# Protecting UV-exposed hair ceramide with oat oil

Emilie Gombert, Cara Dewis – Oat Cosmetics

The hair shaft is composed of a cuticle, cortex and medulla. The cuticle is the outermost protective layer (consisting of overlapping scale-like cells) that provides the hair sensory and shine characteristics.

The cuticles overlap like roof shingles, protecting the hair from chemical and physical treatments.[1] The cortex is the major component of hair and is responsible for its mechanical strength and pigmentation.[1]

The innermost layer is the medulla. The structural integrity of hair is due to a specific chemical composition, primarily keratin proteins, lipids, and water.

The proteins are complex natural compounds that contribute to hair's physicochemical properties. Hair is also comprised of 1-9% lipids, which contribute to enhanced conditioning properties such as flexibility, surface gloss, and lubricity of hair.[2]

The majority of lipids are cholesterol, free fatty acids, triglycerides, and ceramides. Ceramides play a crucial role in maintaining the structure of the hair and act as a part of the intercellular cement that holds the cuticle cells of the hair shaft together.[3]

The presence of ceramides in the hair structure enhances its strength and resistance to damage, reinforcing the hair shaft, making it less prone to breakage, split ends, and other forms of mechanical damage. They contribute to the overall integrity of the hair, allowing it to withstand external stresses and maintain its structural form.[4]

## Importance of hair protection from sun exposure

Whilst knowledge on the importance of protecting the skin from the sun is mainstream, the consequence of sun damage on hair is not as well documented. Sun exposure can break down the proteins and lipids in the hair cuticle, leaving the hair dry, brittle, and dull.

Prolonged exposure to the sun can have various damaging effects on the structure, composition and appearance of the hair, as detailed below.

- Effect on hair strength: UV light from the sun can strip the hair of its natural moisture, leading to dryness and brittleness. The cuticle can become damaged, resulting in rough and porous hair due to the breakdown of the proteins and lipids (particularly a depletion of ceramides).[5]
- Effect on hair structure: UV light can weaken the protein structure of the hair which gives hair its strength. This can result in hair that is more prone to breakage, split ends and frizz.[5]
- Effect on hair appearance: Sun-damaged hair appears dull and lacks the natural shine and lustre. The damaged cuticles reflect light less effectively, making the hair look flat and lifeless.[6]

## Oat oil as multifunctional and sustainable ingredient

Oat Cosmetics developed Oat Lipid e (INCI name: Avena sativa (oat) Kernel Oil), a superior oat oil with a unique lipid profile. This oat oil is rich in polar lipids, including ceramides (1-2%), triacylglycerols (56%), cholesterol/sterols (14%), as well as antioxidants such as tocotrienol and tocopherol (400ppm) and free fatty acids (9%) (of which 40% oleic acid C18:1n9 and 38% linoeic acid C18:2n6). Oat oil has many functional properties including moisturising, antioxidant and a soothing agent for the hair.

Oat oil is made from selected batches of Avena sativa which are cleaned, dehulled and size separated. Oat kernels are then stabilized by heat treatment and flaked before extracting in ethanol bath. Finally, solids and ethanol are removed.

This oat oil is naturally sourced, a by-product of the food industry (reusing waste product) and biodegradable. This work presents its efficacy to protect the ceramide content after UV exposure in hair as well as improving hair shine.

**ABSTRACT**

Ceramides are lipids that naturally occur in the hair strands. The hallmark of a healthy hair strand is a tightly packed cuticle layer which maintains its strength, elasticity, and shine, without it, hair becomes vulnerable to unwanted damage. The main purpose of ceramides is to 'glue' cuticle layers together to ensure the hair will lay flat and remain intact. Although ceramides occur naturally in the hair, sun exposure (UV light), over time, depletes them leading to raised cuticles, resulting in the loss of moisture, causing the hair strands to become fragile. Oat Cosmetics have developed Oat Lipid e (INCI name: Avena sativa (oat) Kernel Oil), a superior oat oil with a unique lipid profile and tested its efficacy to protect the ceramide content in hair after UV exposure, which effectively improves hair shine as well.

