

Supporting Information

Hollow Silica Nanoparticles Loaded with Industrial Dyes for High Exhaustion Leather Dyeing and its sustainability impact

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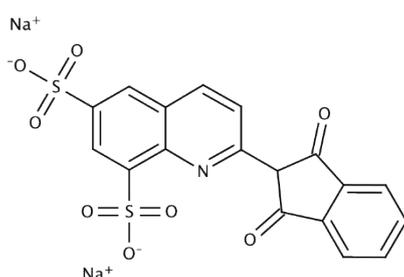


Figure S1- Structure of the dye

Table S1 Sample code and its corresponding description

S.no	Sample name	Description	Dye characteristics
1	QY	Quinoline Yellow	Anionic Dye
2	QY-Si-OH	Quinoline Yellow modified with silica nanoparticles contains OH terminal.	
3	QY-Si-Methyl	Quinoline Yellow modified with silica nanoparticles contains methyl terminal.	

Table S2 Post-tanning recipe adopted for upper leather processing

Raw Materials: Chrome tanned leather (goat)				
Process	Chemical Name	% Offered	Duration	Remarks
Neutralization	Water	100	(3 x 10 min) + 60 min	Cross-section pH: 5.2-5.5 Drain/Wash/Drain
	Neutralizing syntan + Sodium bicarbonate + water	1 + 0.5 + 10		
Dyeing	Dye	1.5	-Run 45 min	Check penetration
Retanning	Acrylic syntan	3	- Run 20 min	-
	Low molecular weight phenolic syntan + Melamine based syntan + GS powder	5 + 4 + 4	-Run 60 min	-
Fatliquoring	Synthetic + Sulphochlorinated fish oil + Semi synthetic + Water	6+4+2+50	(3 x 15 min)) + 120	-
Washing	Water	200	15 min	Drain
Fixing	Water	10	(3 x 5 min)	Check exhaustion /Drain
	Formic acid	3	+ 60 min	
Next day:- Setting/ Vacuum Drying/ Hooking/ Stacking/ Buffing.				

