Nanostructure and Physical Properties of Collagen Biomaterials

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Nanostructure and Physical Properties of Collagen Biomaterials

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Abstract

Collagen is the main structural component of leather, skin, pericardium, and other tissues. All of these biomaterials have a mechanical function and the physical properties are partly a result of the structure of the collagen fibrils. The architecture of the collagen network and how it changes when different chemical and mechanical processes are applied is not fully understood and forms the foundation of this thesis. Synchrotron-based small angle X-ray scattering has been used to quantify aspects of the collagen structure, specifically the orientation index (OI) and D-spacing of the collagen biomaterials investigated. In leather, the nanostructural changes of the collagen network and the strength of the material across a range of different animals, through each stage of the leather-making process, and when model compounds are added or the fat liquor addition is varied has been investigated. Both the D-spacing and fibril orientation were found to change with leather processing. The changes to the thickness of the leather during processing impacts the fibril OI and, once taken into account, the main difference in OI is due to the hydration state of the material with dry materials being less oriented than wet. Model compounds urea, proline, and hydroxyproline were found to increase D-spacing. It was found that as the fat liquor addition is increased, the D-spacing increased. Pure lanolin resulted in a similar increase in D-spacing. The collagen fibril structure and strength of both adult and neonatal pericardium was also investigated. Significant differences were observed with the neonatal tissue having a higher modulus of elasticity and being significantly more aligned than adult pericardium. Neonatal pericardium is advantageously thinner for heart valve applications. This research proves it has the necessary physical properties required. By understanding the hierarchical structure of collagen and its mechanisms for modification when subjected to different chemical and mechanical processes, we gain valuable insight in understanding the performance of leather and skin in biological, medical, and industrial contexts. This will lead to better comprehension of current processes and informs future processing developments.

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