## Oat oil ceramide classes analysis

Ceramides are sphingolipids with diverse physiological roles. A ceramide is composed of a sphingoid base and a fatty acid, which are linked via an amide bond. An analysis of ceramides content was undertaken by using the sphingolipid analysis as described in 2007 by Markham and Jaworski.[7]

A single solvent system with reversed-phase high-performance liquid chromatography coupled to electrospray ionization tandem mass spectrometry detection was used. This enabled the sphingolipids from oat oil to be separated and measured.

Hair ceramides, similar to skin ceramides, consist of various classes and species, each with unique structural features. The exact ratio of each ceramide's classes can vary based on individual genetics, hair types, age, environmental factors and other variables.

For this work, ceramides are classified based on their chemical structure (sphingosine backbones) and types of fatty acids they contain. Ceramide NS is present in the hair cortex and is involve in reinforcing the hair's moisture barrier and improving moisture retention.[8] It contains long-chain fatty acids (C16 to C22) attached to sphingosine.[9]

Ceramide NP is a major ceramide in hair and is maintaining the structural integrity of the hair (to help to strengthen the hair cuticle).[8] It also consists of a long-chain fatty acid (C16 or C18) attached to sphingosine.[9]

Ceramide EOH (or EOP) is present in the outermost layer of the hair cuticle and is helping to form a protective barrier on the hair's surface, preventing moisture loss and enhancing the hair's natural defence mechanisms.[8] It contains shorter-chain fatty acids (C14 to C16) attached to sphingosine.[9]

Ceramide AS is found in the hair cuticle and is essential for strengthening the hair's lipid barrier.[8] It consists of medium-chain fatty acids (C16 to C20) attached to sphingosine.[9]

Ceramide AP is the most abundant ceramide in hair and is contributing to the hair's moisture retention abilities.[8] It contains a long-chain fatty acid (C16 or C18) attached to sphingosine.[9]

## Protection of UV exposure induced hair ceramide degradation with oat oil

A blind study was performed to evaluate the ceramide protective efficacy of oat oil after exposure to UV light. Three hair shafts were dipped into 0.5% oat oil in a vehicle control (C12-15 Alkyl Benzoate), three into the vehicle control and three were untreated (control group).

**TABLE 1: OAT OIL CERAMIDE CLASSES**

| Ceramide Classes | Hair Identical Ceramides Including Isomers (%) | Hair Identical Ceramides Including Isomers and Analogs (%) |
|---|---|---|
| Ceramide 2: Non-hydroxy-sphingosine (NS) | 3 | 23 |
| Ceramide 3: Non-hydroxy-phytosphingosine (NP) | 35 | 35 |
| Omegahydroxy-6-hydroxy-sphingosine (EOH) | 6 | 27 |
| Alphahydroxy-sphingosine (AS) | 6 | 12 |
| Ceramide 6: Alphahydroxy-phytosphingosine (AP) | 3 | 3 |

After the treatments, the hair shafts (blonde Caucasian) were exposed to UVA light (irradiation 84 J/cm², peak at 365 nm) for six hours. This was done to degrade the ceramide content of the hair and mimic real-life exposure to stress. The control group was not exposed to stress conditions.

Ceramides were detected by using a primary specific antibody, then revealed by using a secondary antibody coupled with a fluorophore. Fluorescent images were then collected with an epi- fluorescent microscope and analysed with ImageJ software. Image collection for the different conditions was achieved using identical conditions of acquisition (40X objective).

Representative images per condition are demonstrated in Figure 1. The images were collected in a full range of intensity of specific signal and analysed with ImageJ software. The quantification of ceramides levels was obtained by the integration of the specific fluorescence signal normalized by the evaluated area.

In each image, the quantification of ceramide levels was independently obtained for the different compartments (cuticle or cortex) and for the overall (total: cuticle and cortex). Three images per condition of sagittal section were used to quantify the carbonylation levels; the mean value and standard deviation were obtained per condition (and per compartment).

