

Enzymes: *Old Tools*, New Possibilities

DR CHETNA PRAJAPATI
LOUGHBOROUGH UNIVERSITY

The Team



Prof. Jinsong Shen
De Montfort University

Discipline:
Textile Chemistry



Dr. Chetna Prajapati
Loughborough University

Discipline:
Textile Design



Dr. Edward Smith
De Montfort University

Discipline:
Textile Chemistry

Enzymes



Enzymes are biological catalysts.

Highly specialised proteins found within the cells of all living organisms.

Enzymes used in this study were extracted from microbes, either bacteria or fungi.

Benefits of using enzymes



Enzymes have very high reaction rates.

Require very little energy for a reaction to start and proceed.

Operate under mild processing conditions.

Highly specific in the reactions they perform.

Rarely produce by-products.

Biodegradable and offer the possibility of recycling.

Established enzyme processes



Bioenergy



Food & Beverages



Detergents



AHN



Agriculture



Biopharma



Leather



Pulp & Paper



Textiles



Wastewater Solutions

Enzymes in Textile Production

Biotechnology in textile processing has been used for more than 2000 years.

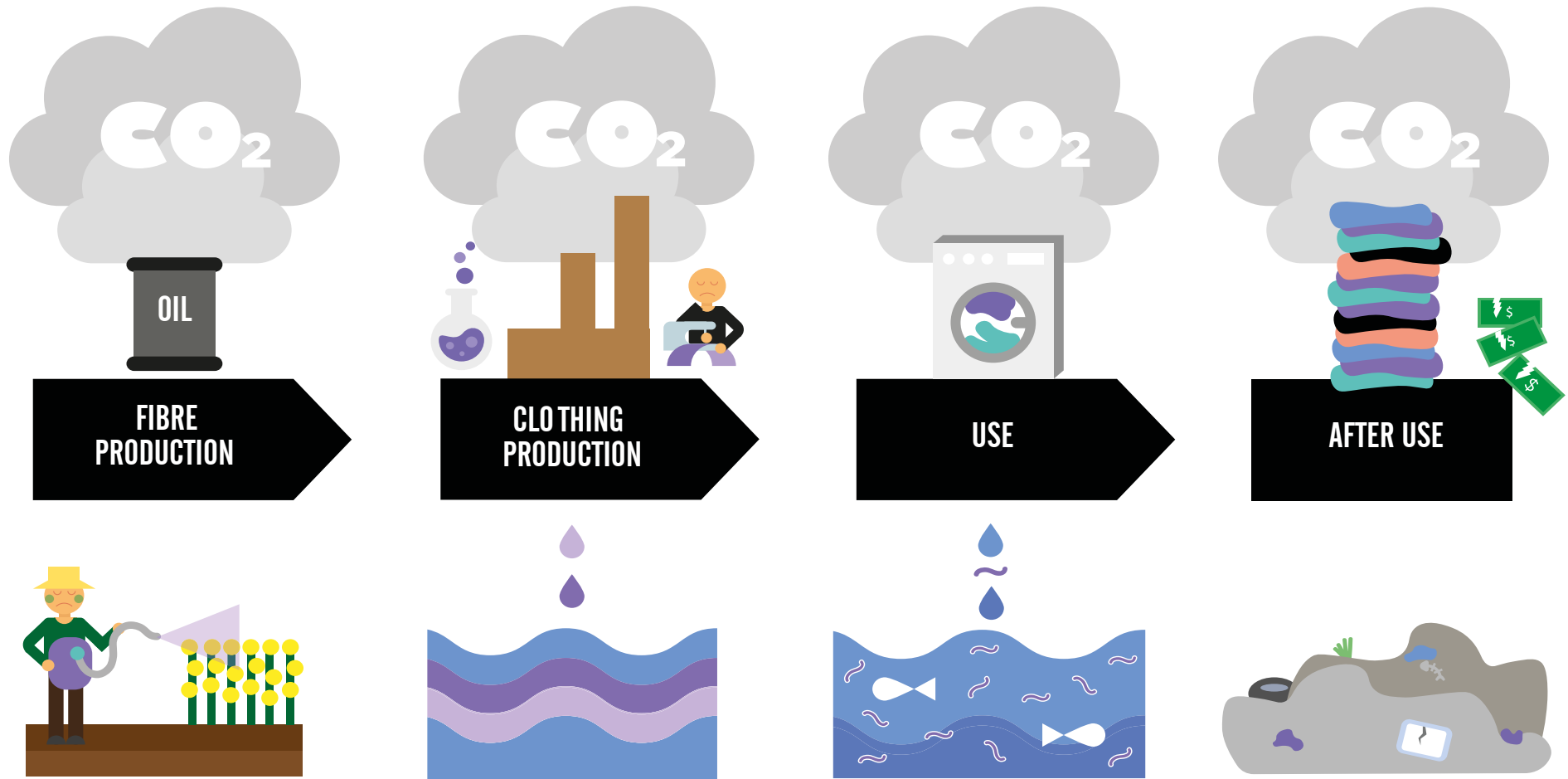
Retting of bast fibres with the use of microorganisms.

