Hair fibres may turn into micro-tubes

The proteins fulfil their functions over certain ranges of pH, pressure, temperature. Focusing on the temperature, the permitted window is not very large; most of proteins become inactive (denature, therefore lose their function) below 100 °C and pyrolyze after 200 °C turning into carbonaceous residues.

The hair fibre, the appendix serving to protect mammal bodies against environmental influences, is organized as a core-shell structure, with the cortex wrapped by cuticle, all being made mainly of hard alpha-keratin, a protein belonging to the fibrous protein class. Although composed of same amino-acids like any other protein, the thermal stability of keratin is relatively high, the fibre properties remaining almost intact until 200 °C. This is assumed to be due to the presence of high amount of Cystine, which cross-links protein chains in cortex and cuticle.

Knowing what happens to the eggs (made of ovalbumin, a globular protein), or to the meat (made of collagen, elastin, myosin, actin, all fibrous proteins) when heated to 100 °C and beyond, we investigated how hair fibres behave when temperature is raised beyond 200 °C.

By heating hair snippets under constant heating rate from room temperature to 300 °C and under a constant flow of nitrogen for purging the evolving gases, and sampling snippets at various temperatures for examining them in the scanning electron microscope we noticed that beyond 230 °C the cortex begins vaporizing and the original fibres convert into tubes, consisting only of cuticle. Because the diameter of the tubes matches those of original hair fibres, of around 50 micron in this particular case, we term them “micro-tubes”. At around 300 °C the micro-tubes appear to become highly brittle and disintegrate into small pieces, still not turning into carbonaceous residue.

Similar results, obtained on fibres sourced from various mammalians, indicate that for keratin fibres the thermal stability of cortex and of cuticle differ significantly. Further analysis show that the micro-tubes maintain most of the original amino-acids of the keratin fibre, except the cross-linker Cystine; they retain also the moisture sorption-desorption properties of keratins, and the atomic force microscopy, AFM, shows also the presence of scales, even if of shrunk size. The tubes may be, thus, regarded like keratin based tubes.

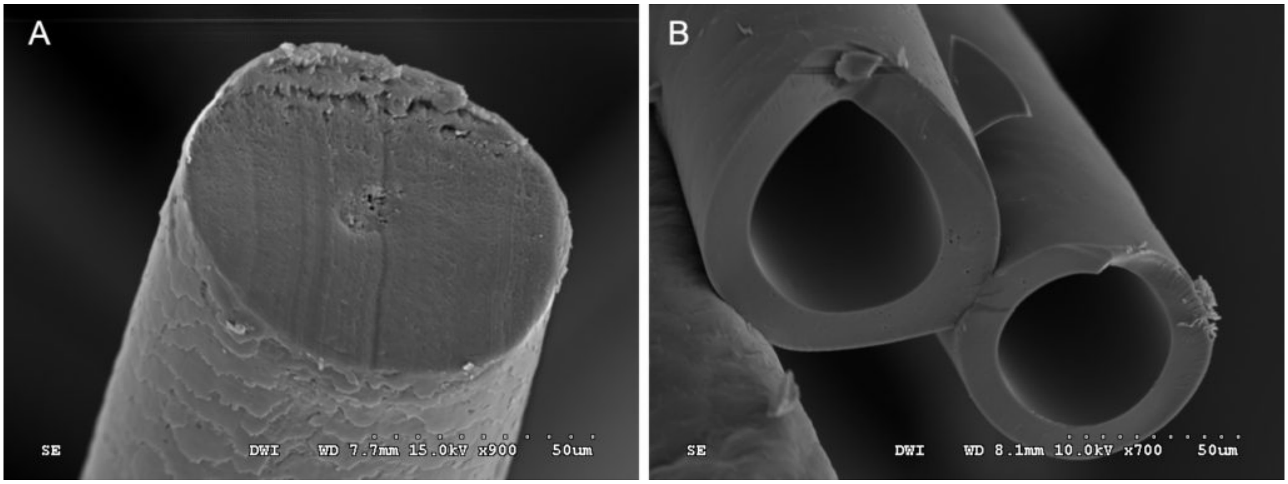

Fig. 1. Effect of heating beyond 200 °C on keratin fibres. A. Hair snippet sampled at any temperature below 230 °C. B. Hair snippets sampled at 250 °C.

We learned this way that, although made of similar proteins and cross-linked by Cystine, the core-shell arrangement of the keratin fibres, and the different morphologies of cortex (the core) and cuticle (the shell) lead to different thermal stabilities of the two components. When heated, the cortex, having a third of its protein components organised as crystals, softens, melts and evaporates above 230 °C, whilst the cuticle, made of amorphous proteins, withstands temperatures even beyond 250 °C despite losing Cystine, the main cross-linker. This paradoxical behaviour of the proteins in cortex and cuticle leads to the formation of protein (keratin) based micro-tubes with fairly well preserved, although slightly distorted, scales as compared to the initial fibre surface (Fig. 1 A, B) and teaches us that, apart the presence of cross-linker Cystine, it is also the way the polypeptide chains pack in the protein structure which plays an important role for tuning the protein overall thermal stability.

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