ActivLayr™ nanofibre technology

Iain Hosie[1*], Pablo Lepe[1], Kathleen Hofman [2], Bhuvana Kannan[1] and Deborah LeCorre-Bordes[2]

[1]Revolution Fibres Ltd, 9A Corban Avenue, Henderson 0612, Auckland, New Zealand
[2] The New Zealand Institute for Plant & Food Research Limited, P.O. Box 5114, Nelson 7010, New Zealand.

*Corresponding author: Iain Hosie, E-mail: iain@revolutionfibres.com, Tel: (+64) (9) 8354805.

ABSTRACT

ActiVLayr™ is composed of marine collagen nanofibres incorporated with bioactives. This patented technology offers new delivery mechanisms for a wide range of biomaterials for skincare applications.

Collagen is solubilized with preferred bioactives in an aqueous based solvent solution to form dry nanofibres via an electrospinning process. During this process the bioactives (depending on the nature of bioactives) are encapsulated or chemically bonded to the nanofibres and attain an even distribution on the matrix. The bioactives remain stable on the matrix during storage of the composition under moisture-free ambient conditions. On exposure to moisture on the skin, the nanofibres dissolve, thereby releasing the bioactives.

Incorporating bioactives into the collagen fibre matrix increases the shelf life of the actives while solubility of collagen on the skin assists the successful delivery of actives to the skin. The diverse nature of the ActiVLayr™ and sonic electrospinning technology provides the potential to carry a wide range of active compounds for many applications such as wound dressings, drug delivery and other healthcare applications.

***Keywords**:* nanofibers, electrospinning, collagen, biomaterials, nanotechnology.

1 INTRODUCTION

Nanofibres are uniquely suited to many medical applications, especially skin scaffolds and wound dressings, due to their 3D structure, which mimics important features of the extracellular matrix of many of the tissues in our body. Nanofibres exihibit profound effects such as high surface energy, increased efficiency, raised surface reactivity, high strength to weight ratio which are not displayed in the bulk form of the same material.

Electrospinning, a one-step, top down process allows for a wide variety of bio-polymers, including many FDA-approved materials, to be readily transformed into nanofibres. In addition many functional additives, such enzymes and growth factors, can be also incorporated into the electrospun nanofibre matrix [1].

Electrospinning is a method of producing fibres in the micro and nano scale, this is between 1 $x10^{-9}$ m (1 nm) and 1 $x10^{-7}$ m (0. 1 μm). During the electrospinning process, a high voltage is applied to a droplet of a polymer solution (or melt), stretching the droplet into a conical shape (known as the Taylor cone) by means of electrostatic repulsion. A jet of polymer solution is emitted from the tip of the Taylor cone if the build-up of internal electrical charge overcomes the surface tension of the droplet.

Given an appropriate combination of electro-viscoelastic properties, the polymer jet initially follows a stable, linear trajectory that resists the Plateau–Rayleigh instability, enabling it to be drawn into a fibre. Otherwise, the solution will break-up into small droplets during flight, as described by the Rayleigh instability (aka electrospraying). Following stable jet formation, the jet typically undergoes a chaotic bending instability that leads to extensive jet thinning through solvent loss. A solid polymer fibre is then collected at an earthed electrode if sufficient solvent has been evaporated during the flight from tip to collector [2].

Determining the electrospinnability of a given material is a complex problem that involves the consideration of many different solution and process parameters. Common theories based on polymer physics and rheology cannot accurately describe the electrospinning behaviour of nonpolymeric systems, such as supramolecular systems with extensive secondary bonding (e.g., biomaterials).

Revolution Fibres has developed many electrospun nanofibre products for the cosmetics, natural health and medical research markets. A particular example of Revolution Fibres innovative commercialization services is ActivLayr™, a skin delivery platform based on water

soluble marine collagen that can be loaded with a wide range of natural extracts.

2 REVOLUTION FIBRES

Revolution Fibres Ltd., a global leader in nanofibre production has created lab, pilot and industrial-scale electrospinning machines (using its proprietary Sonic Electrospinning Technology™), enabling partner companies and research institutes to produce superior products based on functional electrospun nanofibres.

