Is the permeability of the skin influenced by a transition from orthorhombic to hexagonal lateral packing?

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Introduction

The lipid organization in the stratum corneum (SC) plays an important role in the barrier function of the skin. SC lipids form two lamellar phases with a predominantly orthorhombic packing (see figure 1). In previous publications a lipid model was presented, referred to as the stratum corneum substitute (SCS) that closely mimics the SC lipid organization and barrier function. Therefore, the SCS serves as a unique tool to relate lipid organization with barrier function. Whith increasing temperature, between 30°C and 40°C the lipid packing in human SC changes from orthorhombic (tight) to hexagonal (less tight), see figure 2. In the present study we examine the effect of the orthorhombic to hexagonal phase transition on the barrier function of human SC and the SCS. Diffusion studies are performed during a step-wise increase in temperature from 28°C to 46°C, sampling the temperature of the orthorhombic to hexagonal phase transition. From the permation data Arrhenius plots were constructed to visualize the influence of the phase transition on the flux.

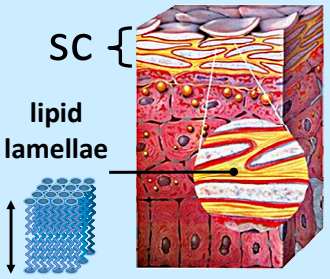

Fig 1 Schematic cross section of the skin with a focus on the lipid layers present in the stratum corneum.

Results

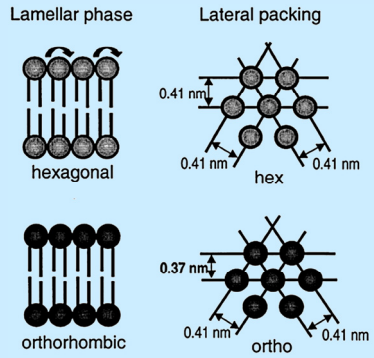

Fig 2 Schematic of the two types of lateral lipid packing present in human SC and the SCS.

Without a phase transition the permeability increases exponentially with temperature. Therefore in an Arrhenius plot the logarithm of the permeability is linearly related to the inverse temperature. This is depicted in figure 3 for the water permeation through pig SC. Since the lipids in pig SC remain in the hexagonal packing whith increasing temperature, a linear relation is observed in figure 3.

A transition from an orthorhombic to hexagonal phase occurs between 30 and 40°C in human SC and the SCS, as observed in FTIR, see figure 4. However, the permeability is not significantly affected as the Arrhenius plots constructed from the permeation data show a linear relationship with 1/T, see figure 5 and 6.

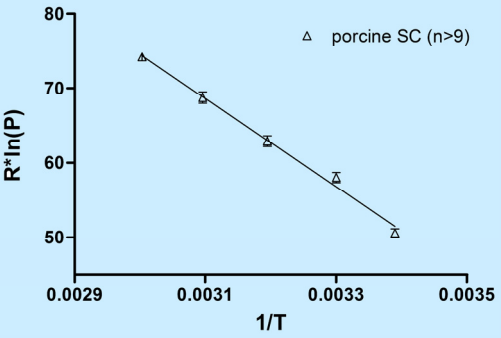

Fig 3 Arrhenius plot for water permeation through porcine SC in which the natural logarithm of the steady state flux is plotted against the inverse absolute temperature. The data was presented in a study by Potts and Francoeur [1]. The solid line shows the linear fit of the flux data with 1/T.

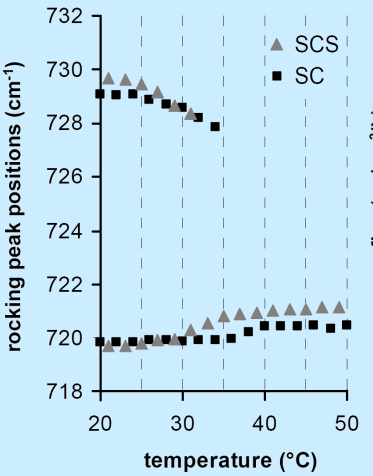

Fig 4 FTIR rocking absorption maxima versus temperature, indicating the orthorhombic to hexagonal phase transition.

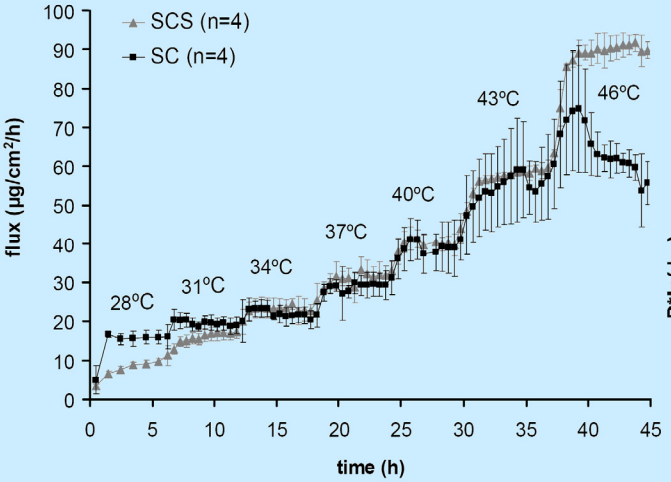

Fig 5 The flux of benzoic acid through human SC and SCS at temperature intervals between 28°C and 46°C.

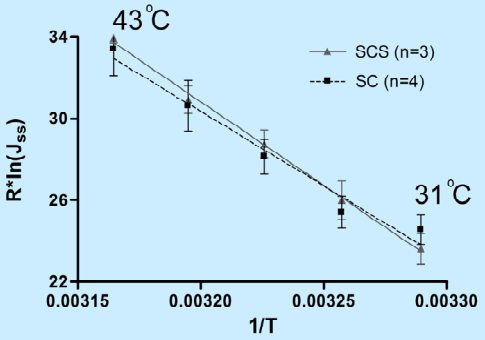

Fig 6 Arrhenius plots for human SC and SCS. Shown are the linear fits trough the flux data of SC and SCS.

Discussion & Conclusion

Remarkably, we found that the permeability of SCS to benzoic acid closely mimics that of human SC at all temperature steps from 31°C to 43°C. Furthermore, the linear relationship of the flux data with temperature as observed in the Arrhenius plots, suggests that the change from orthorhombic to hexagonal packing in human SC and SCS does not have an effect on the barrier function. These results are in contrast with those of a recent study focusing on the permeation of water through human SC [2]. In this study it is reported that the water transport is influenced by the relative population of lipids forming an orthorhombic packing. Perhaps the difference in physical properties of the solute (water versus benzoic acid) or the difference between inside-out permeation (TEWL) and outside-in permeation (benzoic acid permeation) can account for the different observations.

1. R.O. Potts, M.L. Francoeur, Lipid biophysics of water loss through the skin, Proc. Natl Acad. Sci. USA 87 (1990) 3871–3873.
2. F. Damien, M. Boncheva, The extent of orthorhombic lipid phases in the stratum corneum determines the barrier efficiency of..., J. Invest. Dermatol. 130 (2010) 611–614.