

INTISARI

Alopesia androgenetik merupakan kerontokan rambut progresif akibat faktor genetik dan peningkatan aktivitas dihidrotestosteron. Penggunaan obat konvensional jangka panjang dapat menimbulkan efek samping, sehingga diperlukan alternatif berbasis bahan alam yang lebih aman. *Sargassum cristaefolium* L. mengandung fukoidan yang berpotensi meningkatkan proliferasi sel papila dermal. Namun, sifat fukoidan yang hidrofilik dan berukuran molekul besar membatasi penetrasinya ke folikel rambut. Hingga saat ini, belum terdapat formulasi *Nanostructured Lipid Carriers* (NLC) ekstrak kaya fukoidan *Sargassum cristaefolium* L. yang dioptimasi secara sistematis untuk meningkatkan stabilitas, penetrasi folikular, dan efektivitas pertumbuhan rambut. Penelitian ini bertujuan untuk mengoptimasi formulasi serum *Nanostructured Lipid Carriers* ekstrak kaya fukoidan alga cokelat untuk meningkatkan penetrasi obat melalui folikel rambut.

Sargassum cristaefolium L. diekstraksi menggunakan akuades (1:20), dan dianalisis kadar sulfat, karbohidrat, dan asam uronat dalam ekstrak yang diperoleh. Kandungan fukoidan dianalisis menggunakan densitometri, dan FTIR. Optimasi formulasi NLC menggunakan variasi konsentrasi monostearin, asam oleat dan Tween 80 berdasarkan *Design-Expert* 10.0.1 dengan metode *Simple Lattice Design* diperoleh 13 formula. Seluruh formula dianalisis berdasarkan parameter ukuran partikel dan distribusi partikel (PDI). Formula optimal NLC diukur zeta potensial dan dianalisis dengan *Transmission electron microscope*. Hasil optimasi formula terbaik diverifikasi dengan uji *one T-Test*. Formula optimal dibuat sediaan serum dengan konsentrasi 5%, 10%, dan 20%, kemudian diuji stabilitas fisik, profil persen tertransport secara *in vitro*, aktivitas pertumbuhan rambut dan iritasi dermal secara *in vivo*. Hasil uji stabilitas dianalisis dengan *paired t-test* ($P < 0,05$). Hasil uji sediaan serum dan aktivitas pertumbuhan rambut dianalisis dengan *one way Anova*.

Ekstrak kaya fukoidan memiliki rendemen sebesar 1,68% dengan kadar karbohidrat 16,33%, kadar sulfat 10,50% dan kadar asam uronat 6,32%. Hasil FTIR dan densitometri mengonfirmasi kandungan fukoidan dalam ekstrak dengan kadar 21,68% b/v. Formula optimum NLC diperoleh dari konsentrasi monostearin: asam oleat: Tween 80 (2,24; 2,01 ;7,66) dengan respons pH $5,01 \pm 0,17$, ukuran partikel $389,94 \pm 65,93$ nm; PDI $0,49 \pm 0,05$; EE $98,37 \pm 0,10\%$ dan potensial zeta $-23,08$ mV. Hasil TEM menunjukkan bentuk partikel NLC *imperfect*. Semua sediaan serum yang dihasilkan stabil, tertransport secara bertahap hingga 90% dalam 480 menit, serta mampu meningkatkan pertumbuhan rambut tanpa menimbulkan iritasi. Secara keseluruhan, serum NLC ekstrak kaya fukoidan efektif memacu pertumbuhan rambut pada model kelinci AGA.

Kata kunci : Alga cokelat, ekstrak kaya fukoidan, NLC, serum rambut, alopesia androgenetik

ABSTRACT

Androgenetic alopecia is progressive hair loss due to genetic factors and increased dihydrotestosterone activity. Long-term use of conventional medications can cause side effects, necessitating safer, nature-based alternatives. *Sargassum cristaefolium* L. contains fucoidan, which has the potential to increase dermal papilla cell proliferation. However, fucoidan's hydrophilic nature and large molecular size limit its penetration into hair follicles. To date, no Nanostructured Lipid Carrier (NLC) formulation of fucoidan-rich *Sargassum cristaefolium* L. extract has been systematically optimized to enhance stability, follicular penetration, and hair growth effectiveness. This study aimed to optimize the formulation of a Nanostructured Lipid Carrier serum containing fucoidan-rich brown algae extract to enhance drug penetration through hair follicles.

Sargassum cristaefolium L. was extracted using distilled water (1:20), and the resulting extract was analyzed for sulfate, carbohydrate, and uronic acid levels. Fucoidan content was analyzed using densitometry and FTIR. Optimization of NLC formulations using varying concentrations of monostearin, oleic acid, and Tween 80 using Design-Expert 10.0.1 with the Simple Lattice Design method resulted in 13 formulas. All formulas were analyzed based on particle size and particle distribution (PDI) parameters. The optimal NLC formula was measured for zeta potential and analyzed using a transmission electron microscope. The best formula optimization results were verified using a one-way t-test. Serum preparations were prepared at concentrations of 5%, 10%, and 20%, then tested for physical stability, in vitro transport profile, hair growth activity, and in vivo dermal irritation. Stability test results were analyzed using a paired t-test ($P < 0.05$). Results from serum preparations and hair growth activity were analyzed using a one-way ANOVA.

The fucoidan-rich extract had a yield of 1.68%, with a carbohydrate content of 16.33%, a sulfate content of 10.50%, and a uronic acid content of 6.32%. FTIR and densitometry results confirmed the fucoidan content in the extract with a concentration of 21.68% w/v. The optimum NLC formula was obtained from the concentration of monostearin: oleic acid: Tween 80 (2,24; 2,01; 7,66) with a pH response of $5,01 \pm 0,17$, particle size response of $389,94 \pm 65,93$ nm; PDI $0,49 \pm 0,05$; EE $98,37 \pm 0,10\%$, and zeta potential $-23,08$ mV. TEM results showed a spherical NLC particle imperfect. All serum preparations produced were stable, gradually transported up to 90% in 480 minutes, and were able to increase hair growth without irritation. Overall, the NLC serum extract rich in fucoidan was effective in stimulating hair growth in the AGA rabbit model.

Keywords: Brown algae, fucoidan-rich extract, NLC, hair serum, androgenetic alopecia