

Pengembangan Katun Fungsional Berbasis Pewarna Alami Inti Batang Pisang Nipah (*Musa paradisica* ‘Nipah’) dan Nanopartikel Perak Melalui Teknik Iradiasi Microwave

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INTISARI

Kemajuan teknologi dan tuntutan keberlanjutan mendorong industri tekstil untuk mengembangkan alternatif pewarna ramah lingkungan sebagai pengganti zat warna sintetis. Salah satu sumber potensial ialah limbah inti batang pisang (IBP) *Musa paradisica* ‘Nipah’ yang mengandung senyawa kromofor. Penelitian ini bertujuan mengidentifikasi kandidat senyawa kromofor dominan dari ekstrak IBP, menganalisis pengaruh pelapisan kitosan dan iradiasi *microwave* terhadap performa pewarnaan katun, serta mengembangkan katun fungsional melalui sintesis *in situ* nanopartikel perak (AgNPs) berbantuan iradiasi *microwave*. Penelitian dilaksanakan dalam tiga tahap. Tahap pertama mengidentifikasi kandidat senyawa kromofor dominan hasil ekstraksi IBP menggunakan analisis fitokimia, spektrofotometri UV–Vis, FTIR, dan LC–HRMS. Tahap kedua melapisi katun dengan kitosan dan memberinya warna dengan ekstrak IBP menggunakan iradiasi *microwave* serta mengoptimasi prosesnya dengan *Response Surface Methodology* (RSM)-*Box–Behnken Design* (BBD). Tahap ketiga adalah melakukan sintesis *in situ* AgNPs pada katun berbantuan iradiasi *microwave* dan mengoptimasi prosesnya menggunakan RSM-BBD, dilanjutkan dengan karakterisasi material, evaluasi performa warna dan ketahanan warna, evaluasi aktivitas antibakteri, dan durabilitasnya.

Hasil penelitian menunjukkan bahwa ekstrak IBP nipah mengandung flavonoid ovalitenin C, ovalitenin A, 2'-hidroksifuran[2'',3'':4',3'] kalkon, dan 3',4'-metilendioksi-[2'',3'':7,8] furanoflavanon, serta senyawa fenolik tetrangulol, 3,4-dihidroksifitalat, asam protokatekuat, dan iso-debromo-laurinterol yang berpotensi sebagai kandidat kromofor dominan. Optimum pewarnaan diperoleh pada daya iradiasi 554 W, waktu 7,10 menit, dan konsentrasi kitosan 0,8%, dengan performa warna lebih baik daripada metode konvensional. Optimum sintesis *in situ* AgNPs diperoleh pada perbandingan AgNO₃-alginat 6:4, daya iradiasi 800 W, waktu iradiasi 6,70 menit, konsentrasi AgNO₃ 4,66 mM, dan konsentrasi alginat 0,65%. Katun termodifikasi menunjukkan aktivitas antibakteri yang sangat tinggi, yang ditunjukkan oleh persentase reduksi bakteri 100% terhadap *Staphylococcus aureus* dan *Escherichia coli* pada kondisi pengujian, serta tetap mempertahankan persentase reduksi bakteri >99,99% setelah 50 siklus pencucian. Hasil ini menunjukkan bahwa ekstrak IBP nipah berperan sebagai sumber kromofor alami, kitosan meningkatkan afinitas dan fiksasi zat warna pada katun, AgNPs memberikan fungsi antibakteri, dan iradiasi *microwave* meningkatkan efisiensi pewarnaan serta sintesis nanopartikel, sehingga secara sinergis mendukung pengembangan katun fungsional.

Kata kunci: kromofor, inti batang pisang, katun fungsional, nanopartikel perak, iradiasi *microwave*

Development of Functional Cotton Based on Natural Dye from Nipah Banana Floral Stem (*Musa paradisiaca* ‘Nipah’) and Silver Nanoparticles through the Microwave Irradiation Technique

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ABSTRACT

Technological advances and sustainability demands have driven the textile industry to develop environmentally friendly dye alternatives to replace synthetic colorants. One promising source is banana floral stem (BFS) waste of *Musa paradisiaca* ‘Nipah’, which contains chromophoric compounds. This study aimed to identify the candidate dominant chromophores in BFS extract, analyze the effects of chitosan coating and microwave irradiation on cotton dyeing performance, and develop functional cotton through microwave-assisted in situ synthesis of silver nanoparticles (AgNPs). The study was conducted in three stages. First, candidate dominant chromophores in the extract were identified using phytochemical analysis, UV–Vis spectrophotometry, FTIR, and LC–HRMS. Second, chitosan-coated cotton was dyed with the extract under microwave irradiation, and the dyeing process was optimized by Response Surface Methodology (RSM) with a Box–Behnken Design (BBD). Third, the microwave-assisted in situ synthesis of AgNPs on cotton was carried out and optimized using RSM-BBD, followed by material characterization, color performance, and color fastness evaluation, antibacterial assessment, and durability testing.

The results showed that the extract contained the flavonoids ovalitenin C, ovalitenin A, 2'-hydroxyfuran [2'',3'':4',3'] chalcone, and 3',4'-methylenedioxy-[2'',3'':7,8] furanoflavanone, as well as the phenolic compounds tetrangulol, 3,4-dihydroxyphthalate, protocatechuic acid, and iso-debromo-laurinterol, all of which were identified as potential candidate dominant chromophores. The optimum dyeing conditions were obtained at an irradiation power of 554 W, an irradiation time of 7.10 min, and a chitosan concentration of 0.8%, resulting in better color performance than the conventional method. The optimum conditions for the in situ synthesis of AgNPs were obtained at an AgNO₃-alginate ratio of 6:4, an irradiation power of 800 W, an irradiation time of 6.70 min, an AgNO₃ concentration of 4.66 mM, and an alginate concentration of 0.65%. The modified cotton exhibited high antibacterial activity, as evidenced by a 100% reduction in bacterial growth against *S. aureus* and *E. coli* under test conditions, and it maintained a bacterial reduction of over 99.99% after 50 washing cycles. These findings indicate that BFS extract serves as a natural chromophore source, chitosan enhances dye affinity and fixation on cotton, AgNPs impart antibacterial functionality, and microwave irradiation improves the efficiency of both dyeing and nanoparticle synthesis. Collectively, these components synergistically support the development of functional cotton.

Keywords: chromophore, banana floral stem, functional cotton, silver nanoparticles, microwave irradiation