

### 1. Introduction

Human skin is the largest organ in the human body and fulfills several essential functions:

Besides serving as a protective layer against harmful environmental influences, pathogens, and UV radiation, the skin plays a crucial role in regulating the body's water balance. Here, especially the outer layer - the *Stratum Corneum* (SC) - serves as a protective layer against dehydration.

Maintaining adequate skin hydration is crucial for ensuring optimal functionality, health, and overall well-being in terms of skin softness, smoothness, and elasticity.

Therefore, the moisture content of the SC-layer should be at least 10 % [1]. According to [1], this can only be assured at relative humidities (RH) larger than 60 %. However, the typical indoor RH level is between 40 % and 60 %. As a result, the skin constantly tends to lose moisture and thus the so-called transepidermal water loss is about 100-150 mL/m<sup>2</sup>\*day [2].

Substances such as hyaluronic acid, urea, and lipids are naturally present in the skin and contribute to improving moisture levels and limiting moisture loss.

Due to these properties and the associated positive effects on the skin, the cosmetics industry uses such substances in creams, body lotions, and body oils. Hyaluronic acid, urea, aloe vera, and natural oils are just a few examples of the ingredients promoted for their hydrating or moisture-retaining effects on the skin.

### 2. Scope

This application note illustrates the use of dynamic vapor sorption analysis for measuring the sorption and desorption behavior of skin. Additionally, several skin care products were tested, and their moisturizing and moisture-retaining effects evaluated.

### 3. Experiment and Results

Measurements were run on a SPS advance having a balance resolution of 1 µg. For analysis, skin samples were cut into round pieces of defined size. Before starting the measurement, the skin samples were preconditioned in the SPS climate chamber at 22 °C and 90 % relative humidity to ensure sufficient hydration state.

Afterwards the skin care products - hyaluronic acid serum, glycerin balsam, urea solution and skin care oil - were applied to the skin so that the entire sample was completely covered. Additionally, the skin care products alone and an untreated skin sample were measured as a control.

For analysis, the temperature was set to 22 °C and the relative humidity was varied in 10 % steps starting at 90 % RH down to 0 % and back to 90 % RH.

Results were evaluated regarding:

- (1) the moisturizing effect of the skin care product by means of moisture uptake during adsorption
- (2) the moisture retaining capacity by the extent and velocity of weight decrease during desorption.

#### 3.1 Water vapor sorption of untreated SC

Fig. 1A shows the dynamic desorption and sorption behavior of the *Stratum Corneum* sample. In Fig. 1B the associated sorption isotherm of the sample is shown.

The results show that the change in weight of the sample occurs almost immediately with the change in relative humidity in the SPS climate chamber, resulting in a step-like progression.

With a look at the sorption isotherm (Fig. 1B), it can be seen that the desorption/sorption process is completely reversible showing no hysteresis.

The results also demonstrate that the skin sample only adsorbs significant amounts of moisture when the relative humidity exceeds 70 % RH. Similar findings, with a steep increase of water vapor sorption at relative humidity > 85 % were reported by [3]. According to their study this behavior could be attributed to structural changes expressed by an increase in the interchain distance and a higher mobility of the keratin filaments - a main component of the SC cells - depending on the hydration state [3]. This is in-line with literature, where an abrupt decrease of elastic modulus of porcine and human SC in the range of 75 % - 90 % RH was detected [3, 4].

