KEY WORDS: MEADOWFOAM SEED OIL, LIMNANTHES ALBA, TRIGLYCERIDE, DIMETHICONE COPOLYOL MEADOWFOAMATE, HUMAN HAIR

• *The oil triglyceride of meadowfoam seed oil has unusually high oxidative stability because a high percentage (96%) of its fatty acids are of long chain lengths (C_{20} and C_{22}) and because the double bonds are well-removed from one another (at the C-5 and C-13 positions). This stability suggests personal-care applications. For example, dimethicone copolyol meadowfoamate, a silicone derivative of meadowfoam seed oil, can penetrate and repair human hair, as the author shows with electron microscopy and X-ray micro-analysis.*

• *Le triglycéride de l'huile de Limnanthes alba offre une stabilité exsudative exceptionnelle parce qu'un pourcentage élevé (96%) de ses acides gras sont à chaîne longue (C20 et C22) et que les liaisons doubles sont très écartées l'une de l'autre (aux positions C-5 et C-13). Cette stabilité suggère des applications possibles en matière d'hygiène personnelle.*

• *Das ölige Triglycerid des weissen Sumpfschnabels zeigt unge-wöhnlich hohe Stabilität gegenüber oxidativen Einflüssen. Der Grund hierfür ist einerseits zu sehen in dem hohen prozentualen Anteil (96%) seiner Fettsäuren, die langkettig (C20 und C22) sind und andererseits darin, dass die Doppelbindungen getrennt von einander liegen (an C5 und C13 Position). Diese Stabilität ist günstig für Anwendungen im Personal Care Bereich.*

• *El triglioérido del aceite de semilla de meadowfoam tiene una desusual alta estabilidad a la oxidación debido a su alto percentaje (96%) de ácidos grasos de cadena larga (C_{20}) y (C_{22}) y debido también a que sus dobles enlaces están bastante separados entre si (en las posiciones C_5 y C_{13}). Esta estabilidad sugiere posibles empleos en productos para cuidados personales.*

A Meadowfoam Seed Oil Derivative and its Activity on Human Hair

From a natural, biodegradable source comes a silicone derivative that can penetrate and repair human hair

Alan Wohlman, PhD
The Fanning Corporation, Chicago, IL USA

The unique fatty acid composition of meadowfoam seed (*Limnanthes alba*) oil[a] and its derivatives provides a very stable oil and suggests application in a wide range of personal-care products. This article introduces a silicone derivative of the oil and reports the derivative's ability to penetrate and repair the human hair fiber.

Figure 1-1. Meadowfoam flower

Meadowfoam Seed Oil

Meadowfoam seed oil is a natural, biodegradable raw material extracted from the plant *Limnanthes alba*. This oil seed crop is grown primarily in the Pacific Northwest of the US, where it has adapted particularly well to the relatively mild winters and warm dry summers of northern California and southern Oregon.

Limnanthes alba (Figure 1-1) is a low-growing winter annual that is usually planted in the fall and blooms in May with delicate white flowers that populate the field so densely that they suggest a foaming meadow.

[a] The Fanning Corp., Chicago, Illinois, has registered the trade name "Fancor Meadowfoam Seed Oil" for the meadowfoam seed oil it produces.

The oil has a very light yellow color and is essentially odorless.

The chemical specifications are as follows:

Color (Gardner)	< 4
Free fatty acids	< 0.5
Specific gravity	0.9-0.911
Saponification value	160 - 175
Iodine value (Hanus)	90 - 105
Heavy metals	< 20 ppm
Unsaponification value	< 2%

