

INTISARI

Pemanfaatan limbah pertanian untuk menghasilkan material berstruktur nano yang ramah lingkungan semakin mendapat perhatian, terutama dalam mendukung pengembangan material komposit. Kulit durian, yang merupakan limbah organik dengan kandungan selulosa tinggi (68%) dan ketersediaan melimpah, memiliki potensi untuk dimanfaatkan sebagai bahan baku *cellulose nanocrystal* (CNC). Penelitian ini bertujuan untuk memproduksi CNC dari limbah kulit durian melalui optimasi proses oksidasi menggunakan *ammonium persulfate* (APS) serta mempelajari karakteristik CNC yang dihasilkan. Selain itu, penelitian ini juga mengevaluasi pengaruh penambahan CNC sebagai penguat pada komposit hibrid poliester/serat rami untuk meningkatkan sifat fisis, mekanis, dan termal komposit.

Pada penelitian ini, limbah kulit durian digunakan sebagai sumber selulosa untuk pembuatan CNC, serat rami digunakan sebagai material penguat, dan resin poliester digunakan sebagai matriks komposit. Penelitian ini dibagi menjadi empat tahapan. Tahap pertama difokuskan pada pembuatan CNC kulit durian dengan metode oksidasi APS. Tahap kedua, penelitian difokuskan pada perlakuan kimia (alkali, esterifikasi, dan gabungan alkali-esterifikasi) pada serat rami. Karakteristik dan sifat tarik tarik serat rami yang telah diberi perlakuan kimia dievaluasi melalui FT-IR, XRD, TGA sedangkan sifat tarik ditentukan menggunakan uji tarik. Tahap ketiga dilakukan kajian pengaruh perlakuan permukaan pada komposit serat rami searah dengan matriks poliester. Setelah diperoleh CNC dengan karakteristik terbaik dan serat rami termodifikasi dengan kekuatan tarik tertinggi, kedua penguat ini kemudian ditambahkan pada matriks poliester dengan proses *vacuum infusion* yang merupakan fokus penelitian tahap keempat. Sifat mekanis komposit hibrid polyester/serat rami searah/CNC dievaluasi melalui uji tarik, uji lentur, uji impak, dan uji *interlaminar shear strength*.

Hasil penelitian tahap pertama menunjukkan bahwa CNC berhasil diisolasi menggunakan metode oksidasi APS. CNC yang dihasilkan berbentuk seperti jarum dan memiliki lebar 5,00-7,81 nm, panjang 114,52-126,83 nm, dan *aspect ratio* 16,76-24,20, dan indeks kristalinitas 88%. Kondisi optimal proses oksidasi yang menghasilkan indeks kristalinitas maksimum dan stabilitas termal tertinggi diperoleh pada suhu oksidasi 80°C dengan 1 M APS. Hasil penelitian tahap kedua menunjukkan perlakuan kimia (alkali, esterifikasi, dan gabungan alkali-esterifikasi) terbukti mempengaruhi sifat dan karakteristik serat rami. Perlakuan kombinasi alkali dan asam oksalat memberikan hasil terbaik dalam melarutkan sebagian daerah *amorf* dengan peningkatan kuat tarik yang signifikan sebesar 136,10 %. Morfologi serat dengan perlakuan alkali, esterifikasi, dan gabungan alkali-esterifikasi menunjukkan defibrilasi dan hilangnya kontaminan pada permukaan serat yang menjadi penyebab diameter serat semakin kecil, yang meningkatkan luas permukaan kontak dan memperbaiki sifat antarmuka serat alam dan matriks polimer. Hasil penelitian tahap ketiga mengungkapkan perlakuan kimia (alkali, esterifikasi, dan gabungan alkali-esterifikasi) pada serat terbukti mempengaruhi sifat mekanik, termal, penyerapan air, dan morfologi komposit poliester/serat rami searah. Perlakuan gabungan alkali-esterifikasi yang diaplikasikan pada serat menaikkan sifat mekanik komposit poliester/serat rami dengan kenaikan kekuatan tarik, modulus tarik, kekuatan lentur, modulus lentur, ILSS, dan kekuatan impak

masing-masing sebesar 36,19%; 22,34%; 49,42%; 95,71%; 56,06%; dan 83,90%. Hasil pengujian TGA memperlihatkan perlakuan kimia pada serat memperbaiki stabilitas termal komposit poliester/serat rami. Pengujian SEM mengungkapkan perlakuan kimia pada serat dapat memperbaiki antarmuka serat dan matriks dimana terdapat pengurangan gap antara kedua material tersebut. Penelitian tahap terakhir membahas tentang pengaruh penambahan CNC (0; 0,5; 0,75; dan 1 wt.%) pada komposit poliester/serat rami dimana serat telah diberi perlakuan gabungan alkali-esterifikasi sebelumnya, sebagai hasil optimal pada tahap penelitian ketiga. Penambahan 0,75 wt.% CNC terbukti menaikkan sifat mekanik komposit poliester/serat rami dengan kenaikan kekuatan tarik, modulus tarik, kekuatan lentur, modulus lentur, ILSS, dan kekuatan impak masing-masing sebesar 27,23%; 33,12%; 39,41%; 84,56%; 31,91%; dan 49,52%. Morfologi patahan uji tarik komposit memperlihatkan adanya gap yang terisi oleh CNC pada antarmuka matriks dan serat yang menandakan perbaikan sifat antarmuka kedua material tersebut.