The New Zealand Institute for Plant & Food Research, a global leader in food and marine science, has developed a unique extraction process to obtain denatured whole chains of collagen suitable for electrospinning. Revolution Fibres produces one of the fastest dissolvable electrospun collagen membranes in the world using the Plant and Food exclusive marine collagen.

3 ACTIVLAYR™

The ActiVLayr™ skin delivery platform is a patented technology (WO/2013/0350720), based on the denatured whole chains of type 1 collagen extracted from NZ hoki fish skins. This collagen has been shown to be an ideal material for electrospinning fibres [3]. The spun fibres are readily soluble in water making them an ideal medium for the targeted delivery of active compounds with properties enhanced by the water holding capacity of collagen.

Collagen molecules are organised into fibrous structures in tissues where they provide strength, flexibility as well as fulfilling many biochemical roles. The principle attribute that enables collagen tissue strength is the presence of strong covalent crosslinks between the molecules within the fibres. These cross links are formed during development via a number of different pathways and chemical steps depending on the tissue and species. While the nature of the crosslinks in mammalian collagens renders their tissues insoluble, in contrast the crosslinks in hoki skin collagen are soluble in acid. This means that it is possible to recover intact native collagen molecules which can be unravelled to provide the individual alpha chains that spin so well.

A second attribute of hoki collagen which reflects its origins from a cold water environment is the low content of the unique amino acids, proline and hydroxyproline, which play a role in alpha chain structure and stability. The low amounts of these amino acids in hoki collagen compared to mammalian collagen, contribute to the remarkable solubility of the fibres spun from this material.

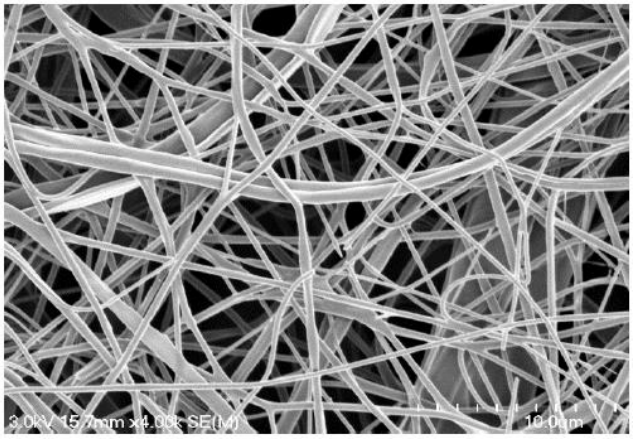

Figure 1 – Scanning electron micrograph of electrospun denatured whole chains of hoki collagen with an averaged density of 3 grams per square meter.

In addition to marine collagen, ActiVLayr™ patches are loaded with a sustainably sourced bioactive formulation called Vinanza®. Vinanza® is a blend of potent antioxidants including catechins, vitamin C, gallic acid, flavonoids, and proanthocyanins (Figure 2). The naturals bio-materials that make the exclusive Vinanza® formulation are extracted from the waste stream of the local wine and food industry processes using aquapure® technology. Aquapure® technology uses only water to extract the bio-functional chemicals from the fruits, skins and seeds (Figure 2). In turn, this allows for the antioxidants, vitamins and all other bio-fuctional extracts to be processed in their natural form with no chemical damage by any other type of solvent. Also, by using Aquapure® technology, there is a 100% warranty that no chemical or solvent residues would be present in the final product.

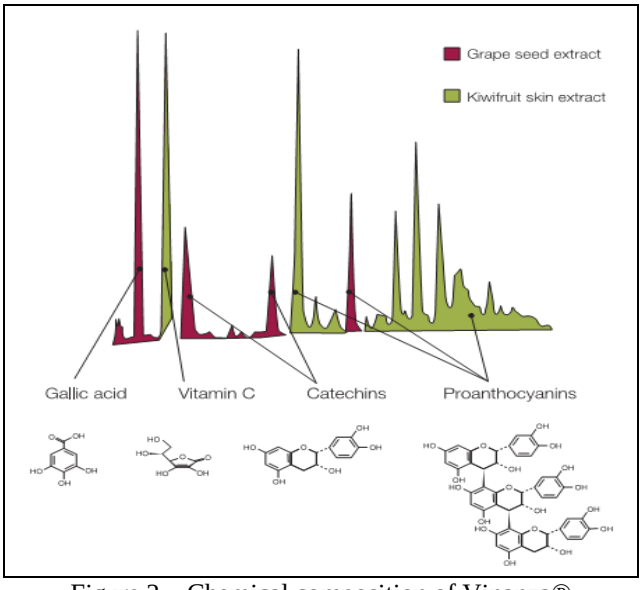

Figure 2 – Chemical composition of Vinanza®

The active extracts are shear blended with the collagen powder prior to electrospinning, to distribute them homogeneously into the collagen structure and to ensure homogeneity of the resultant electrospunfibre mat.

