Chitosan as a Consolidant for Fragile Silk

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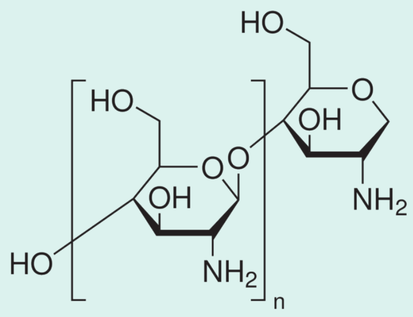
Introduction

Chitosan was applied to silk fabrics to evaluate its effectiveness and suitability as a consolidant. Treated silks were tested for strength, stiffness, and colour change, among other properties. Chitosan is de-acetylated chitin, a linear polysaccharide found in the exoskeleton of crustaceans and other natural sources. Chemically, chitosan is a co-polymer of β-(1-4)-D-glucosamine and N-acetyl-glucosamine; its chemical structure similar to cellulose, but with an acetyl or amino functional group substituting the hydroxyl group at carbon #2. Chitosan is non-toxic, anti-microbial, soluble in dilute acids, and non-soluble in organic solvents. Chitosan is capable of hydrogen and electrostatic bonding with organic substrates, producing hard, thin films, and coating fibres.



Chemical structure of chitosan

Experimental

Materials

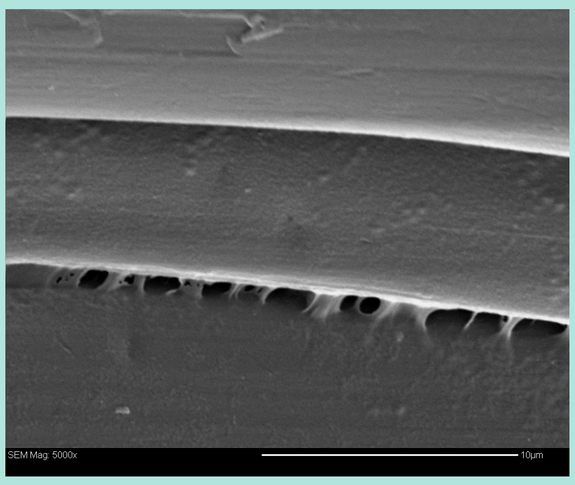
- New Testfabrics Inc. white silk habutae #609
- Naturally aged blue and red silk damask fabrics
- 75% de-acetylated low molecular weight chitosan

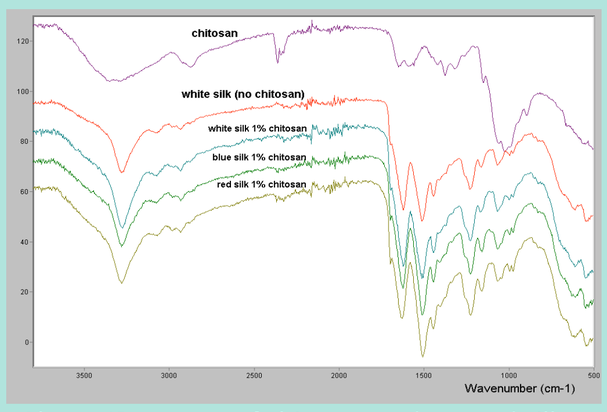
Method

- Chitosan prepared as 0.5% and 1% w/v solutions in dilute acetic acid in distilled water, at pH 4-4.2.
- Silk samples immersed in chitosan solution for 15 minutes and rinsed in distilled water for 5 minutes.
- Aging: 50°C, 65% RH and 13,000 lux + UV for 100 hours.

Experimental Conditions

Code	Chitosan Treatment	Artificial Aging
Ø	-	-
Ø *	-	Thermal + light
0.5% Ch	0.5% chitosan + rinsing	-
0.5% Ch*	0.5% chitosan + rinsing	Thermal + light
0.5% Ch-X	0.5% chitosan, no rinsing	-
1% Ch	1% chitosan + rinsing	-



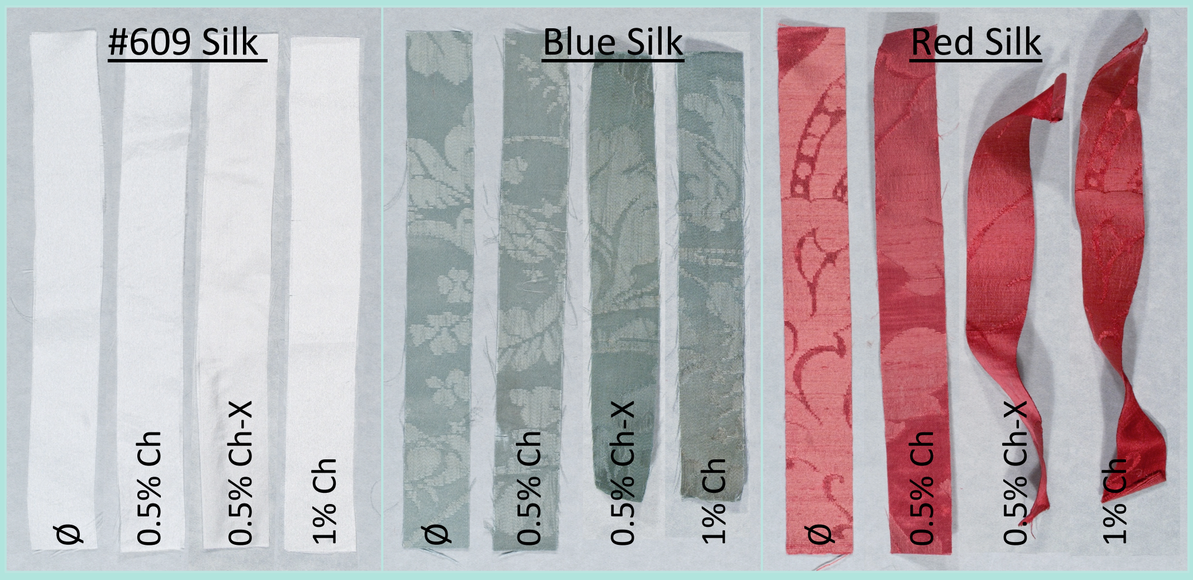


Above: IR spectra of chitosan and treated silks.
Left: Chitosan on blue silk 0.5% Ch-X (1000x SEM)