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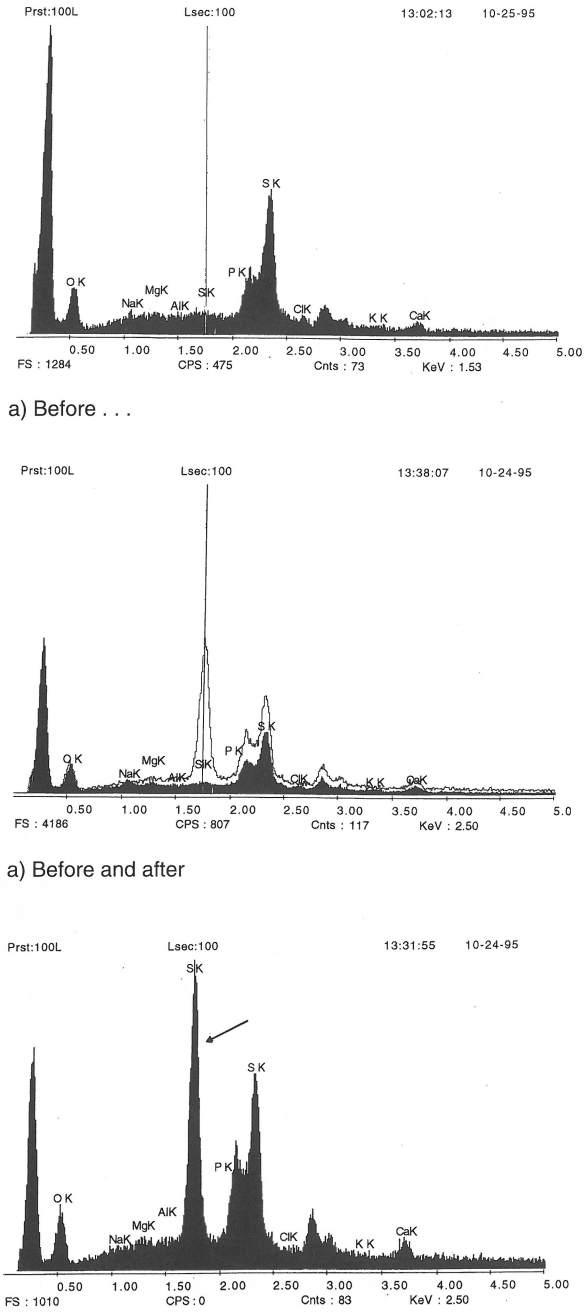


Figure 1-2. EDAX scans of damaged hair fiber
a) Cuticle surface before treatment with DCM
b) Cuticle surface before (lower) and after (upper) treatment with water-insoluble DCM
c) Endocuticle after treatment with water-insoluble DCM and heat

As Table 1-1 shows, this oil triglyceride is exceptionally rich in long-chain fatty acids. Approximately 96% of the fatty acids are of C_{20} and C_{22} chain lengths, which are uniquely stable owing to the location and distribution of the double bonds.

The combination of monoenoic acids and dienoic acids with double bonds well removed from one another (at the C-5 and C-13 positions) confers a high degree of oxidative

Table 1-1. Fatty acid profile of meadowfoam seed oil

*Structure**	*Acid*	*%*
20:1Δ5	(5-eicosenoic acid)	60
22:1Δ5	(5-docosenoic acid) and	
22:1Δ13	(13-docosenoic acid)	17
22:2Δ5,13	(5,13-docosadienoic acid)	19
		96

* For example, 20:1Δ5 suggests a structure with 20 carbon atoms and a double bond at the fifth carbon (between C5 and C6).

Formula 1-1. Leave-in conditioner base

Stearyl alcohol	0.50%
Cetyl alcohol	0.50
Cocamidopropyl dimethyl amine	1.00
Meadowfoam seed oil	0.30
Dimethicone copolyol meadowfoamate	1.00
Glycerine	0.50
Lactic acid	0.27
Water (aqua)	95.93
Fragrance (parfum) and preservatives	qs
	100.00

stability to the meadowfoam oil triglyceride.[2] The AOM value of approximately 200 is more than five times that of most common vegetable oils.[b] The stability of the triglyceride fatty acids provides an oil whose physical and chemical attributes remain relatively constant during long periods of time; this is in spite of changing environmental conditions.

Stability of the oil means that, over time, it will not develop odors, change color, form precipitates or lose important rheological properties. Therefore, one would expect performance evaluations and safety tests performed on developmental formulations containing meadowfoam seed oil to be more reliable and predictable over an extended timeframe than had a less stable oil been used.