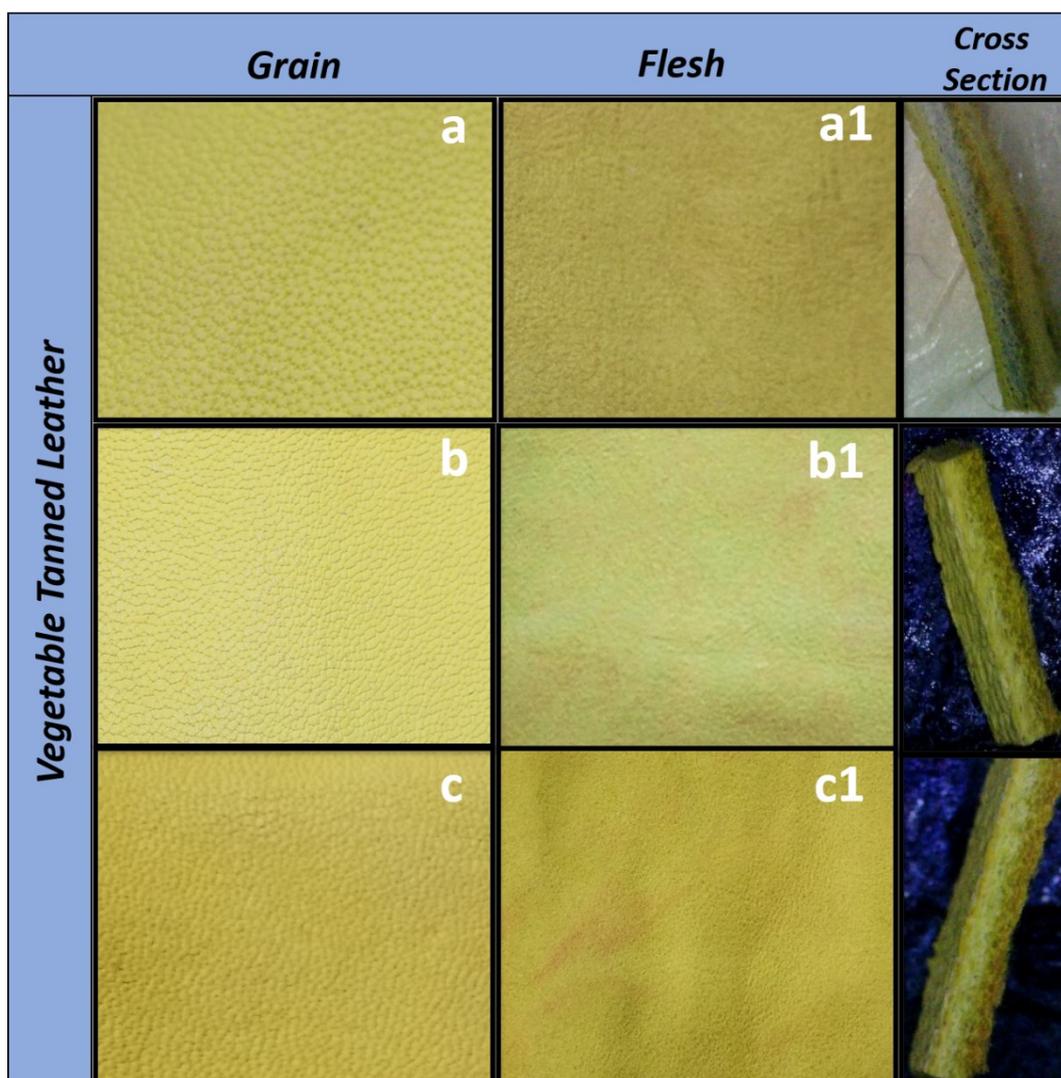


Figure S2 The grain, flesh and cross-sectional view of chrome leather dyed with (a) Quinoline yellow dye, (b) Quinoline yellow modified silica with surface OH group (QY-Si-OH) and (c) Quinoline yellow modified silica with surface methyl group (QY-Si-Methyl). (a1), (b1), and (c1) represent their corresponding flesh side of dyed leather

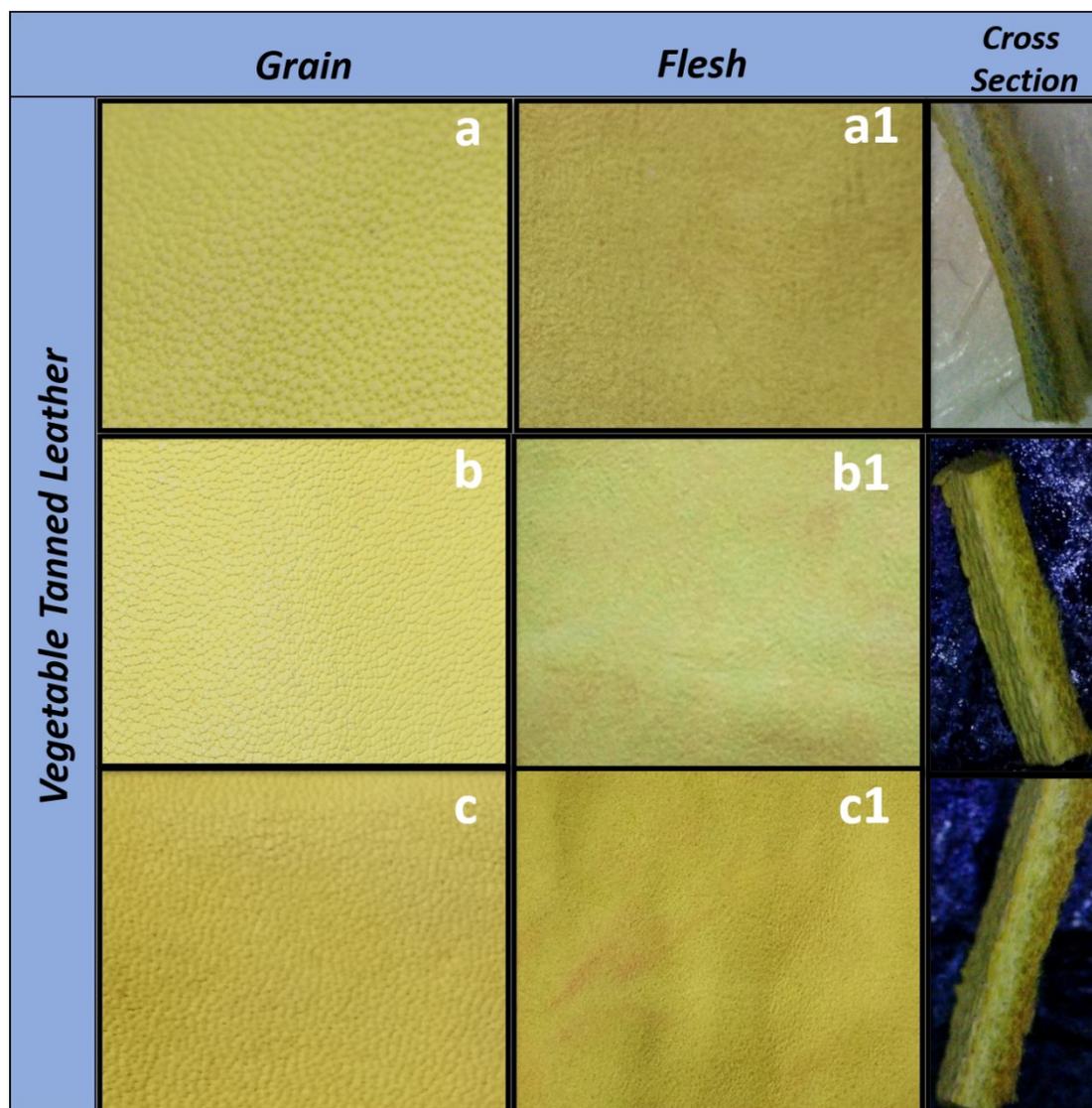
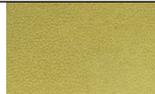
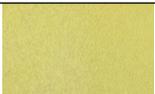
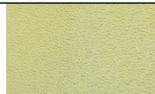