Desizing by soaking fabrics in liquor containing barley to remove starch.

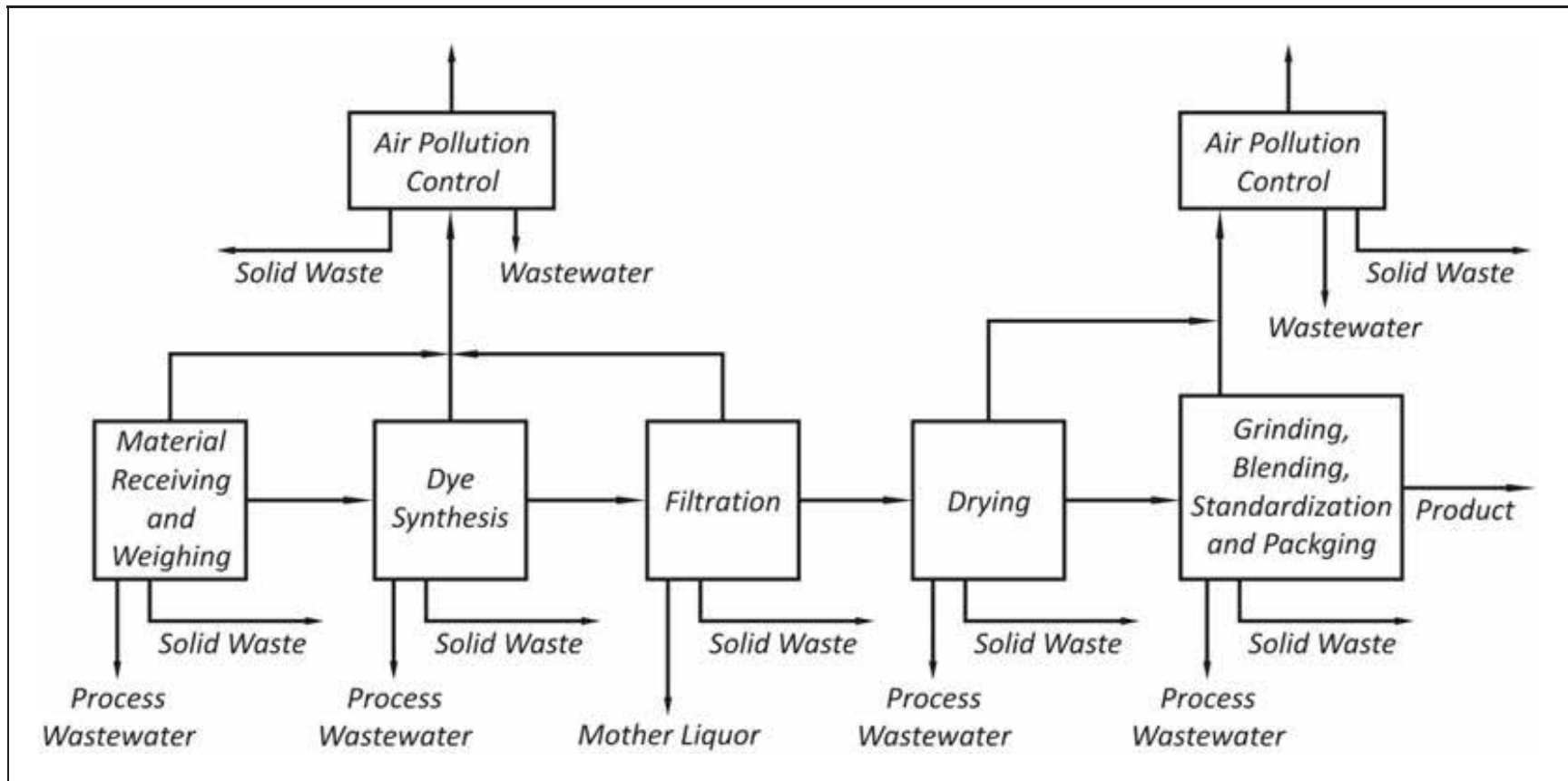
Well established processes: Bio-scouring, Bio-polishing, Denim finishing and Bleach clean-up.

