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作品名稱　Synthesis of Nanocomposite Nanocellulose From Durio zibethinus L. and TiO2 NPs as Potential Food Packaging Antibacterial (E. coli Wild Type and Resistance)

得獎獎項　成就證書

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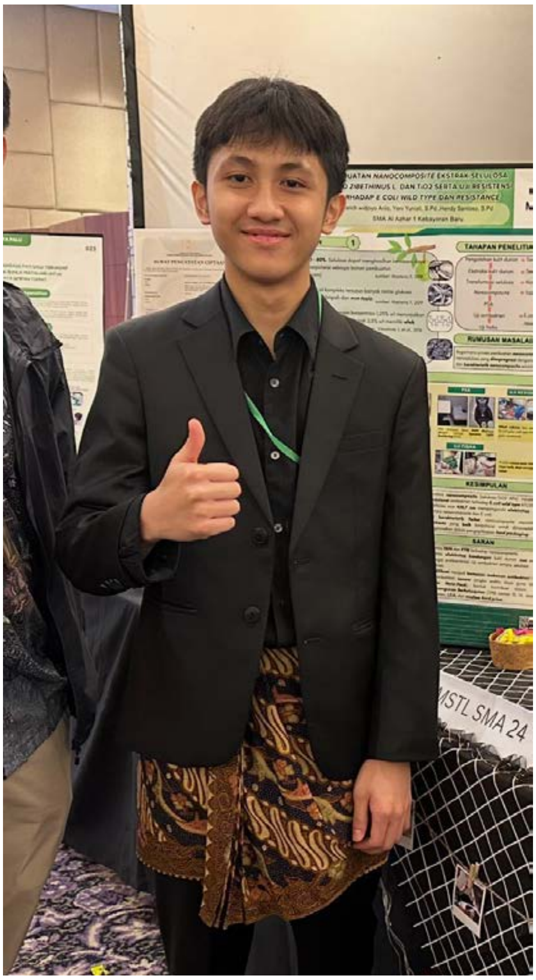
關鍵詞　Nanocellulose、TiO2 NPs、Nanocomposite、E. coli、Durio Nano-Pack

作者照片



Synthesis of Nanocomposite Nanocellulose From *Durio zibethinus* L. and TiO_2 NPs as Potential Food Packaging Antibacterial (*E. coli* Wild Type and Resistance)

「奈米纖維素奈米複合材料的合成 從“**Durio zibethinus L** 和 **TiO_2 NPs**”作為潛在的食品包裝抗菌劑

”E. Coli Wild Type 和 **Resistance”**

Synthesis of Nanocomposite Nanocellulose From *Durio zibethinus* L. and TiO_2 NPs as Potential Food Packaging Antibacterial (*E. coli* Wild Type and Resistance)

INDONESIA

According to the Indonesian Association of Olefin Aromatic and Plastic Industries/INAPLAS, 2019 national plastic consumption still relies on plastic packaging at 65% and surprisingly, around 60% of plastic waste is absorbed by the food and beverage industry. The waste has been widely sought to be environmentally friendly, one of which is by developing biodegradable packaging. The purpose of this research is to make durian peel cellulose nanocomposites impregnated with TiO_2 NPs, to form antibacterial properties against *E. coli* wild type and resistance. In this research, there are research methods consisting of nanocomposite synthesis, PSA test, FTIR, physical characteristics test and resistance test. The results analyzed that the nanocomposite nanocellulose-TiO_2 NPs was successfully made using a 1:1 ratio and had a particle size of 458.7 nm based on the PSA test, which is classified as a nano size. The success of nanocomposite synthesis was proven by the results of FTIR analysis, which showed the formation of 698.65 cm^{-1} and 1633.99 cm^{-1} spectra, indicating the peak of TiO_2 NPs and O-H functional groups on TiO_2 NPs, as well as 1028.98 cm^{-1} and 1158.42 cm^{-1} showing C-O and C-O-C bonds in cellulose. The antibacterial test performed showed no significant activity in disc diffusion and well diffusion tests against *E. coli* wild type and resistance. This is potentially caused by inhomogeneous particle size variation. Physical characteristics test showed that the tensile strength test (0.075 > 0.0125 MPa) Durio Nano-Pack is superior to styrofoam, but the compressive strength test (0.125 > 0.875 MPa) shows the opposite. In this study, nanocomposite has a potential innovation that provides good mechanical properties and has a dual function mechanically as bio-based food packaging and chemically as antibacterial. Further research is needed to improve the particle size homogeneity of nanocomposites, modify the impregnation method, so that it has the potential to develop multifunctional materials that excel in various applications.

