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The Hair Tensegrity: applying an architecture-inspired concept to hair care

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Introduction:

Traditionally, the hair care has been focused on the hair shaft, ignoring the rest of the structure (follicle and scalp). Nowadays, the interrelation of hair fibers and scalp has been revealed key for the proper activity of the entire tissue. Scalp is essential for hair health **[1, 2]**, as it conditions the emerging hair strength and shine among other properties. The skin of the scalp anchors the hair follicles, and the extracellular matrix is fundamental in this interaction, as well as ion the formation of healthy hair. These intrinsic and extrinsic interactions, together with the forces which the full structure must face, are governed by a continuum, built from the extracellular elements and the cells (keratinocytes, fibroblasts, dermal papilla cells, germ cells, and trichocytes). Hair tensegrity corresponds to the biological engineering supporting and articulating the entire structure **[3, 9]**, being essential that the skin remains cohesive, compact, elastic, and firm, for an adequate tissue maintenance.

Hair follicles connect on one side with the scalp, and on the other side with the emerging hair fibers **[10]**. Thus, on the outside, the follicle is surrounded by a vitreous membrane, a layer of fibrous connective tissue binding it to the cutaneous dermis. All these elements are interconnected and contribute to the correct hair formation and cohesion.

Hence, to guarantee the right tensegrity of the hair tissue it must maintain certain viscoelastic properties based on the materials which compose them (fibrous proteins like keratin, and lipids, the Cell Membrane Complex, CMC). Also relevant are the anchoring proteins (versican, collagen 17, etc.) which connect the follicle with the scalp dermis, and the scalp in which the hair follicles are embedded.

In this paper we have evaluated the effect of an Encapsulated Cellular Oil (ECO) product -based on the phyto-lipidic fractions of *Olea europaea* var. *sylvestris* plant stem cell cultures developed at Vytrus Biotech S.A.- on different tensegrity parameters on scalp and hair fibers. Additional properties of the ECO were evaluated in *in vitro*, *ex vivo* and *in vivo* assays to characterize this product.

Materials & Methods:

***Ex vivo* evaluation of hair diameter and hair strength:**
Hair tresses were immersed for 10 min in ECO and placebo, after which diameter was determined by *Hand USB Digital Microscope images*. Initial hair strength was determined by measuring the maximum force (mN/µm) that each tress could withstand while being stretched before breaking. Then, 5 tresses were soaked in placebo lotion and 5 in 1% ECO, then they were left to dry naturally for 12 hours (leave-on application). Finally, a hair straightener (230ºC) was applied, and strength was measured again, comparing with the initial values.

***Ex vivo* evaluation of hair proteins carbonylation vs UV radiation:**
Hair tresses were exposed to UV-A radiation (LED source, emission peak at 365 nm, 84 J/cm^2), and compared with tresses previously treated for 10 minutes with placebo lotion or with a lotion with 1% ECO. Carbonylated proteins were labeled using a fluorescent probe (Ex=647nm/Em=650nm) which binds carbonyl groups. Image collection for the different conditions was achieved using identical conditions of acquisition (40X objective).

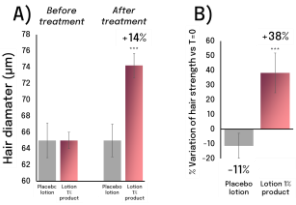
***In vivo* evaluation of scalp redness:**
Double-blind, placebo-controlled. 20 female volunteers with sensitive scalp and high scalp redness, aged 19-70 years old, half-head application (placebo vs 0.5% ECO) once daily for 4 days. Microphotographs of the scalp were taken and evaluations by technicians were carried out before and after the application test.

***In vivo* evaluation of scalp hydration and expression of anchoring proteins:**
Double-blind, placebo-controlled. 15 female volunteers aged 19-70 years old, half-head application once daily for 28 days (placebo vs 1% ECO). Analysis of the scalp TEWL with a Nano Tewameter® (Courage & Khazaka). On a subgroup of 10 volunteers, hairs were carefully plucked to analyze the gene expression of two hair anchoring proteins, versican and collagen 17A, by qRT-PCR (first time *in vivo* test).

Results & Discussion:

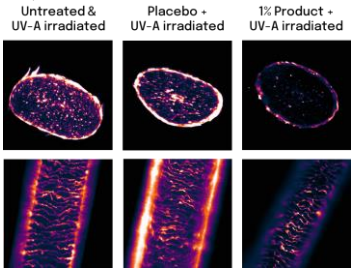
***Ex vivo* increase in hair diameter and in hair strength:**
The lotion containing 1% of ECO significantly increased (p<0.001) the hair diameter by a 14% (9.2 µm), while the placebo lotion did not modify the hair diameter **(A)**.

The active also increased significantly the hair strength in front of high temperatures (hair straightener, 230°C), by 38% (p<0.001) **(B)**.



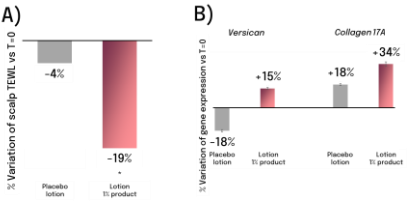
Results & Discussion (continued):

***Ex vivo* protection of hair proteins carbonylation vs UV radiation:**
The lotion containing 1% of ECO **significantly prevented the UV-induced carbonylation** by 60% in the shaft (p<0.001), by 70% in the cuticle (p<0.001), and by 54% in the cortex (p<0.05).



***In vivo* scalp redness reduction :**
The lotion with 0.5% ECO **reduced the redness on the volunteers with sensitive scalp**. On average, ECO performed better than placebo by a 32% after 4 applications.

***In vivo* scalp hydration and expression of anchoring proteins:**
The lotion with 1% ECO **significantly reduced the scalp TEWL at 28 days, increasing the scalp hydration** (p<0.05) **(A)**. Furthermore, it **increased the versican and collagen 17A expression**, by 15% and 34% respectively, two key proteins which anchor the hair follicles in the scalp (**first time measured *in vivo***), outperforming the placebo **(B)**.



Conclusions:

The deep characterizations of ECO activity on individual cells, isolated hair fibers, volunteer's scalp and hair have demonstrated the potential of the product in the maintenance of hair tensegrity by affecting several biological processes in a multimodal approach. ECO has been revealed as a strong antioxidant treatment with a potent activity on protein protection against stress modifications (glycation, carbonylation, etc). Further, ECO's activity on human hair fibers has proven excellent in increasing their diameter and resistance, while stimulating the production of matrix compounds such as collagen in in vitro cells. In volunteer trials, ECO proved their potential to improve several hair and scalp parameters, reduce redness and TEWL, and enhance the extracellular matrix composition and hair anchoring in the scalp by promoting the production of vesican and collagen 17. Altogether the results demonstrated that ECO is a novel and perfect treatment to maintain and boost scalp and hair health by an innovative tensegrity promotion approach.

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