Question:

How can enzymes be used as creative tools to provide the textile industry with realistic and viable options to move towards a circular economy?



Current Textile Industry puts pressure on resources, pollutes the environment, and creates negative societal impacts (Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion's future, 2017)



Manufacture of synthetic dye (Rosa et al., 2014)

Enzyme: Laccase













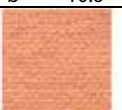



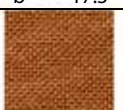



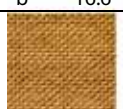
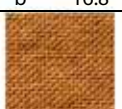


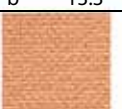
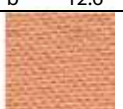
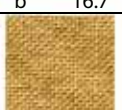
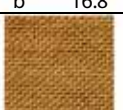


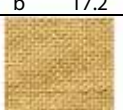
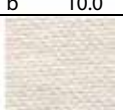
Laccase can effectively break down conventional textile dye molecules facilitating the removal of colour from dyed textile fibres resulting in a bleached or faded effect.




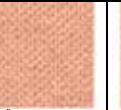











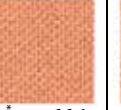
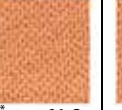

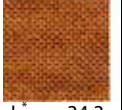

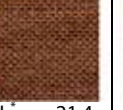

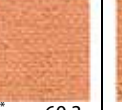

Laccase is also capable of catalysing the polymerisation of simple aromatic compounds to create coloured compounds (dyes) useful for textile fibre coloration.




















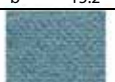





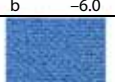
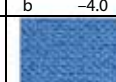

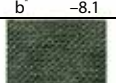



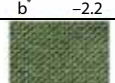

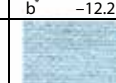

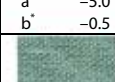
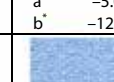
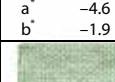
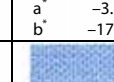
Both approaches indicate design potential.



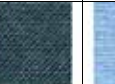
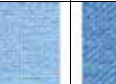
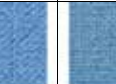
















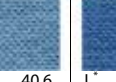


Laccase + aromatic compound + textile → **coloured textile**
liquor solution: set pH

Group	Aromatic compound	Chemical structure and form	Coloured product	Coloration on nylon and wool	
1	1,2-Dihydroxybenzene	 <chem>Oc1ccccc1O</chem>			
	1,4-Dihydroxybenzene	 <chem>Oc1ccc(O)cc1</chem>			
2	2,7-Dihydroxynaphthalene	 <chem>Oc1ccc2cc(O)ccc2c1</chem>			
3	Catechin	 <chem>Oc1cc(O)c2c(c1)oc(O)c2O</chem> + xH ₂ O			
4	Ferulic acid	 <chem>OC(=O)/C=C/c1ccc(O)c(OC)c1</chem>			
	Gallic acid	 <chem>OC(=O)c1c(O)c(O)c(O)c1</chem>			
	Syringic acid	 <chem>OC(=O)c1c(O)c(OC)c(OC)c1</chem>			
5	2,5-Diaminobenzenesulfonic acid	 <chem>Nc1ccc(N)cc1S(=O)(=O)O</chem>			
	3-Amino-4-hydroxybenzenesulfonic acid	 <chem>Nc1ccc(O)cc1S(=O)(=O)O</chem>			