Kata kunci: *cellulose nanocrystal*, kulit durian, *ammonium persulfate*, serat rami, poliester

ABSTRACT

The utilization of agricultural waste to produce environmentally friendly nanostructured materials has gained increasing attention, particularly in supporting the development of composite materials. Durian peel, an organic waste with a high cellulose content (68%) and abundant availability, has the potential to be used as a raw material for cellulose nanocrystals (CNC). This study aims to produce CNC from durian peel waste by optimizing the oxidation process using ammonium persulfate (APS) and to investigate the characteristics of the resulting CNC. Additionally, this research also evaluates the effect of adding CNC as a reinforcement in polyester/ramie fiber hybrid composites to enhance the physical, mechanical, and thermal properties of the composite.

In this research, durian peel waste was used as a source of cellulose for extracting CNC, ramie fiber was used as a reinforcing material, and polyester resin was used as a composite matrix. This research was divided into four stages. The first stage focused on isolating CNC durian peel using the APS oxidation method. In the second stage, the research was focused on the chemical treatment (alkali, esterification, and combined alkali-esterification) on ramie fiber. The characteristics and tensile properties of chemically treated ramie fiber were evaluated via FT-IR, XRD, TGA while the tensile properties were determined using a tensile test. The third stage was carried out to investigate the surface treatment effects on the unidirectional ramie fiber/ polyester matrix composite. After obtaining CNC with the best characteristics and modified ramie fiber with the highest tensile strength, these two reinforcements were then added to the polyester matrix using a vacuum infusion process which was the focus of the fourth stage of research. The mechanical properties of the unidirectional polyester/ramie fiber/CNC hybrid composite were evaluated through tensile tests, bending tests, impact tests, and interlaminar shear strength tests.

The results of the first stage of research show that it has succeeded in producing CNC made using the APS oxidation method. The resulting CNCs were needle-like and had a width of 5.00-7.81 nm, a length of 114.52-126.83 nm, and an aspect ratio of 16.76-24.20, and a crystallinity index of 88%. Optimal oxidation process conditions that produce maximum crystallinity index and highest thermal stability are obtained at an oxidation temperature of 80°C with 1 M APS. The results of the second stage of research showed that chemical treatments (alkali, esterification, and combined alkali-esterification) was proven to influence the properties and characteristics of ramie fiber. The combination treatment of alkali and oxalic acid gave the best results in dissolving some of the amorphous materials there was a significant increase in tensile strength of 136.10%. The morphology of the fibers after chemical treatments (alkali, esterification, and combined alkali-esterification) showed defibrillation and loss of contaminants on the fiber surface which caused the fiber diameter to become smaller, which increased the contact surface area and improved the interfacial properties of natural fibers and polymer matrices. The results of the third stage of the study revealed that chemical treatments (alkali, esterification, and combined alkali-esterification) on the fibers were proven to affect the mechanical, thermal, water absorption, and morphological properties of unidirectional polyester/ramie fiber composites. The combined alkali-esterification treatment applied to the fibers increased the

mechanical properties of the polyester/ramie fiber composites with an increase in tensile strength, tensile modulus, flexural strength, flexural modulus, ILSS, and impact strength of 36.19%; 22.34%; 49.42%; 95.71%; 56.06%; and 83.90%, respectively. The results of the TGA test showed that chemical treatment on the fibers improved the thermal stability of the polyester/ramie fiber composites. SEM evaluation revealed that chemical treatment of fibers can improve the fiber and matrix interface where there is a reduction in the gap between the two materials. The final stage of research discussed the effect of CNC addition (0; 0.5; 0.75; and 1 wt.%) on polyester/ramie fiber composites where the fibers had been applied a combined alkali-esterification treatment beforehand, as the optimal result in the third stage of research. The addition of 0.75 wt.% CNC was proven to increase the mechanical properties of polyester/ramie fiber composites with an increase in tensile strength, tensile modulus, flexural strength, flexural modulus, ILSS, and impact strength of 27.23%; 33.12%; 39.41%; 84.56%; 31.91%; and 49.52%, respectively. The fracture morphology of the composite tensile test shows the presence of gaps filled by CNC at the matrix and fiber interface, indicating an improvement in the interfacial properties of the two materials.

Keywords: *cellulose nanocrystal, durian peel, ammonium persulfate, ramie fiber, polyester*