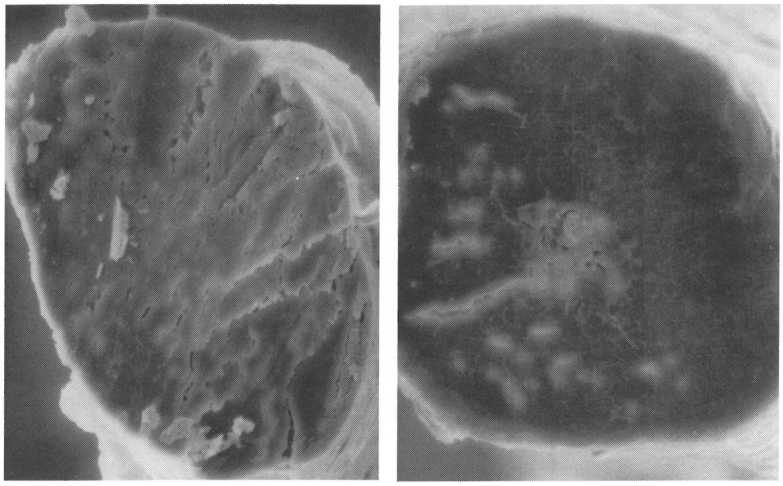
In light of these advantages, it is not surprising that meadowfoam seed oil is being evaluated in a wide range of personal-care products including skin care, hair care and toiletries.

Derivatives

In our labs, we prepared and tested a number of very interesting meadowfoam seed oil derivatives, including the following:

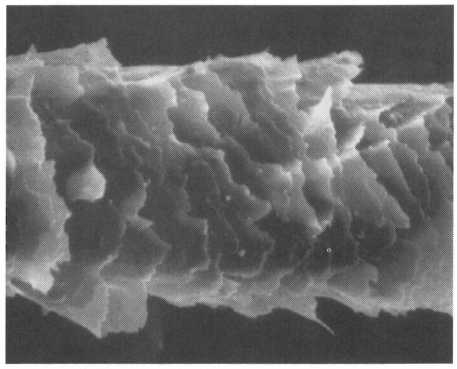
- A sulfated quaternium derivative[c] used to enhance conditioning in skin and hair care products.
- An ethoxylated ester[d] that provides emolliency and improved emulsification properties in a water-soluble form.
- A hydrogenated derivative[e] with the physical attributes of a wax.
- A series of silicone derivatives,[f] all bearing the INCI

[b] AOM (for "Active Oxygen Method") is the time required to obtain a predetermined peroxide value when washed air is bubbled through a fat sample held at 97.8°C.
[c] Fancor Meadowquat, Fanning Corp., Chicago, Illinois, USA
[d] Fancor Meadowsol, Fanning Corp.
[e] Fancor Meadowax, Fanning Corp.
[f] Fancorsil LIM-1, Fancorsil LIM-2 and Fancorsil LIM-3, Fanning Corp. LIM-1 is readily soluble in water. LIM-2 is insoluble in water. LIM-3 is water-dispersible.

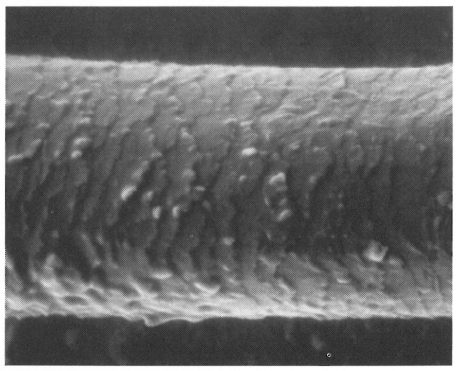


a) Before b) After

Figure 1-3. Scanning EM cross-sections of damaged hair fiber
a) Before treatment with DCM
b) After treatment with water-insoluble DCM



a) Before



b) After

Figure 1-4. Scanning EM of the surface (cuticle) of damaged hair fiber
a) Before treatment with DCM
b) After treatment with water-insoluble DCM

name dimethicone copolyol meadowfoamate, that combine the conditioning properties of meadowfoam seed oil with the surface-active benefits contributed by the silicones.

