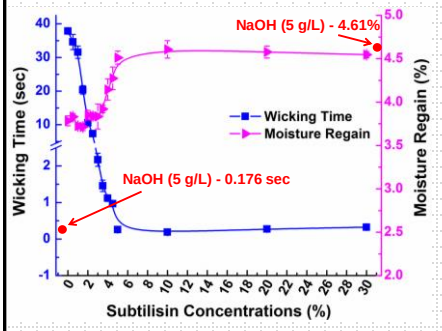
Untreated 38 sec



Peak Performance at 50 to 55°C.

Better performance from neutral to weak alkaline pH range.

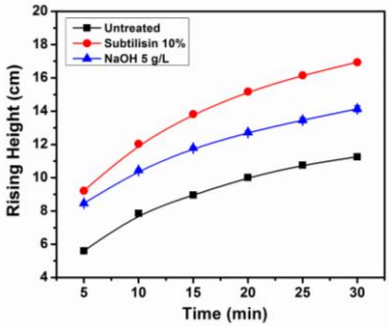
Wettability and Moisture Regain



✓ Greatest wettability and moisture regain improvement between 3% to 6%(owf).

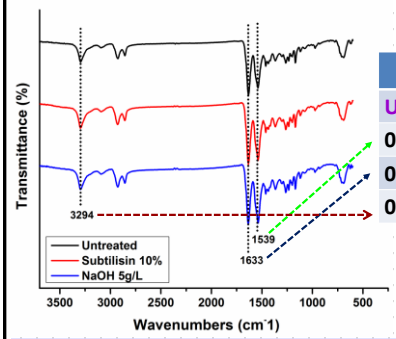
✓ Alkali treatment gets moisture regain higher than Enzymatic but the wicking time is relatively same.

Capillary Height



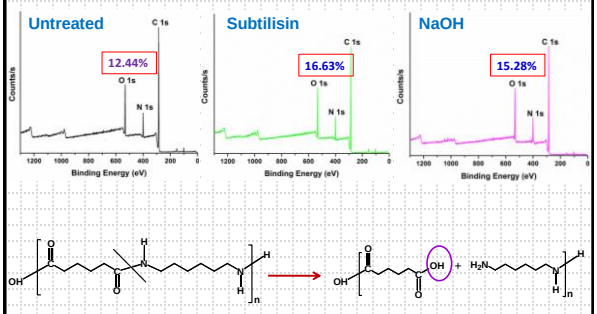
✓ Subtilisin treatment resulted higher capillary impact than NaOH.

Surface Chemistry

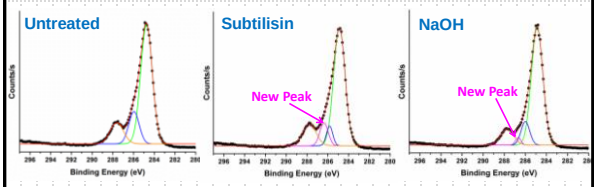


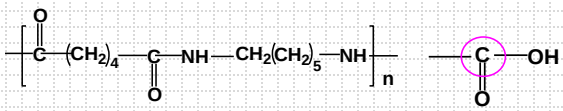
T (%)		
Untr	Sub	NaOH
0.696	0.812	0.814
0.676	0.798	0.769
0.873	0.928	0.913

Elemental Analysis by XPS

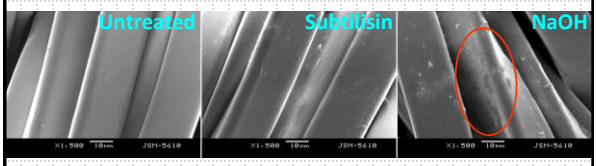


XPS spectra of C1s peaks



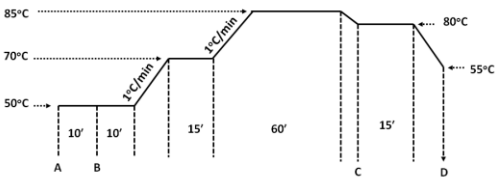


Surface Morphology



✓Subtilisin shows a fairly milder treatment evidenced by the absence of etches, carves and roughness on the surface.

