Biophysical and mechanical response of keratinous fibres to changes in temperature, humidity and damage

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Intact mammalian hair and wool fibres are multi-compartmental composite materials consisting of a sulphur-rich outer protective cuticle layer surrounding elongated, highly keratinized, cortex cells. The cortex cells themselves are made up of crystalline, filamentous, low-sulphur α-helical keratin molecules embedded in a matrix of highly cross-linked, globular high-sulphur keratins. It is the structurally organised and highly disulphide cross-linked nature of these materials that provides them with their remarkable mechanical properties. However these mechanical properties are sensitive to environmental conditions such as water content, temperature and chemical treatment and the importance of their ultra-structural arrangements to overall mechanical properties in different environments is still not fully understood. The work described here aims to explain the effects of these environmental changes in terms of the mechanical properties of the hair fibres and the molecular transitions which underpin them. Tensile and torsional mechanical analyses of hair fibres have been performed as functions of relative humidity (RH) in the range 10-100% and of temperature in the range 22-50°C. As the RH (and therefore fibre moisture content) increases, a decrease in both the tensile and torsional stiffness is observed, but no significant changes are seen for these properties when the temperature is increased within the experimental range when actual humidity is maintained at a constant value. Raman microscopy and IR spectroscopy have been used to examine the concomitant conformational transitions of the proteins within the fibre and show that even at this relatively low temperature range, clear changes in protein secondary structure can be observed, while changes in relative humidity have little effect. X-ray diffraction has also been used to measure the effects of these conditions on supra-molecular organisation and reveals changes in microfibrillar organisation upon increasing temperature and humidity.