Generally polyphenols are prone to oxidation when exposed to sunlight thus limiting their shelf-life as active bio-agents. With electrospinning, the goodness of the potent antioxidant mixture of the extracts is locked inside the matrix of the electrospun fibre mat, which slows down the oxidation rate of the polyphenols.

This collagen-bioactive matrix has been clinically proven to improve skin elasticity (16%), trans-epidermal water loss (15%), and to reduce the appearance of wrinkles and sun spots (Figure 3). Furthermore, by adjusting the extract composition, actiVLayr® can target various skin problems. A broad range of formulations has been developed, including:

- Skin moisture and elasticity face masks
- Skin brightening patches (under-eye or full face)
- Anti-inflammatory and pain relief patches
- Anti-acne and antimicrobial patches
- Nappy liners that reduce irritation
- Burn treatment composite dressings

Moreover, ActiVLayr® products do not contain any added preservatives (no emulsifiers or stabilizers), or chemicals (whereas most creams do); as the bioactivity of our collagen nanofibres naturally deters biological degradation.

Furthermore, ActiVLayr® patches can be stored indefinitely (provided there is no humidity and sun interaction), as the activity of the extracts is also prolonged by the encapsulation effects provided by the collagen fibres.

ActiVLayr™ technology is now available in the market under a white-label customization service (Figure 4). It is also undergoing extensive clinical tests, in collaboration with key industry global partners.

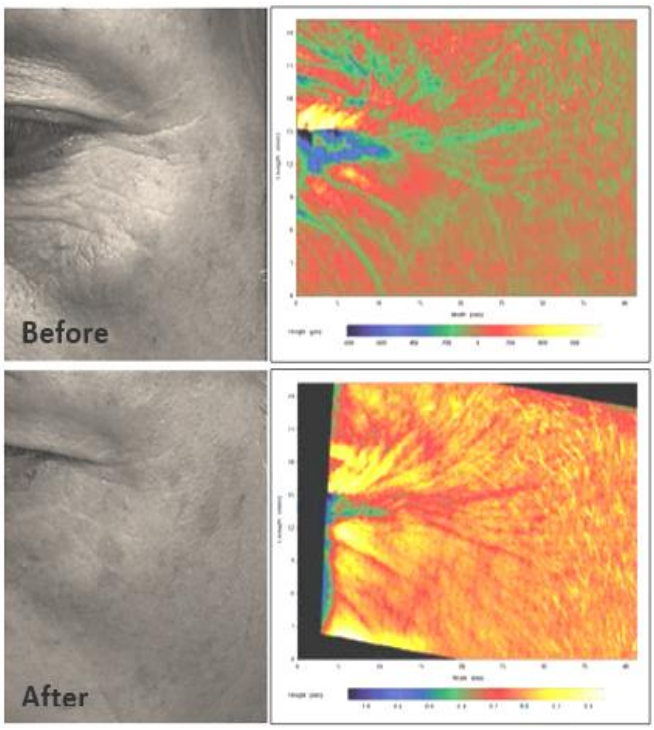

Figure 3 – Photographs and thermal infrared images showing the before and after effects of using ActiVLayr™ once a day for seven days.

4 CONCLUSIONS

ActiVLayr™ patches are usually commercialised using a wide range of plant and fruit extracts derived from the waste stream of the New Zealand wine and food industries. The ecologically sourced extracts contain a wide range of polyphenols, catechins, vitamins, flavonoids, and others.

Electrospun nanofibre membranes have huge commercial potential for cosmeceutical and healthcare applications. Nanofibres from bio-sourced materials (e.g., marine collagen), can be readily functionalized with many bio-actives, such as natural extracts, enzymes and food ingredients.

Figure 4 – Photograph of market ready ActiVLayr™ patches.

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