Chapter 10
Experimental Characterization of Skin Biothermomechanics

10.1 Introduction

In the previous chapter, a mathematical approach has been introduced for determining the thermomechanical response in skin tissue, e.g. that induced by electromagnetic heating whereby simulating medical treatments. Whilst insightful, there are, nonetheless, some limitations, where the main deficiency is that the skin tissue is assumed to have constant properties due to the comparatively few relative studies. More experiments are thus needed to better understand the variation in properties with temperature and the corresponding collagen denaturation, so that these properties can be reliably used in future, more sophisticated models.

The experimental characterization of thermomechanical behaviour of skin tissue is presented in this chapter. The objective is to test the hypothesis that collagen is a significant determinant of the thermally-induced change in the mechanical properties of skin tissue. For this purpose, differential scanning calorimetry analysis is used to detect the denaturation of collagen in skin tissue and to measure its thermal stability. The integrity of the collagen network is analyzed using the thermal damage integration [see Equation (3.34) in Chapter 3]. Hydrothermal tensile and compressive experiments are then performed to assess the thermal dependency of skin mechanical behaviour. In order to characterize viscoelastic properties of skin tissue as a function of temperature and collagen denaturation, stress relaxation tests under tension and dynamic mechanical analysis versus temperature are also performed.

10.2 Experimental Methodology

10.2.1 Sample preparation techniques

1) Selection of samples

The ethical and immunological issues associated with human skin tissue
testing request us to find a substitute tissue. Pig skin tissue is chosen due to its structural and functional efficacy compared to human skin tissue\textsuperscript{[1\textendash}5], including the histology, morphology, cell kinetics, density of hair, etc. Furthermore, repetitive tests can be realized for the same animal because of its large size, reducing the variation in results\textsuperscript{[6]}.

Pig skin tissue varies in thickness by site; however, there appears to be a good concordance in thickness among age-matched donors. Therefore, skin samples from the cheek, ear, back, belly, and flank areas are used. Specifically, pig ear skin tissue taken from the center auricle is used for tensile tests, which has been shown to be very similar to human skin tissue\textsuperscript{[7]}, while skin tissue from the back of pig is chosen for compression tests in consideration of its large thickness and low anisotropy\textsuperscript{[8]}. In this series of experiments, skin samples from domestic British breeds of pigs are used, which are obtained from a local slaughter house near Cambridge, at Dalehead Foods in Linton.

2) Sample procurement

Samples of pig skin tissue to a depth of the subcutaneous fat at different body sites are procured daily, ten minutes post mortem by block dissection. The skin sample is excised with sharp scissors and a single-edged razor blade, taking care to minimize the mechanical strain applied to the tissue. They are then fast-chilled following the standard tissue procurement protocol to 4°C in a pregassed Krebs-Henseleit Ringer\textsuperscript{1)} (KHR, pH 7.4). The components of the KHR solution are given in Table 10.1 Samples are transported to the laboratory immediately afterwards, where the samples are separated from subcutaneous fat by wet/fast-dissection in KHR at 4°C and the epidermal layers are not removed to prevent the death of cells caused by mechanical trauma. The skin samples are tested within a few hours of slaughter, in order to minimize degradation of the tissue structure. In all, efforts have been placed on keeping the cellular component of the samples viable. Any storage of test samples at room temperature has been avoided, and only samples that have been stored at 4°C are used in this study. This routine has been shown to best preserve the samples\textsuperscript{[7,9]} and fibroblasts remain viable for long periods\textsuperscript{[10]}.

3) Sample preparation

Sample cutting

Before cutting, any hair on the skin tissue is closely clipped with electric

\textsuperscript{1)} A physiological solution that meets the metabolic requirements of skin tissue and prevents sample degradation, which is supplied on a daily basis by the Pharmacology Department, Cambridge University.