A significant increase of ceramides is observed in the hair shaft, cortex and cuticle regions, upon 0.5% oat oil application in presence of UVA-stress. When compared to the control (not treated and not exposed to stress):

- +60%*** of ceramides with 0.5% oat oil on the whole sagittal section of hair
- +67%*** of ceramides with 0.5% oat oil on the cortex region
- +36%*** of ceramides with 0.5% oat oil on cuticle region

*In situ* detection of ceramides (carbonylation) was performed by epifluorescence microscopy on sagittal sections (Figure 2). The application of 0.5% oat oil increases the ceramides levels in hair fibres, when compared to the control and vehicle control. Oat oil protects ceramide degradation from UV light, in the different hair regions (shafts, cuticle and cortex).

## Increase of hair shine effect with oat oil

Healthy hair with smooth outer cuticles will reflect light and give the hair a shiny appearance. Many factors, like overexposure to sun can damage cuticles and cause dull hair. In order to examine the hair shine effect of oat oil, five hair tresses (blonde Caucasian) were treated with a shampoo containing 0.5% oat oil, five with a placebo shampoo and five with a silicone shampoo containing 1% dimethicone (5cps).

The treatment, which was designed to mimic real-life hair washing, consisted of soaking hair in water for one minute at 37°C; applying 2g of

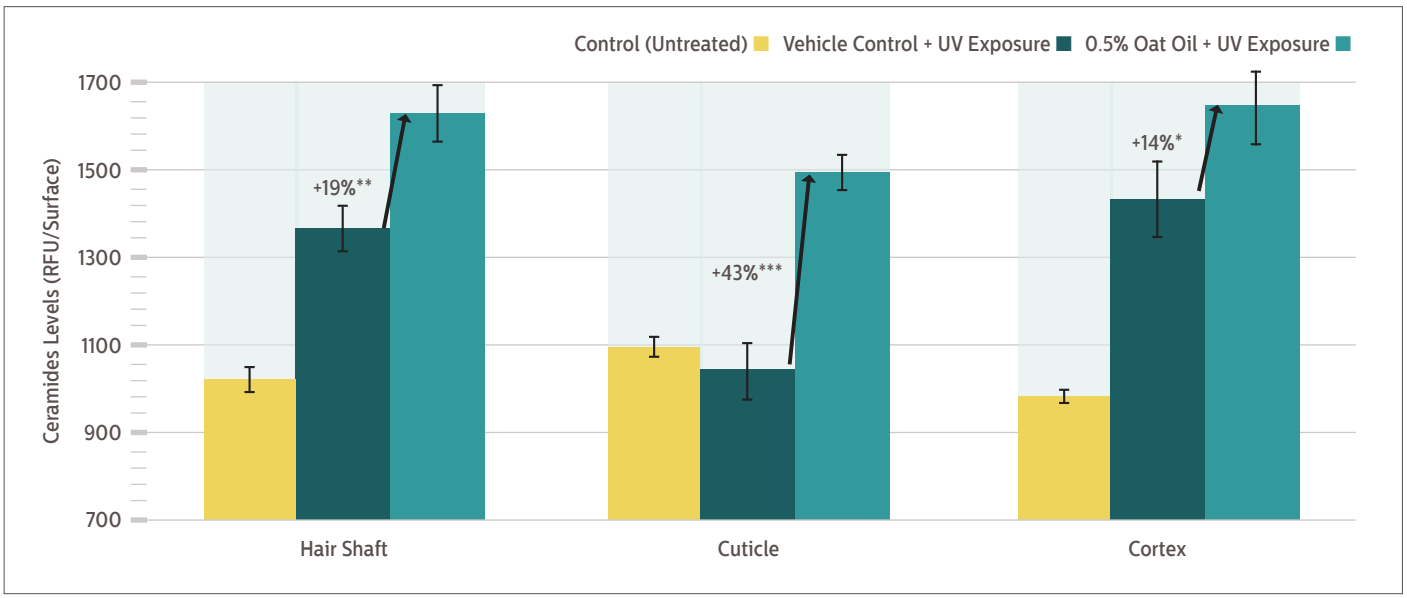


**Figure 1:** Ceramides levels of the hair shaft, cuticle and cortex after UVA exposure. t-Test, Significant: ***=p<0.001, **=p<0.01 (99%) and *=p<0.05 (90%)

shampoo, massaging for 30 seconds, leave for two minutes; rinsing with water for 30 seconds at 37°C and natural drying of the tress.

