Formulating Anhydrous Sunscreen products that Applies Clear on Skin that is Wet.

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ABSTRACT
One approach to reduce the risk associated with UV exposure is the use of sunscreen products. These products are available as creams, lotions and sprays. Sunscreens are typically applied before UV exposure, but there are many instances where re-application may be necessary. Conditions such as swimming, exercising, and perspiration may be detrimental to the retention of the sunscreen on the skin and reapplication is necessary to maintain the UV protection. Spray products appear to be the most preferred form of use because of its convenience; however, the application of spray products on wet skin presents many challenges. These spray products normally apply clear on dry skin, but typically turn cloudy and white when applied on wet skin. This unsightly whitening effect does not look good aesthetically, and may also compromise the protection as they can form an incomplete film. Our formulation approach has solved the whitening effect of spray sunscreen on wet skin.

Objective
The composition of anhydrous spray sunscreen formulations typically includes ethanol, sunscreen filters, esters, and a polymer that increases water resistance. These formulations are normally clear and go on clear when they are applied on dry skin. However, when the skin is wet these spray products appear milky as a result of the emulsification process. The sunscreen oil and the water on the skin are not miscible; therefore, one is dispersed into the other forming many oil and water interfaces which scatter light thus appearing white.

Methodology
Immiscible materials have different physical-chemical properties. For example, water is highly polar whereas esters and sunscreen are mostly non-polar. Our formulation approach is to bring these two polarity extremes closer, so we can bridge the polarity gap and create products that apply clear on wet skin. One way to compare polarities of materials is to measure their dielectric constant. The dielectric constant is the ability of a molecule to separate its charges when an electric field is applied; therefore a polar molecule will have a higher dielectric constant. We measured the dielectric constant of all the materials used in the formulations with a BI-870 dielectric constant meter. The appearance of certain esters on wet skin was also evaluated. This was achieved by applying 1.2 mg/cm² of tap water on a 5 x 5 cm section of the forearm, then 1.2 mg/cm² of each formulation was applied and spread by hand using a finger cot. The
appearance was recorded as either clear or milky. All formulations were prepared with standard UVA and UVB sunscreens and a combination of esters and a polymer in an alcohol-based formulation. The homogeneity of the sunscreen film applied was also measured using special UVA photography. Image analysis was performed on the spot to determine the homogeneity of the film applied on dry versus wet skin.

RESULTS
After investigating each ester when applied directly on a wet skin, we found that esters with dielectric constant above 5 go on clear; while those with dielectric constant below 5 appeared white. Since the composition of the sunscreen filters are mostly fixed, we then focused on the ethanol and esters mix which are the major component of an anhydrous formulation. A series of experiments were done to adjust the esters and ethanol ratios. For example, we used a standard anhydrous sunscreen formulation which contained 61 % (w/w) alcohol that appeared white when applies on wet skin and replaced the alcohol content with a mixture of alcohol and esters with dielectric constant higher than 5. We found that once the alcohol content dropped below 45% (w/w) in the alcohol esters mix, the formulation then goes on clear when applied on skin that is wet. Image analysis has shown these films to be more homogeneous when compared to the films from product that appeared white.

CONCLUSION
Our formulation approach has solved the whitening effect of spray sunscreen on wet skin. Using this technology, consumers no longer need to dry off before applying or re-applying water-resistant sunscreens as the formulations for continuous spray go on transparently in the presence of water.