Figure S3 The grain, flesh and cross-sectional view of vegetable leather dyed with (a) free Quinoline yellow dye, (b) Quinoline yellow modified into silica with surface OH group (QY-Si-OH) and (c) Quinoline yellow modified into silica with surface methyl group (QY-Si-Methyl). (a1), (b1), and (c1) represent their corresponding flesh side of dyed leather.

Table S3 Greyscale rating of leather dyed with free and dye modified silica nanoparticles during fastness to the water

Sample Name		Cellulose acetate	Bleached cotton	Spun nylon	Spun polyester	Spun acrylic	Worsted spun wool
<i>Chrome Tanned Leather</i>	QY	4	4	4	4	4	4
	QY-Si-OH	4	4/5	4	4/5	5	5
	QY-Si-Methyl	4/5	4/5	5	4/5	4/5	4/5
<i>Vegetable Tanned Leather</i>	QY	4	4	3/4	4	4	3/4
	QY-Si-OH	4/5	4/5	5	4/5	5	5
	QY-Si-Methyl	4/5	4/5	4	4/5	4/5	4/5

Table S4 Coloured matrix exposed to different temperatures with its greyscale rating and their respective colour swatches.

	Sample name	Grey Scale Rating					Colour Swatch	
		50°C	100°C	150°C	200°C	250°C	0°C	250°C
<i>Chrome Tanned Leather</i>	QY	5	5	4/5	4	4		
	QY-Si-OH	5	5	5	4/5	4/5		
	QY-Si-Methyl	5	5	5	5	4/5		
<i>Vegetable Tanned Leather</i>	QY	4	3/4	3	3	2		
	QY-Si-OH	5	5	5	4	4		
	QY-Si-Methyl	5	5	4/5	4/5	4/5		