pH	Wool			Nylon		
	AB	CB	PB	AB	CB	PB
3	 L* 54.5 a* 11.8 b* 16.8	 L* 52.4 a* 11.1 b* 17.7	-	 L* 74.4 a* 12.8 b* 11.1	 L* 76.9 a* 5.2 b* 13.9	-
4	 L* 48.1 a* 12.4 b* 18.0	 L* 46.2 a* 12.4 b* 17.5	-	 L* 68.1 a* 14.3 b* 11.2	 L* 70.5 a* 12.1 b* 10.6	-
5	 L* 39.7 a* 14.8 b* 17.3	 L* 41.5 a* 14.7 b* 17.6	 L* 37.7 a* 15.4 b* 17.3	 L* 68.7 a* 19.1 b* 12.4	 L* 66.5 a* 20.6 b* 13.2	 L* 66.1 a* 22.0 b* 12.5
6	 L* 34.1 a* 15.2 b* 16.6	 L* 37.4 a* 15.4 b* 16.8	 L* 34.4 a* 16.3 b* 16.8	 L* 66.4 a* 19.4 b* 13.4	 L* 66.5 a* 20.5 b* 13.3	 L* 66.1 a* 21.8 b* 12.6
7	 L* 39.2 a* 11.1 b* 17.0	 L* 35.9 a* 13.8 b* 16.7	 L* 34.2 a* 16.1 b* 16.8	 L* 62.4 a* 15.5 b* 12.9	 L* 63.0 a* 17.1 b* 12.8	 L* 58.8 a* 18.4 b* 12.4
8	-	 L* 45.1 a* 8.3 b* 16.7	 L* 37.9 a* 11.2 b* 17.2	-	 L* 70.2 a* 7.0 b* 9.9	 L* 72.0 a* 8.3 b* 10.0
9	-	-	 L* 49.3 a* 7.5 b* 16.9	-	-	 L* 73.4 a* 3.6 b* 5.7

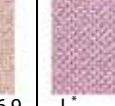
Time, h	Wool			Nylon		
	1:1	1:2	1:4	1:1	1:2	1:4
1	 L* 46.9 a* 15.8 b* 17.4	 L* 39.2 a* 16.7 b* 17.1	 L* 33.5 a* 16.2 b* 15.5	 L* 72.6 a* 19.7 b* 11.5	 L* 68.9 a* 21.4 b* 12.9	 L* 63.8 a* 21.6 b* 14.1
2	 L* 41.5 a* 15.9 b* 17.0	 L* 33.6 a* 16.6 b* 16.1	 L* 27.1 a* 15.6 b* 13.5	 L* 69.6 a* 20.4 b* 11.9	 L* 65.5 a* 22.3 b* 13.5	 L* 61.2 a* 21.3 b* 14.1
4	 L* 37.7 a* 15.7 b* 16.8	 L* 30.5 a* 16.0 b* 15.0	 L* 23.6 a* 14.5 b* 11.5	 L* 66.1 a* 21.3 b* 12.5	 L* 61.8 a* 22.3 b* 14.0	 L* 58.4 a* 20.7 b* 14.4
8	 L* 34.3 a* 15.3 b* 15.6	 L* 26.7 a* 15.1 b* 13.2	 L* 21.4 a* 12.9 b* 9.3	 L* 63.1 a* 21.7 b* 13.4	 L* 60.3 a* 20.3 b* 13.4	 L* 54.2 a* 18.7 b* 14.1