Keywords: Nanocellulose, TiO_2 NPs, Nanocomposite, *E. coli*, Durio Nano-Pack,

1. INTRODUCTION

According to the Indonesian Association of Olefin Aromatic and Plastic Industries/INAPLAS, 2019 national plastic consumption still relies on plastic packaging at 65% and surprisingly, around 60% of plastic waste is absorbed by the food and beverage industry. Such is the projection of plastic waste in Indonesia.

It was recorded in 2017-2024 that there were 9.8 million tons of plastic bags in Indonesia every year [1]. Consumption of plastic goods because it has various advantages such as flexible, malleable, transparent, unbreakable, and relatively cheap price [1]. However, this will have a harmful effect on living things as well as the environmental ecosystem. Packaging made of strong and durable materials can protect the product from damage during the transportation process and storage until it reaches the hands of consumers [2].

According to the World Trade Organization (WTO), packaging is an integrated system to preserve and prepare products until they are ready to be distributed to consumers in easily and efficiently way. Nanyang Technological University (NTU) and Harvard TH Chan School of Public Health research team; antibacterial food packaging can be a futuristic solution to overcome food waste problems, reduce environmental pollution, preserve ecosystems wordy to maintain natural balance, human health and improve food quality [3]. Durian peel extract polysaccharide gel has antimicrobial activity against Escherichia coli, Staphylococcus aureus, Candida albicans, and Staphylococcus cerevisiae [4].

However, cellulose is not enough to be a strong packaging as it is still susceptible to damage, especially by bacteria. Therefore, composting with other materials is necessary. Titanium dioxide (TiO_2) is a metal that has low toxicity and is reported to have antibacterial properties. Cellulose-TiO_2 nanocomposite has antibacterial activity which has an inhibition zone value of 14 mm and 13 mm [4]. Based on these facts and citations, researchers conducted research in several stages; processing durian peel to extract cellulose, impregnated with TiO_2 in the manufacture of nanocomposites, PSA tests, antibacterial tests and physical characteristics tests and applied them into nanocomposites in the form of Durio Nano-Pack. To further test its antibacterial strength, researchers conducted resistance tests on *E. coli* wild type and resistance in order to get a further picture of the antibacterial ability of the material made.

Table 1. State of art literature review

Number	Name and Year of Research	Process	Similarity	Difference
1.	Zacarich Widjoyo Arilo, 2023	Processing durian skin into art paper	Conducted physical examination. Using organic waste that has high cellulose.	No LCA/biodegradable, Packaging durability process (cellulose function as an alternative to art paper), Durian peel specifications.
2.	Yusup Subagio Sutanto1, Agnes Sri Harti2, Nony Puspawati3, Magdalena, 2022	Diffusion method	Antimicrobial testing of S. aureus ATCC 25923, Bacillus subtilis ATCC 6633, E. coli ATCC 25922, Salmonella typhi ATCC 13311, Pseudomonas aeruginosa ATCC 27853.	Using Polysaccharide Gel (PG) and Chitosan Gel (CG) from durian skin.
3.	Klaudia Maślana, Anna Żywicka, Karolina Wenelska, Ewa Mijowska, 2021	Mixture of two kind of fibers, SEM, FTIR, determination of Antibacterial Activity (MIC) and (MBC).	Cellulose/TiO_2 nanoparticles as anti-bacterial E. coli (gram negative bacteria) and S. aureus (gram positive bacteria).	Analyzed by Scanning Electron Microscope (SEM) and FTIR.
4.	M.V. Arularasu, M. Harb, R. Sundaram, 2020	FTIR, TEM, Screening for antibacterial activity (MIC) and (MBC).	Cellulose/TiO_2 nanocomposites. Analysis of antibacterial activity against E.coli.	Docking studies analysis. TiO_2 and cellulose/ TiO_2 nanocomposite ukuran 400−500 nm
5.	Lubna Abdulazeem, BahaHamdi Hakim AL-Amiedi, Hadeel Alana Alrubaei, Yasir H. AL-Mawlah, 2021	FTIR, antibacterial activity (MIC) and (MBC), X-Ray diffraction.	Nanoparticles size, Antibacterial activity analysis against E.coli.	X-Ray *diffraction*, FTIR.

Nanocomposite manufacturing process method: starting from the manufacture of nanocellulose with the stages of acid hydrolysis, bleaching, nano-transformation, and combining the two materials [5], has examined nanocellulose and TiO_2 NPs using the method (antimicrobial activity MIC, MBC) and the same nanocomposite comparison. Novelty: innovation in the manufacture of food packaging (Durio Nano-Pack) based on cellulose from durian peel waste, and physical tests were carried out, namely; thickness, attractiveness, and absorbency.