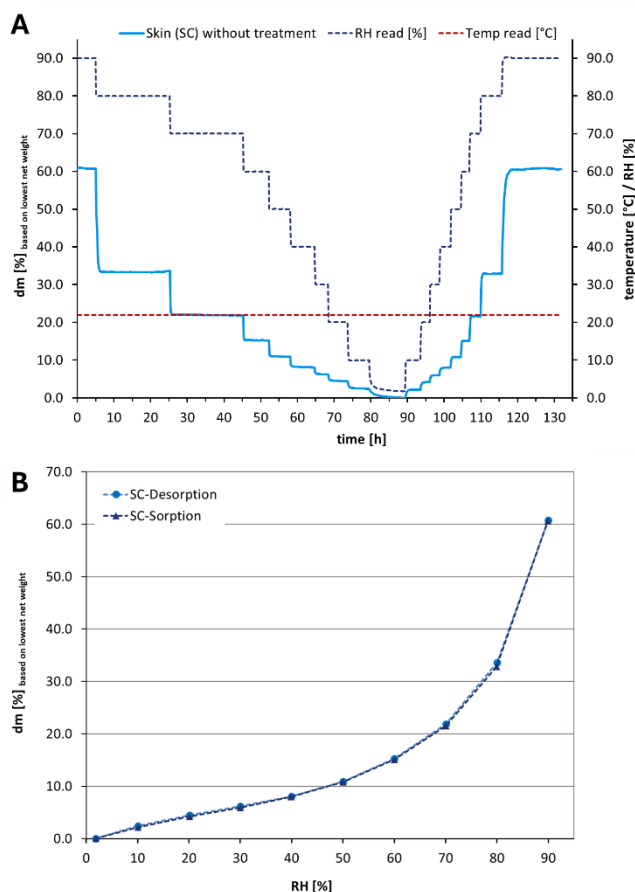


Fig. 1: Dynamic sorption/desorption behavior (A) and sorption isotherm (B) of a SC sample at 22 °C starting at RH of 90 %

## 3.2 Sorption behavior of skin care products and their effect on skin moisturizing

### 3.2.1 Water vapor sorption of skin care products

The water vapor sorption of several skin care products was tested prior to their application to a SC-sample. DVS experiments were run at 22 °C and started at a RH of 90 %. Fig. 2 shows the mass loss of the samples with decreasing relative humidity. Data show that all products have a high moisture sorption capacity of up to 267 % (hyaluronic acid serum). However, data also show that the products lose 44-55 % of their initial moisture when the relative humidity of the surrounding decreases to 70 %.

In contrast, the skin care oil was less influenced by moisture due to the hydrophobic character of the product. Here, a maximum moisture uptake of ~ 0.2 % could be measured (Fig. 2B).

### 3.2.2 Effect of skin care products on water vapor sorption of SC

Fig. 3 shows the water vapor desorption/sorption behavior of an SC-sample treated with various products advertised for their moisturizing effects. The data is presented in comparison to an untreated SC-sample. In contrast to the data shown in Fig. 2, it is noticeable that it is not the SC sample treated with hyaluronic acid serum that has the highest moisture absorption capacity, but that a treatment with glycerin balsam appears to be more effective in terms of skin moisturization. This result may possibly be explained by the characteristics of the hyaluronic acid. Depending on the molecular size of the hyaluronic acid molecules, the substance is able to penetrate deeper layers of the skin and therefore, in contrast to glycerin, has more than just a superficial effect.

According to the product specifications, skin care oils are not intended to moisturize the skin, but rather to form a protective film that locks in moisture and reduces moisture loss. As expected, the SC-sample treated with skin care oil showed the lowest moisture adsorption capacity, also in comparison with the non-treated SC-sample. This result aligns with the expected

behavior of an oil-based product due to its hydrophobic nature

A study conducted by [5] thoroughly investigated the effect of natural moisturizers on the molecular mobility of *Stratum Corneum* components. Similar to the finding in [3] they found that urea and glycerol were able to not only increase the mobility but also to maintain a higher mobility of the *Stratum Corneum* structures even at low relative humidities. According to the authors, maintaining the flexibility is vital to maintain the permeability and to assure enzymatic driven recovery of the SC barrier after perturbation [5].

As stated by [1], the critical moisture content of the SC-layer should be 10 % to assure healthiness and proper barrier function. Therefore, the results of the skin care products shown in Fig. 3 were also evaluated by their ability to maintain this critical moisture content.

Falling below and exceeding the critical 10 % value is visualized by the help of the red line (Fig. 3) and corresponding data are shown in Fig. 4.

For evaluation, data were fitted using the GAB approach and the critical RH values corresponding to a moisture content of 10 % were calculated.

