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Interaction between human skin and sunscreen-loaded nanosuspensions from beeswax and jojoba oil: a DSC-study

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Nanosuspensions composed of titanium dioxide as inorganic sunscreen within a matrix of beeswax and jojoba oil in a 2:1 ratio and stabilized by eudermic surfactants were previously investigated relating to their sun protection and particle size distribution [1]. In this study the focus will be on the interaction of stratum corneum (SC) with these nanosuspensions and the respective surfactant solutions.

Differential scanning calorimetry (DSC) enables the detection of changes in SC lipid arrangement affected by the interactions with formulation ingredients. Four endothermic transitions T1–T4 are observed by means of DSC when SC is heated up to 120 °C [2-5]. While T1 (~40 °C) and T4 (~100 °C) are not always visible, the presence of T2 (~70 °C) and T3 (~85 °C) are more reliable. T1 and T4 were found to be strongly dependent on the skin source and its water content during measurement [4]. According to Leopold and Lippold, shifts lower than 3.0 °C are considered statistically significant [5].

Methods: Nanosuspensions were manufactured by dispersing a molten lipid phase consisting of beeswax and jojoba oil at the ratio of 2:1 into an aqueous phase by using high-pressure homogenization. Either sodium lauroyl sarcosinate (SLS), sucrose laurate (SL) or potassium stearate (PS) were used as surfactants in the aqueous phase.

For DSC experiments, hydrated SC with a water content of 20 % was incubated at 37 °C for 30 minutes with the suspensions and surfactant solutions, respectively. Samples were sealed in aluminium pans and subsequently measured from 20 °C to 120 °C with a heating rate of 5 K/min and an empty aluminium pan as reference using DSC 1 Stare System with HSS7 sensor (Mettler Toledo, Schwerzenbach, Switzerland). Furthermore suspensions and surfactant solutions were measured without SC from 20 °C to 105 °C, cooled down to 5 °C and reheated up to 105 °C with the same heating rate of 5 K/min.

Up to four endothermic thermal transitions were recorded, indicated as T1–T4, but only the T3 and T4 were reliable for further interpretation. The transition temperature evaluation was made using software STARe V10.00.

Results: Nanosuspensions showed a broad melting event around 60 °C (peak maximum). Due to the combination of solid beeswax and liquid jojoba oil as the lipid matrix there is no sharp melting peak, but a broad melting range. Upon cooling recrystallization occurred around 52 °C. With increasing amount of SLS (1 % up to 5 %) a slight increase in onset temperature was

observed. A similar phenomenon resulted from formulations containing SL as surfactant. In contrast to this, nanosuspensions with PS as surfactant exhibited an exothermic event around 90 °C, possibly because of evaporation and/or decomposition. With increasing concentration of PS the onset temperature of the exothermic event shifted slightly to lower temperatures.
After incubation of the SC with different nanosuspensions it was noticeable that the broad melting peak resulting from the lipid matrix coincided with the endothermic transition shift T2, therefore the emphasis was placed on the endothermic transition shift T3. In comparison to untreated SC (T3: 86.87 ± 1.10 °C) and with increasing surfactant concentrations the endothermic transition shifts became more visible (see Table 1). As an example, T3 shifted for about -10 K formulations of 10 % of PS or SL, respectively. Low concentrations of 1 % surfactant showed a minor change of T3 by about -6-8 K.

Table 1: Endothermic transitions T2-T4 after incubating the SC with nanosuspension or surfactant solution

	Nanosuspension * T3 [°C]	T4 [°C]	Surfactant solution Δ T2 [°C]	T3 [°C]	T4 [°C
SLS					
1%	79.86 ± 0.77	93.22 ± 0.89		71.99 ± 0.89	90.82 ± 0.64
2 %	79.56 ± 0.10	93.89 ± 0.45		71.53 ± 0.44	89.15 ± 0.36
5 %	77.15 ± 0.56	91.72 ± 0.27		72.32 ± 1.22	88.07 ± 0.78
SL					
1 %	78.42 ± 1.05		68.77 ± 0.18	77.27 ± 0.06	90.64 ± 1.77
5 %	76.62 ± 0.65	92.09 ± 0.58	69.00 ± 0.65	77.30 ± 0.47	91.38 ± 1.18
10 %	76.84 ± 0.50	92.53 ± 0.41	68.40 ± 0.63	76.18 ± 0.69	90.51 ± 0.34
PS					
1 %	80.39 ± 0.80	91.71 ± 0.85		77.61 ± 0.35	86.32 ± 3.83
2 %	80.31 ± 0.64	91.22 ± 1.28		77.18 ± 0.44	85.30 ± 0.03
5 %	78.08 ± 0.57	90.14 ± 2.50		78.01 ± 0.44	
10 %	76.27 ± 0.34	86.60 ± 0.78		75.64 ± 0.35	
* Skin donor: 45-year-old woman, abdomen; T2: 71.43 ± 0.72 °C, T3: 86.87 ± 1.10 °C (untreated SC)					
Δ Skin donor: 44-year-old woman, abdomen; T2: 70.96 ± 0.37 °C, T3: 83.51 ± 0.43 °C (untreated SC)					

In order to evaluate the interaction of SC with the surfactants alone, SC was also incubated with surfactant solutions (1-10 %). Solutions of SL and SLS caused an exothermic event of SC at about 90 °C, but no endothermic events at lower temperatures. PS in concentrations of 1 % up to 10 % offered an additional endothermic event of about 38.5 up to 46.8 °C. Independent of the SLS concentration, T3 transition of SC shifted to lowest temperatures by -11 K compared with PS and SL, which in contrast revealed slight concentration dependence (see Table 1). The SL solution caused a further endothermic shift of the T2 transition of SC, which did not show clear concentration dependence with regard to a minor shift of about -2 to -3 K. Furthermore another endothermic event at about 90 °C was observed after incubating both, nanosuspensions and surfactant solutions, with SC.

This may be attributed to a shift of T4.

In conclusion, the surfactant is likely to cause the major interaction with the stratum corneum lipid structure, both from the continuous phase of the nanosuspension and from the surfactant solution itself.

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