1.1. Durian Peel Cellulose

One durian fruit will produce 60 - 80% of its peel, 50 - 60% cellulose, lignin and starch each by 5%, tannins, alkaloids, flavonoids, saponins, and triterpenoids as antibacterial compounds [6,7]. The high content of cellulose can produce packaging with high tear resistance so it has great potential as a basic material for making Biodegradable Foam (Biofoam). Food Engineering and Postharvest Technology Research Department, Agricultural Engineering Research Institute states that; various polymers obtained from agricultural products are very suitable to be formulated as basic materials for making food packaging. These polymers like polysaccharides can be used in various forms such as coatings, films, composites and nanocomposites. Cellulose is one of the most abundant polysaccharides on earth and is non-toxic with an attractive combination of different properties [6-8]. However, the efficient use of cellulose as a raw material for packaging is rational and a subject that should be considered [9, 29]. Cellulose extracted from durian peel waste has good purity so it can be applied as an environmentally friendly food wrapping clear coat [10, 27]. Other contents such as lignin 15.45%, hemicellulose 73.45% and α-cellulose 60.45% [12, 13]. Journal of Chemical Engineering and Environment explained that the polysaccharide gel contained in durian peel with a concentration of 1.25% wt. Showed an inhibitory effect on staphylococcus aureus bacteria, while the 2.5% wt. Extract had the same effect on *E. coli* [14,15]. Characterization of nanocomposites is essential during the development stage to obtain materials with desired properties for food packaging applications [16,17]. Some important characteristics of nanocomposite materials are morphology, thermal properties, functional groups, mechanical properties, UV-blocking efficiency, and barrier properties. The source of nanoparticles and other materials used in the formulation of nanocomposites has the most influence on the properties of the developed materials. Nanocellulose is stable, non-toxic, renewable, highly flexible, strong, non-rigid, and biodegradable [12, 13, 22].

1.2. *E. coli* Bacteria

Infection-causing bacteria are mostly due to the presence of *E. coli* and Staphylococcus aureus bacteria [11]. *E. coli* bacteria (-), generally living in the human intestine, is the cause of diarrheal disease [23]. This is in line with the opinion of [17], that when bacteria enter the blood circulation, they can spread to other organs and cause infection and death. The main processes underlying the antibacterial effect of Nanoparticles (NPs) are; disruption of the bacterial cell membrane, formation of Reactive Oxygen Species (ROS), penetration of the bacterial cell membrane, and induction of intracellular antibacterial effects, including interactions with DNA and proteins [18-20,30].

1.3. Titanium Dioxide Nanoparticles (TiO_2 NPs)

TiO_2 NPs support the inactivation of microorganisms due to their strong oxidizing power by the generation of free radicals, such as hydroxyl radicals and superoxide anions, which showed growth reduction against some microorganisms, such as Escherichia coli [19, 26]. TiO_2 NPs have gained attention because they have important benefits as food additives, food safety, allergy prevention and hazard-free, the nanoparticles are relatively affordable to produce and have antimicrobial and photocatalytic activities [20]. TiO_2 NPs cannot penetrate the human dermis, even when the particle size is smaller than 100 nm [21, 28]. TiO_2 NPs that successfully penetrate the peel do not show toxicity under certain conditions [21,25].

2. RESEARCH METHOD

2.1. Research Design

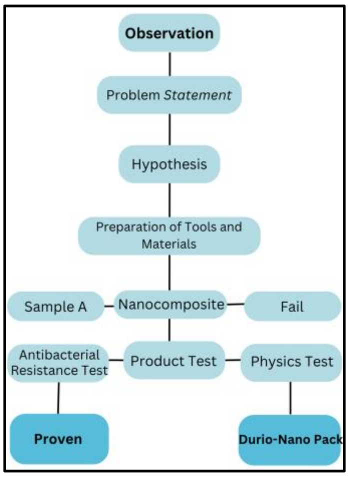


Figure 2. Experimental design

Stages of the experimental method.

Potential Problems

a. The initial stage is to identify the problem of utilizing durian peel cellulose and TiO_2 NPs.

b. Data and Information Collection

After identifying existing problems NPs as potential antibacterial food packaging (*E. coli* Wild Type and Resistance).

c. Product Design

Researchers carry out planning in making product designs referring to existing journals. After that, conduct antibacterial tests, test physical characteristics and then consult with the research supervisor.

d. Product Design Validation

Product design validation requires experts and research supervisors.

e. Design Revision

After completing the validation design and getting input from experts. The next step is improvement.

2.2. Research Variables

The dependent variable is antibacterial properties against *E. coli* wild type and resistance, physical characteristics. Nanocomposite independent variable.