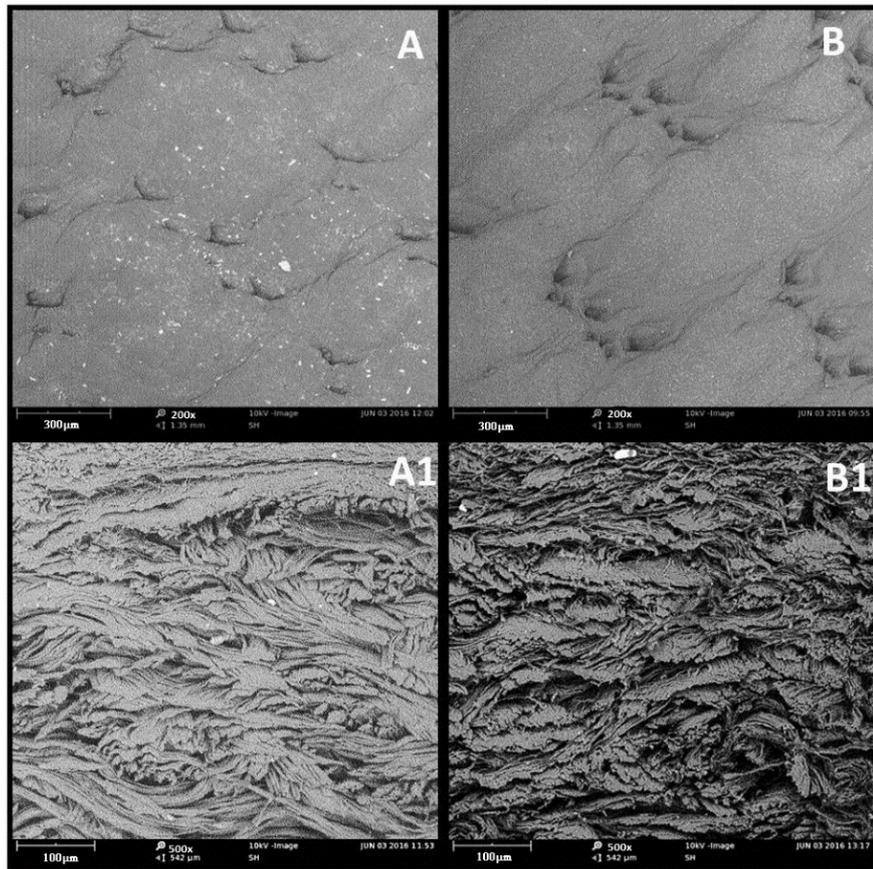
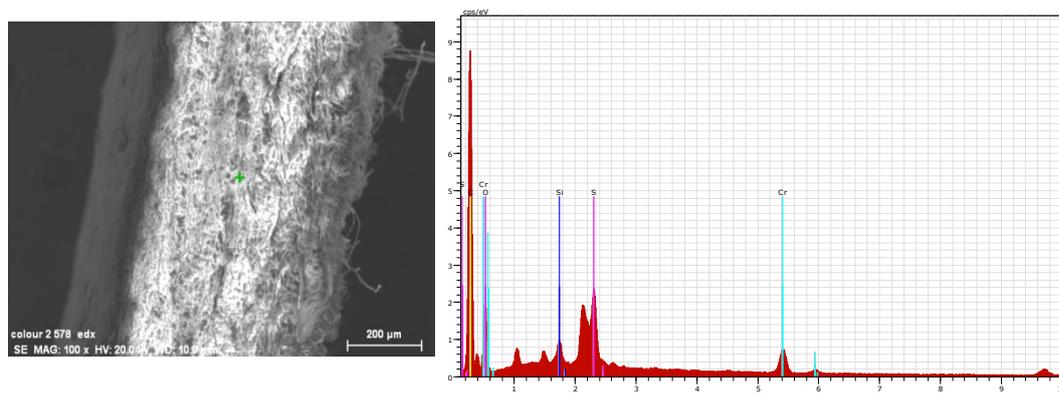
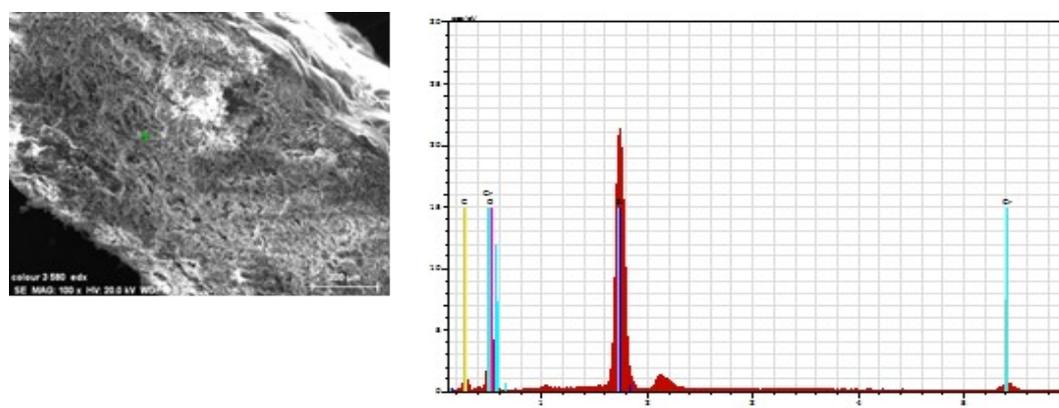