The hair shine measurement was taken before and after hair treatment. Measurement of specular reflection gloss was performed by a glossmeter. Shine is determined by projecting a beam of light at a fixed intensity and angled onto a surface and measuring the amount of reflected light at an equal but opposite angle.

Images from the surface of the hair were taken with a Scanning Electron Microscope (SEM) before and after shampoo use are shown in Figure 3. Figure 3 images show that the use of a shampoo with 0.5% oat oil flattened the hair cuticles, in comparison to untreated hairs. Softer hair cuticles reflect more light and smooth hair. Oat oil provide significant higher gloss levels.

The results demonstrate that the shine of the hair is improved with application of oat oil, resulting in healthy-looking hair. As the SEM images show, silicone does not seal the cuticle layer of the hair shaft, so shine is not increased. Silicone forms an additional layer and will 'sit' on the surface of the hair. Silicone will not allow the shampoo to penetrate the hair. Instead, it will weigh the hair down, making it limp and dull.

Oat oil is rich in oleic acid, linoleic acid, and tocotrienols and tocopherols (Vitamin E). Its nutrient-rich nature will nourish and strengthen hair, creating the ideal conditions to increase hair shine. Oat oil can be claimed as being a natural replacement to synthetic ingredients in haircare products like silicones where shine, lustre and a strengthening effect are needed.

## Oat oil applications in hair care

Oat oil is suitable for applications such as shine conditioner, hair protection oil treatment, hair repair masks, hair sun protection spray, detangle shampoo. Table 2 gives an example of application oat oil in a hair protection spray. This formulation demonstrates the exciting opportunities for this unique oat oil, resulting in protected, smooth hair with a healthy shine.


**Figure 2:** *In situ* visualisation of ceramides (sagittal view). The fluorescence emission signal for ceramides was obtained by specific immunofluorescence labelling and microscopy (objective 40x)


**Figure 3:** SEM images comparison of hair after single application of different shampoos. +42% increase hair shine compared to placebo, and by +52% compared to the silicone shampoo

## Conclusion

The results show that damaging the hair with sun UV exposure results in a loss of ceramides throughout the hair shaft and that application of Oat Lipid e, prior to the exposure, helps to protect the ceramide loss. While hair ceramides are not directly involved in protecting the hair from UV light, they contribute to overall hair health, which can indirectly minimize the impact of sun damage.

Healthy hair with well-maintained cuticles is better able to resist external stressors, including sun exposure. Oat oil is therefore a promising cosmetic ingredient to prevent hair ceramide degradation and to protect from the harmful effect of the sun, resulting in shiny, strong hair. **PC**

**TABLE 2: HAIR PROTECTION SPRAY WITH OAT OIL**

| Phase | Ingredients / INCI | w/w (%) |
|---|---|---|
| **A** | Dicaprylyl Ether, Tocopherol | 2.000 |
| | Coco-Caprylate/Caprate | 2.000 |
| | C14-22 Alcohols, C12-20 Alkyl Glucoside | 0.500 |
| | *Avena sativa* (Oat) kernel Oil | 0.500 |
| **B** | Aqua | 50.000 |
| | Sodium Gluconate | 0.200 |
| **C** | Hydroxyethyl Acrylate/Sodium Acryloyldimethyl Taurate Copolymer, Aqua, Squalane, Polysorbate 60, Sorbitan Isostearate | 0.750 |
| **D** | Aqua | 40.550 |
| | Glycerin, Aqua | 2.000 |
| | Phenoxyethanol, Ethylhexylglycerin | 1.000 |
| | Glycerin, Vinegar, *Lavandula angustifolia* (Lavender) Flower Extract, *Rosmarinus officinalis* (Rosemary) Leaf Extract, *Salvia officinalis* (Sage) Leaf Extract, *Thymus vulgaris* (Thyme) Flower/Leaf Extract, Potassium Sorbate, Sodium Benzoate | 0.500 |
| **ZADJ** | Aqua, Citric Acid | 0.000 |

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