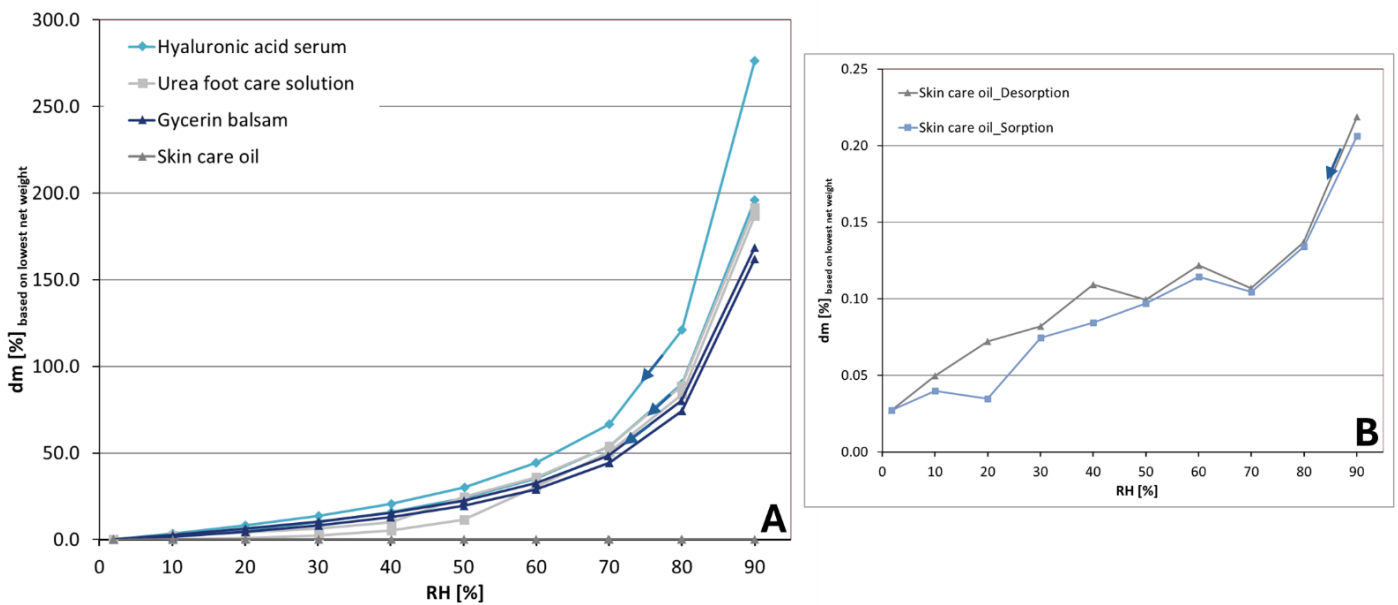


Fig. 2: Sorption isotherm of several skin care products at 22 °C, and a desorption-sorption profile of 90 - 0 - 90 % RH in 10 % RH steps (A). Enlarged view of skin care oil (B). Blue colored arrows indicate the desorption isotherm.