pH	Wool				Nylon			
	AB	CB	PB	BCB	AB	CB	PB	BCB
3	 L* 77.3 a* -0.4 b* 12.2	 L* 66.7 a* 1.0 b* 20.6	-	-	 L* 87.2 a* 2.0 b* 5.7	 L* 77.6 a* 3.7 b* 15.5	-	-
4	 L* 59.9 a* 0.9 b* 17.3	 L* 60.3 a* 1.5 b* 18.1	 L* 52.0 a* 2.6 b* 13.2	-	 L* 75.2 a* 3.9 b* 12.8	 L* 67.8 a* 6.4 b* 22.0	 L* 64.9 a* 5.8 b* 19.6	-
5	 L* 47.5 a* 0.9 b* 10.1	 L* 48.6 a* 2.3 b* 12.8	 L* 44.2 a* 2.0 b* 10.8	-	 L* 57.9 a* 4.3 b* 15.2	 L* 57.7 a* 4.3 b* 14.3	 L* 57.2 a* 4.4 b* 14.8	-
6	 L* 30.6 a* -4.3 b* -5.6	 L* 33.8 a* -2.6 b* 0.6	 L* 36.4 a* -1.8 b* 1.9	-	 L* 40.0 a* -3.5 b* -6.0	 L* 40.1 a* -2.7 b* -4.0	 L* 40.8 a* -2.2 b* -4.1	-
7	 L* 27.2 a* -4.2 b* -7.9	 L* 27.4 a* -4.1 b* -8.1	 L* 28.6 a* -3.6 b* -6.7	-	 L* 36.7 a* -2.5 b* -16.4	 L* 37.0 a* -2.5 b* -15.0	 L* 37.2 a* -2.6 b* -12.6	-
8	-	 L* 25.6 a* -2.1 b* 2.6	 L* 27.3 a* -3.4 b* -2.2	-	-	 L* 39.3 a* -2.3 b* -12.9	 L* 40.3 a* -2.4 b* -12.2	-
9	-	-	 L* 34.1 a* -3.3 b* 4.5	 L* 36.5 a* -5.0 b* -0.5	-	-	 L* 56.2 a* -4.7 b* -7.2	 L* 53.9 a* -5.0 b* -12.1
10	-	-	-	 L* 43.7 a* -4.6 b* -1.9	-	-	-	 L* 58.8 a* -3.1 b* -17.1
11	-	-	-	 L* 53.4 a* -4.4 b* 4.2	-	-	-	 L* 55.9 a* -1.4 b* -17.8

Time, h	Wool			Nylon		
	1:1	1:2	1:4	1:1	1:2	1:4
1	 L* 31.2 a* -4.7 b* 1.2	 L* 22.9 a* -4.9 b* -2.9	 L* 21.9 a* -5.6 b* -3.8	 L* 52.3 a* -3.3 b* -10.9	 L* 43.3 a* -3.3 b* -14.2	 L* 42.6 a* -3.2 b* -12.2
2	 L* 28.4 a* -3.6 b* 2.1	 L* 20.6 a* -3.6 b* -2.1	 L* 16.9 a* -2.6 b* -3.0	 L* 46.4 a* -3.4 b* -11.0	 L* 36.2 a* -3.0 b* -15.26	 L* 32.9 a* -2.9 b* -13.9
4	 L* 27.6 a* -3.3 b* 2.0	 L* 21.1 a* -3.3 b* -1.9	 L* 16.5 a* -2.0 b* -2.5	 L* 44.7 a* -3.3 b* -11.2	 L* 33.1 a* -2.4 b* -15.5	 L* 27.7 a* -1.9 b* -13.8
8	 L* 27.3 a* -2.8 b* 2.4	 L* 20.5 a* -2.8 b* -1.6	 L* 16.1 a* -1.4 b* -2.4	 L* 40.6 a* -2.8 b* -10.6	 L* 32.0 a* -2.4 b* -14.4	 L* 24.3 a* -1.6 b* -12.0

AB, acetate buffer; CB, citrate buffer; PB, phosphate buffer; BCB, bicarbonate/carbonate buffer.