Figure S4 The Scanning Electron Microscopic Image A) and B) showing the details of grain surface of dye modified with silica nanoparticles treated Chrome tanned leather and Vegetable tanned leather respectively and A1- B1 are their corresponding cross-sectional image.



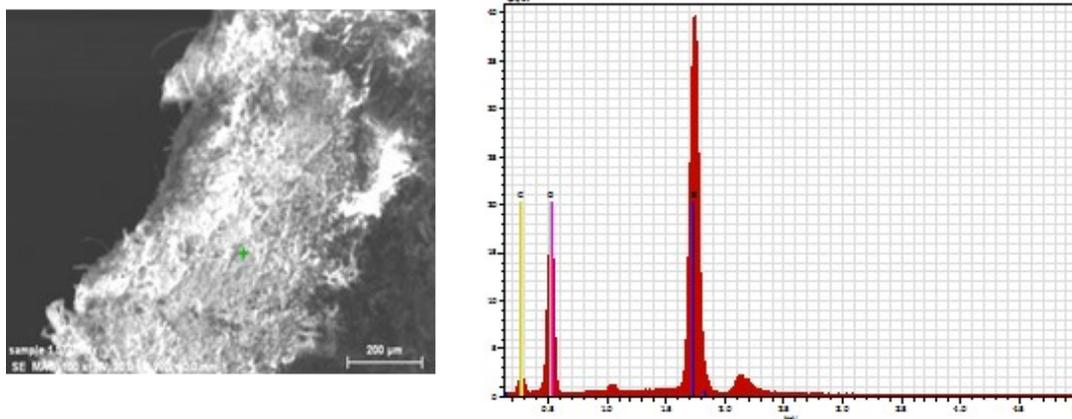
El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [wt.%]	Error [wt.%]
O	8	K-series	6.67	52.43	73.35	1.0
S	16	K-series	2.41	18.91	13.20	0.1
Cr	24	K-series	3.26	25.63	11.03	0.1
Si	14	K-series	0.39	3.03	2.42	0
		Total:	12.73	100.00	100.00	

Figure S5 The Scanning Electron Microscopic image and elemental analysis of chrome tanned leather dyed with a free dye



El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [wt.%]	Error [wt.%]
O	8	K-series	15.44	43.36	58.39	1.9
Si	14	K-series	18.33	51.45	39.47	0.8
Cr	24	K-series	1.85	5.19	2.15	0.1
		Total:	35.62	100.00	100.00	

Figure S6 The Scanning Electron Microscopic image and elemental analysis of chrome tanned leather dyed with dye modified silica nanoparticles



El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [wt.%]	Error [wt.%]
O	8	K-series	23.04	57.28	70.19	2.6
Si	14	K-series	17.18	42.72	29.81	0.8
		Total:	40.22	100.00	100.00	

Figure S7 The Scanning Electron Microscopic image and elemental analysis of vegetable tanned leather dyed with dye modified silica nanoparticles.

Equation 1

$$E \text{ Factor} = (\text{Mass of the waste}) \div (\text{Mass of the Product})$$

Equation 2

$$\text{Mass Intensity} = ((\text{Total mass of material used})(Kg)) \div ((\text{mass of the product})(Kg))$$