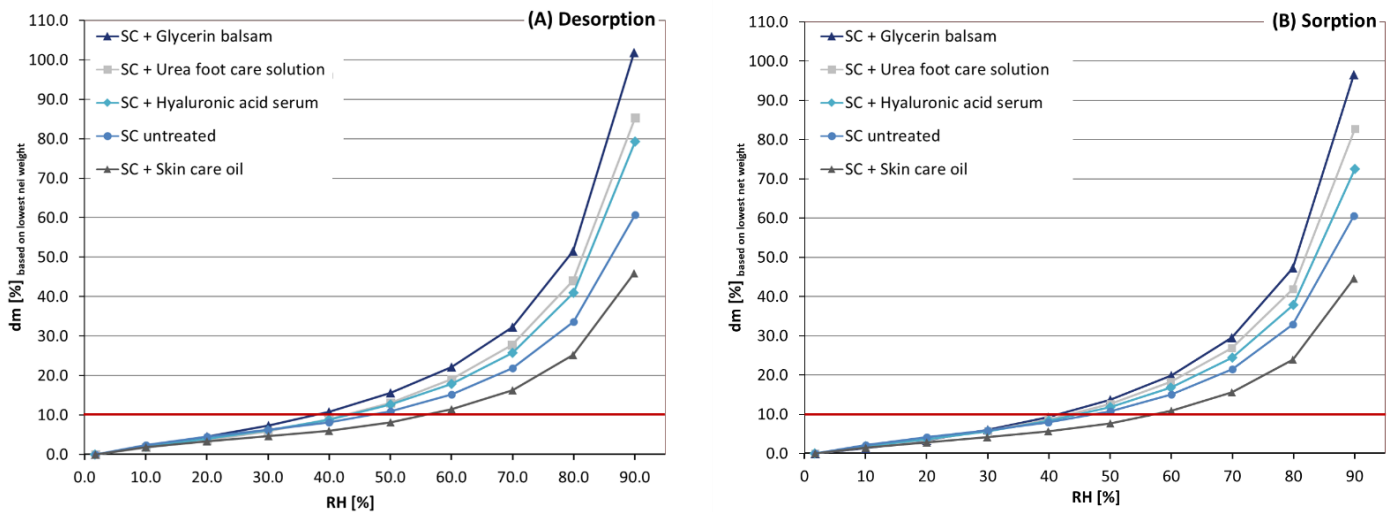


Fig. 3: Desorption (A) and sorption (B) behavior of untreated skin and skin treated with several skin care products. The measurement was run at 22 °C with a desorption/sorption profile of 90 - 0 - 90 % RH in 10 % RH steps. The red line indicates the critical moisture content of 10 %.

### 3.3.3 Moisturizing and moisture-retaining effect

Fig. 4 shows the critical RH in the surrounding when the moisture content of the (treated) SC sample falls below or exceeds the critical moisture content of 10 %.

Accordingly, in Fig. 4, a high relative humidity in the desorption data indicates that the critical moisture content has been decreased earlier, suggesting that the skin care product is less effective in moisture-retaining.

Similarly, a high RH value in the sorption data indicates that the critical moisture content of the skin is only exceeded at higher RH values in the environment. This suggests that the product is less effective at moisturizing.

Furthermore, it is noticeable that, starting from a dry state, a higher relative humidity is required to ensure the necessary skin moisture level of 10 % which might be explained by hysteresis effects.

In general, when comparing the untreated and the treated SC samples, a positive effect of the treatment could be observed, with glycerin balsam being the most suitable for maintaining a sufficient hydration state. In-line with previous results and this evaluation, the skin care oil is less effective at maintaining the moisture content of the SC sample.

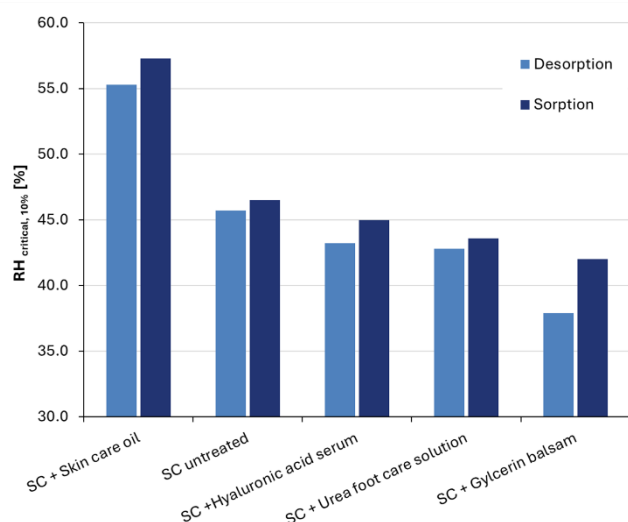


Fig. 4: Ambient relative humidity when the moisture content of the SC sample falls below (desorption) or exceeds (adsorption) the critical value of 10 %, depending on the skin care product applied.

## 4. Summary

The water vapor sorption and desorption behavior of *Stratum Corneum* and various skin care products was analyzed using the proUmid DVS device "SPS advance".

Both the products themselves and their effects after application to the skin were tested for their moisturizing and moisture-retaining properties. Significant differences between the products could be measured.

Maintaining skin moisture is a key selling point of many skin care products, due to the positive effect on appearance, skin health, and overall well-being. As the results demonstrate, water vapor sorption measurements can provide a valuable contribution to the optimization of product formulations with regard to moisturizing and moisture-retaining effects.

## 5. References

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