Stiffness Testing Results

Mean Flexural Stiffness (% Change)

Condition	#609 Silk	Blue Silk	Red Silk
Ø	1.77	7.06	12.5
0.5% Ch	1.80 (+1.3%)	14.7 (+108%)	21.2 (+70%)
0.5% Ch-X	23.2 (+1210%)	69.2 (+881%)	25.5 (+105%)
1% Ch	3.2 (+82%)	53.9 (+664%)	12.3 (-0.94%)

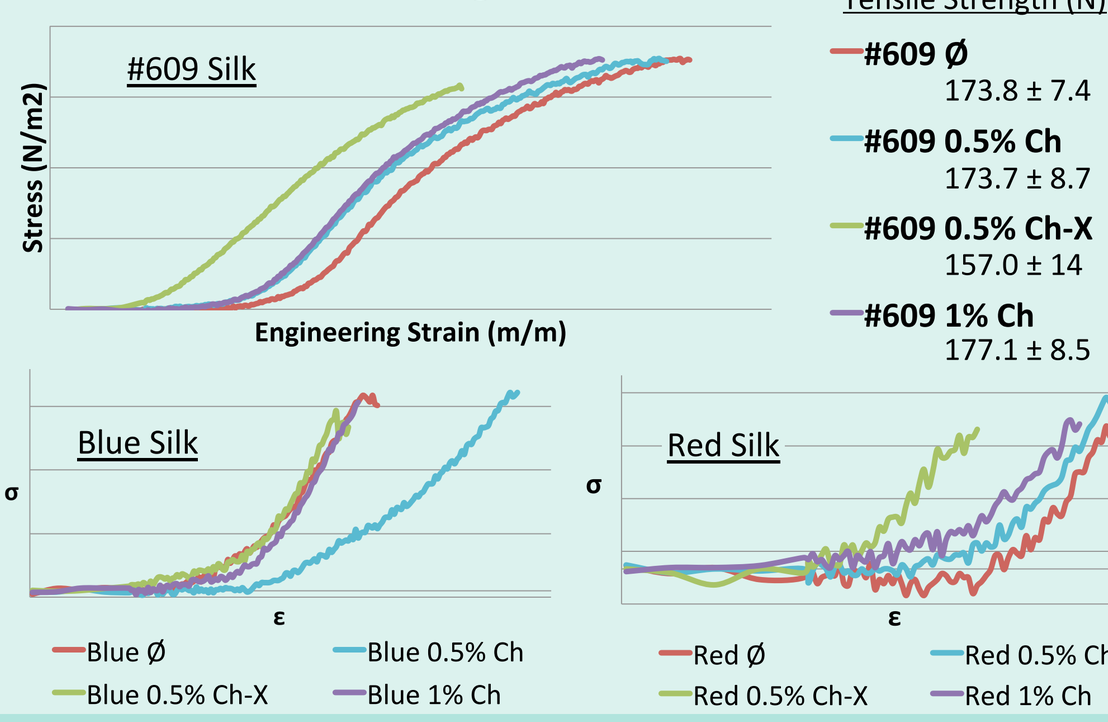


Comparisons of experiment conditions. Treated silks darkened, and some curled and twitsted.

Tests & Results

- **Optical Microscopy**: No change in appearance or optical properties of silk fibres under normal or polarized light.
- **SEM**: Chitosan "bridges" found between fibres; appear to be extensions of a thin chitosan coating on fibres.
- **Colour Change**: All treated silks became slightly darker in colour (lower L*values), with ΔE* > 1 in blue and red silks.
- **FTIR**: No chitosan found in spectra of treated silks; amount of chitosan present likely below detection limit.
- **XRF**: No metallic weighting agents, mordants, dyes, or pesticides present in silk fabrics.
- **pH**: The pH of treated #609 silk was not lowered if samples were rinsed. The pH of blue and red silks increased, as the wet treatment likely washed out acidic degradation products. All 1% Ch and 0.5% Ch-X condition silk samples smelled of acetic acid after treatment.
- **Tensile Testing:** No statistically significant increase in ultimate tensile strength; #609 0.5% Ch-X silk strength fell.
- **Stiffness Test**: Treatment increased fabric stiffness, especially 1% Ch and 0.5% Ch-X conditions. Yarns felt locked in place, stopped fraying, and stopped powdering. The blue and red silks curled up after treatment; chitosan rendered the silk slightly hydrophobic, and unresponsive to humidification and flattening.

Tensile Testing Results



Mean Ultimate Tensile Strength (N)

- **#609 Ø** 173.8 ± 7.4
- **#609 0.5% Ch** 173.7 ± 8.7
- **#609 0.5% Ch-X** 157.0 ± 14
- **#609 1% Ch** 177.1 ± 8.5

Conclusion

Chitosan had a mild consolidating effect, but did not increase the tensile strength of silk fabrics. Most samples became stiff, and some curled and twisted. Noticeable colour change (darkening) occurred in some samples. Therefore, using this application method, chitosan is ineffective and unsuitable as a consolidant for fragile silk textiles.

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