pH	Wool			Nylon		
	1:1	1:2	1:4	1:1	1:2	1:4
3	 L* 40.1 a* 18.4 b* 8.0	 L* 43.1 a* 16.0 b* 2.7	 L* 33.5 a* 16.6 b* -2.6	 L* 70.0 a* 10.0 b* 4.9	 L* 49.5 a* 10.8 b* 1.3	 L* 44.6 a* 12.7 b* -2.9
4	 L* 45.4 a* 18.2 b* 20.5	 L* 22.2 a* 13.5 b* 9.7	 L* 16.2 a* 8.3 b* 2.3	 L* 76.5 a* 15.8 b* 29.5	 L* 58.6 a* 16.5 b* 25.0	 L* 54.2 a* 16.3 b* 22.2
5	 L* 42.2 a* 15.3 b* 19.8	 L* 29.8 a* 15.2 b* 17.1	 L* 21.9 a* 13.0 b* 10.2	 L* 77.8 a* 8.6 b* 25.3	 L* 68.0 a* 17.2 b* 32.3	 L* 64.1 a* 15.3 b* 33.1
6	 L* 51.0 a* 14.2 b* 22.0	 L* 40.3 a* 15.3 b* 21.6	 L* 31.0 a* 14.4 b* 18.0	 L* 87.2 a* 1.5 b* 16.4	 L* 83.0 a* 7.4 b* 27.1	 L* 79.5 a* 8.7 b* 32.5
7	 L* 61.4 a* 10.0 b* 24.7	 L* 49.2 a* 13.2 b* 25.6	 L* 39.2 a* 13.2 b* 20.3	 L* 89.0 a* 0.8 b* 6.2	 L* 88.8 a* 1.6 b* 12.7	 L* 86.0 a* 3.2 b* 20.4

Time, h	Wool			Nylon		
	1:1	1:2	1:4	1:1	1:2	1:4
1	 L* 37.2 a* 16.7 b* 6.1	 L* 23.7 a* 15.0 b* 4.6	 L* 24.6 a* 12.6 b* -0.6	 L* 68.3 a* 5.3 b* 4.5	 L* 61.5 a* 6.9 b* 1.5	 L* 52.8 a* 8.9 b* -3.3
2	 L* 35.4 a* 17.1 b* 5.1	 L* 21.7 a* 15.4 b* 3.4	 L* 21.5 a* 13.1 b* -1.1	 L* 64.9 a* 6.2 b* 5.7	 L* 56.9 a* 7.7 b* 2.2	 L* 49.3 a* 10.2 b* -2.0
4	 L* 36.9 a* 17.1 b* 7.7	 L* 22.1 a* 15.4 b* 4.2	 L* 20.8 a* 13.5 b* -0.5	 L* 61.1 a* 7.1 b* 4.7	 L* 53.4 a* 8.8 b* 1.4	 L* 45.8 a* 11.5 b* -2.7
8	 L* 30.6 a* 17.0 b* 5.8	 L* 20.1 a* 13.7 b* 2.9	 L* 16.2 a* 8.4 b* 0.3	 L* 59.6 a* 9.9 b* 3.2	 L* 49.4 a* 11.8 b* -0.9	 L* 45.0 a* 13.8 b* -4.4



Key advantages

New methods of textile coloration: eliminates the use of pre-manufactured dyes and chemical auxiliaries and facilitates dyeing at ambient temperatures, reduces the complexity of the dyeing process, and downstream processing, leading to economic and environmental advantages.

New methods and model for designing textiles: the process offers opportunities for multiple colours and shading to be achieved through the simple alteration of processing conditions, currently not possible with conventional dyes and methods.

Further study

A good range of colours is achievable by this method, it is not known yet whether a full gamut of colour shades can be achievable.

To examine whether the enzymatic process has the potential to be scaled up to a viable industrial process which can be reproducible and meet commercial standards.

**Prajapati, C., Smith, E., Kane, F., Shen, J. (2018) Laccase-catalysed coloration of wool and nylon
Coloration Technology, 134, p. 423 - 439.**

**Prajapati, C., Smith, E., Kane, F., Shen, J. (2017) Enzyme catalysed coloration and surface patterning
International Dyers, 202 (3), p. 59 - 61.**

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