Dimethicone Copolyol Meadowfoamate

While all of these derivatives provide qualitatively different functional benefits, the dimethicone copolyol meadowfoamate (DCM) family of silicone compounds has been successful in both skin- and hair-care applications. These compounds result from the esterification of meadowfoam triglyceride fatty acids with either dimethicone copolyol or dimethiconol otherwise referred to as silanol. The DCM compounds vary in their solubility in aqueous systems.

Long chain fatty acids, such as those found in meadowfoam seed oil, easily penetrate through the semi-permeable barriers of skin and hair restoring lipid fractions that were lost due to degenerative processes such as oxidation. The restoration of physiological oil/water interfaces provides an environment where proteins and other structural elements of the skin and hair reassume their natural configurations, leading to improved tensile strength and elasticity.

We postulated that this activity would be further augmented by combining the meadowfoam seed oil with surface-active functional moieties such as silicone.

To test our hypothesis, we looked for answers to two questions:

- Does DCM penetrate the hair fiber?
- Does DCM have the capacity to repair structural damage in hair and/or skin?

Penetration of the Hair Fiber

After using a bleach/permanent wave process to damage European blond hair tresses, we treated the hair with either water-soluble DCM in a 5% aqueous solution or water-insoluble DCM at 1% in a leave-in conditioner base (Formula 1-1). Then we rinsed, dried and cross-sectioned each hair tress for microscopic study.

Using energy dispersive X-ray microanalysis, we measured the ability of the DCM to penetrate the hair fiber. The electron beam of an electron microscope, in addition to producing an image of the sample, can also be used to generate characteristic X-ray emissions resulting from bombardment of the atoms that are on or near the surface of the sample. By analyzing these X-rays into an energy spectrum, we selected emission peaks that specifically identify the elemental composition of the sample.

We examined hair cross-sections for the presence of silicone in the endocuticle and inner cortex regions of the fiber. In some cases, we used heat to facilitate the penetration of DCM into the shaft.

The atom silicon, present in DCM, serves as a useful marker for cuticle substantivity or penetration into the hair shaft. The 1740 EV silicon peak shows up slightly to the left of the pronounced 2310 sulfur peak present in hair sulfhy-

dryl groups. Note that in Figure 1-2a, an EDAX scan[g] of the untreated sample, no silicon peak is evident. However, following treatment of the hair fiber with DCM, a distinct silicon peak is evident on the cuticle, as can be seen in Figure 1-2b.

When coupled with a small amount of heat from a blow dryer, treating the hair with DCM resulted in penetration into the endocuticle as evidenced by the pronounced silicon peak seen in Figure 1-2c.

Restoration of the Hair Fiber

Having established that the dimethicone copolyol meadowfoamate does indeed penetrate into the fiber, we turned our attention to evaluating the effects upon the morphology and behavior of the hair. Since the active ingredient was specifically identified on the surface and within the endocuticle of the hair fiber, we sought structural effects in both of these areas.

The cell membrane complex within the cortex of the hair fiber forms a structural network that contributes to the overall tensile strength of the shaft.[1,3] Damage to this lipoprotein network produces dramatic and observable changes in hair fiber integrity, as shown by the discontinuous nature of the cortical region micrographed in Figure 1-3a. Treating the hair with DCM resulted in a significant degree of repair, as shown by the more continuous nature of the cortical region micrographed in Figure 1-3b.

The scanning electron micrograph in Figure 1-4a clearly shows the damaged, lifted cuticle plates on the surface of the fiber. However, following exposure to the leave-in conditioner containing DCM, the surface of the fiber appears, in Figure 1-4b, to have returned to a normal state.

Conclusion

We synthesized dimethicone copolyol meadowfoamate, a silicone ester of meadowfoam seed oil, and we studied it with respect to its activity on human hair. Electron microscopy and X-ray microanalysis demonstrated hair repair subsequent to uptake of this new material into the submicron regions of the hair shaft.

[g] Edax, International, Mahwah, New Jersey, USA

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