Wool Reactive Dyeing



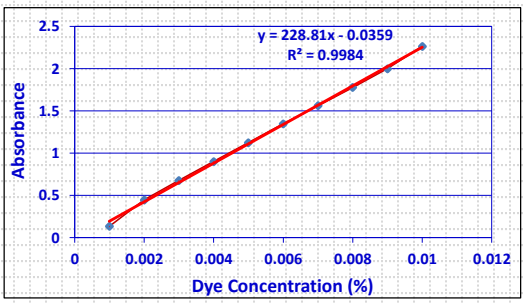
A
$Na_2SO_4.10H_2O$: 50g/L
CH_3COOH: To adjust pH 7.0 – 4.5

B
Lanasol Red 5B 2% owf

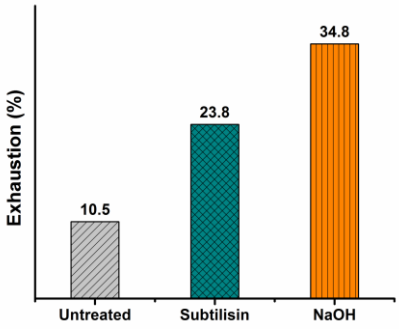
C
$NaHCO_3$: To adjust pH 8.0-8.5

D
Bath Drop, Rinse – Warm and Cold

Wool Reactive Dyeing



Reactive Dyeing Exhaustion



Color Strength

Table: K/S Values of Lanasol Red 5B (2%owf) Dyed Samples at 570 nm

	Untreated	Subtilisin 10% (owf)	NaOH 5 g/L
K/S	2.22 (±0.03)	3.93 (±0.05)	4.85 (±0.05)

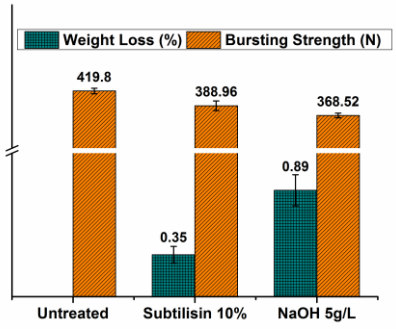
Color Fastness

Table: Color Fastness to Wash

Color Change		Staining					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Untreated	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Subtilisin	5	4-5	4-5	4-5	5	5	5
NaOH	5	5	4-5	4-5	4-5	4-5	4-5

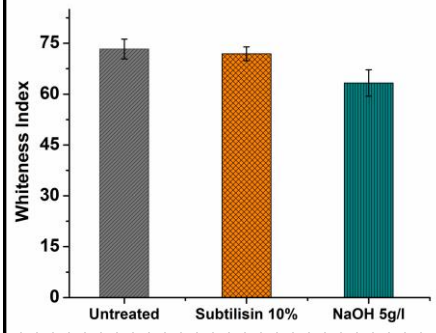
*Wash fastness: class 1, very poor; class 2, poor; class 3, fair; class 4, good; and class 5, excellent

Physio-Mechanical Properties



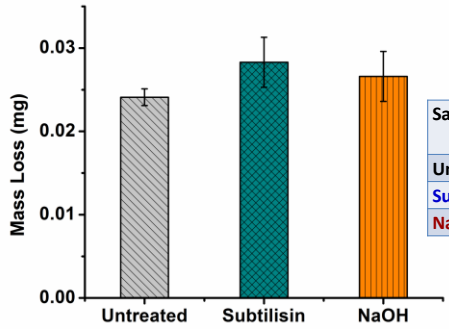
✓ Both treatments have some weight loss and strength loss but enzyme one is better.

Whiteness Index



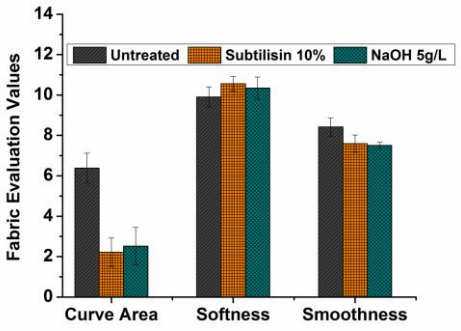
✓Higher Whiteness loss in Alkaline than Enzymatic treated.

Pilling and Abrasion Resistance



Sample	Pilling Rating
Untr	4
Subtilisin	4-5
NaOH	4-5

Fabric Handle Analysis



Conclusion

NaOH

- Higher fiber damage
- Higher mass loss
- Higher fabric strength loss
- Lower capillary height
- Greater fabric yellowing
- More waste water
- Harsh process

Subtilisin

+ Improves Wettability
+ Moisture Regain
+ Capillary Movement
+ Minimal Fabric Damage
+ Minimal Chemical Waste
+ Less waste water
+ Milder and Gentle Process

***Subtilisin may be used as a sustainable Hydrophilization alternative.

Acknowledgements

Thank you!!