INTISARI

Spirulina platensis (SP) merupakan salah satu mikroalga sumber *Phycocyanin* (PC) yang dapat berfungsi sebagai antioksidan, anti kanker, dan anti inflamasi. *Spirulina platensis* dipilih karena mengandung banyak protein, hidup di air tawar, serta mudah dibudidayakan dalam skala besar. Berbagai cara ekstraksi komponen bioaktif dari mikroalga telah dilakukan, antara lain: maserasi, homogenisasi, ultrasonikasi, *microwave*, *pulsed electric field*, ekstraksi superkritis, dan *freezing-thawing*. Sejauh ini, dari berbagai metode tersebut, *freezing-thawing* memiliki keunggulan, yaitu terjaganya kualitas produk, karena PC harus disimpan pada suhu rendah (beku). Pengaturan kadar air pada SP merupakan kunci keberhasilan pemecahan dinding sel dengan perlakuan awal *freezing-thawing*. Penelitian ini mempelajari pengaruh kadar air, waktu pembekuan, perbandingan solven terhadap biomassa, dan keseimbangan ekstraksi. Penelitian ini juga menganalisis model *freezing-thawing* secara numeris pada daerah dua fase. Terakhir, *life cycle assessment* (LCA) juga dilakukan, agar diketahui proses ekstraksi yang memberikan dampak lingkungan terkecil.

Pengaturan kadar air dilakukan dengan tiga cara, yaitu: 1) pengeringan SP segar (basah) menggunakan oven pada suhu 30-60°C, 2) perendaman SP basah, dan 3) perendaman SP kering. Selanjutnya SP dimasukkan ke dalam *freezer* hingga waktu yang ditentukan (24 jam hingga 141 hari), dilakukan *thawing*, dan disaring menggunakan alat penyaring vakum. Filtrat dianalisis absorbansinya menggunakan spektrofotometer pada panjang gelombang 615 dan 652 nm. Untuk analisis model *freezing-thawing*, sampel ditempatkan di dalam loyang *stainless steel* yang berukuran 10 x 10 x 2 cm^3. Sampel yang tebalnya 1 cm diukur suhunya pada posisi dasar, tengah, dan atas, dengan jarak masing-masing 0,5 cm. Alat dilengkapi dengan sensor suhu dan perekam data, yang dapat menyimpan data rekaman suhu dari awal proses pendinginan, pembekuan, hingga selesainya *thawing* pada suhu ruangan. *Phycocyanin* hasil ekstraksi juga diuji kadar aktivitas antioksidannya menggunakan metode DPPH (2,2-*Diphenyl*-1-*picrylhydrazyl*).

Hasil penelitian menunjukkan bahwa kadar air sangat berpengaruh terhadap keberhasilan pemecahan dinding sel melalui perlakuan awal *freezing-thawing*. Pengeringan SP segar (basah) di dalam oven pada suhu optimum 50°C, selama 15 menit, menjadikan kadar air optimum 80,16% (basis basah), dengan *yield* optimum 84,21%. Pada perendaman SP kering selama 6 jam diperoleh kadar air optimum 81,9% basis basah (dengan yield 81,65 %). Penambahan air suling pada SP basah cenderung menurunkan hasil ekstraksi. Lamanya pembekuan setelah 24 jam relatif tidak berpengaruh pada hasil ekstraksi, apabila kadar air sebelum proses *freezing* sama. Semakin besar perbandingan solven terhadap biomassa, maka semakin besar *yield*, dan optimum pada 100 mL/g. Keseimbangan ekstraksi mengikuti persamaan Langmuir. Uji aktivitas antioksidan menggunakan metode DPPH menunjukkan PC memiliki aktivitas sebagai antioksidan. Hasil ekstraksi yang berasal dari SP basah mempunyai nilai IC_{50} sebesar 2,783 mg/L, sedangkan dari SP kering sebesar 1,485 mg/L. Analisis numeris dari pemodelan *freezing-thawing* pada daerah transisi (cair-beku) lebih sesuai menggunakan Model 1, yaitu: nilai fraksi beku (α) merupakan fungsi linear terhadap suhu *freezing*. Hasil analisis LCA menggunakan perangkat lunak OpenLCA 1.11.0 menunjukkan bahwa proses ekstraksi PC dari SP secara *freezing-thawing* dari bahan baku SP segar memberikan dampak lingkungan yang terkecil.

ABSTRACT

Spirulina platensis (SP) is one of the microalgae sources of Phycocyanin (PC) which can function as an antioxidant, anti-cancer, and anti-inflammatory. *Spirulina platensis* was chosen because it contains much protein, lives in freshwater, and is easy to cultivate on a large scale. Various extraction methods of bioactive components from microalgae have been carried out. These include maceration, homogenization, ultrasonication, microwave, pulsed electric field, supercritical extraction, and freezing-thawing. So far, of the various methods, freezing-thawing has the advantage of maintaining product quality because PC must be stored at low temperatures (frozen). The regulation of water content in SP is the key to the success of cell wall disruption by freezing-thawing pretreatment. This research studied the effect of water content, freezing time, the ratio of solvent to biomass, and extraction equilibrium. This study also analyzed the freezing-thawing model numerically in the two-phase region. Finally, a life cycle assessment (LCA) is also carried out to identify the extraction process with the minor environmental impact.

The setting of water content was carried out in three ways, namely: 1) drying of fresh (wet) SP using an oven at a temperature of 30-60°C, 2) soaking wet SP, and 3) soaking SP powder. Then the SP was put in the freezer for a specified time (24 hours to 141 days), and thawing was carried out and filtered using a vacuum filter. The filtrate was analyzed for absorbance using a spectrophotometer at 615 and 652 nm wavelengths. The samples were placed in a 10 x 10 x 2 cm^3 stainless steel pan for the freezing-thawing model analysis. Samples of 1 cm thickness were measured for the temperature at the bottom, middle, and top positions, with a distance of 0.5 cm each. The tool was equipped with a temperature sensor and data recorder, which could record temperature data from the beginning of the cooling process, freezing, until the completion of thawing at room temperature. The extracted phycocyanin was also investigated for its antioxidant activity using the DPPH method (2,2-Diphenyl-1-picrylhydrazyl).

The results showed that water content greatly influenced the success of cell wall disruption through freezing-thawing pretreatment. Drying fresh (wet) SP in the oven at an optimum temperature of 50°C for 15 minutes resulted in optimum water content of 80.16% (wet basis), with an optimum yield of 84.21%. Immersion of SP powder for 6 hours obtained optimum water content of 81.9% on a wet basis (with a yield of 81.65%). Adding distilled water to wet SP tends to decrease the extraction yield. The duration of freezing after 24 hours had relatively no effect on the extraction results if the water content before the freezing process was the same. The greater the ratio of solvent to biomass made, the greater the yield and the optimum at 100 mL/g. The extraction equilibrium follows the Langmuir equation. Antioxidant activity was investigated using the DPPH method showing PC activity as an antioxidant. The extraction result from wet SP had an IC_{50} value of 2.783 mg/L, while it was 1.485 mg/L from SP powder. Numerical analysis of freezing-thawing modeling in the transition region was more suitable using Model 1: the freezing fraction (α) value was a linear function of the freezing temperature. The results of the LCA analysis using the OpenLCA 1.11.0 software showed that the freezing-thawing process of PC extraction from SP from fresh SP raw materials had a minor environmental impact.