2.3 Research Procedure

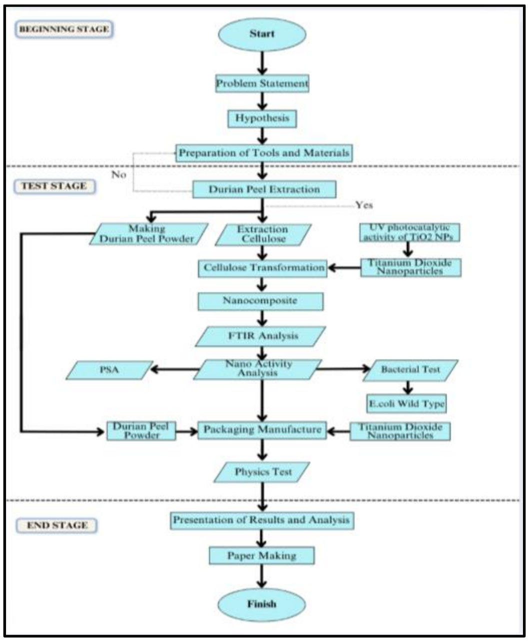


Figure 3. Research procedure

2.4. Tools

500 ml beaker, spatula, 100 ml measuring cup, stirring rod, dropper pipette, particle size analyzer (PSA) centrifuge bottle, digital balance vial, dynamometer, petri dish, micropipette, test tube, centrifuge, petri dish, filter cloth, hot plate stirrer, oven, well plate, litmus paper, thermometer, ohaus balance, sonicator, freeze drying.

2.5 Materials

Durian peel, NaOH solids, H_2SO_4 (Sulfuric Acid) solution, NaoCl 2.5%, Titanium Dioxide Nanoparticles (TiO_2 NPs), phosphate saline buffer (PBS buffer 7.4), distilled water, agar media, *E. coli*, tapioca powder, distilled water, DMF (Dimethylformamide), urea, NH_4OH, ethanol.

2.6 Preparation and Processing of Durian Peel into Powder

Preparing durian peel; cleaned, cut into smaller parts. Perform drying to remove water content, then puree using a blender until powder texture [38].

2.7 Extraction of Durian Peel Cellulose

Through 2 stages namely; alkaline hydrolysis and bleaching process [31].

2.8 Transformation of Durian Peel Cellulose

Using a suspension centrifuged for 10 minutes at speed of 8000 rpm and resulting precipitate was dialyzed with distilled water. Furthermore, the suspension was sonicated for 20 minutes and dried again in the oven at 60°C for 24 hours [5, 28].

2.9 Titanium Dioxide Nanoparticles (TiO_2 NPs)

Researchers get TiO_2 NPs material from Nanomaterials for Renewable Energy.

2.10 Determining the Composition of Nano Cellulose with TiO_2 NPs

Mix nano cellulose extract with TiO_2 NPs in a ratio of 1: 1, referring to research that has been done [2].

2.11 Nanocomposite Process (Nano Cellulose-TiO_2 NPs)

A 1:1 ratio of nano cellulose and TiO_2 NPs was used to make cellulose-TiO_2 NPs nanocomposite. NH_4OH solution: Dimethylformamide (DMF): H2O: urea namely; 25 : 25 : 25 : 25 moles [5].

2.12 PSA Test (Particles Size Analyzer)

Measurement of particle size with PSA Zetasizer Nano ZS90 Malvern with Dynamic Light Scattering (DLS) method [34].

2.13 Antibacterial Activity Test

2.13.1 Disc Diffusion and Well Diffusion

Preparation of bacterial suspensions (*E. coli* wild type strain ATCC 35218 and resistance strains) equivalent to 0.5 McFarland on 5 ml MHB media [5, 36].

2.13.2 MIC (Minimum Inhibitory Concentration)

Using the microdilution method, starting with the preparation of a suspension of *E. coli* bacteria wild type ATCC 35218 and resistance strains in Mueller Hinton Broth (MHB) liquid media as much as 5 ml [5, 36].

2.14. Physical Characteristic Test

2.14.1 Thickness

The thickness value was obtained by measuring the thickness of the sample at five different points using a screw micrometer and then dividing the result by 5 [35].

2.14.2 Density

ρ is density (n/cm^3), m is mass (grams), divided by V is volume (cm^3). The density value of the Durio Nano-Pack produced uses the unit of g/cm^3 [36].

2.14.3 Tensile strength

Using a dynamometer/spring reader to determine the area of the research object being tested. The formula is found in equation (1).

$$F = \frac{P}{A} \quad (1)$$

Details:

F = tensile strength (MPa)

P = starting weight (N)

A = test weight after submersion (mm^2)

2.14.4 Absorbency

Analyze the amount of air voids present in the composite. By forming the sample in the form of 2 × 2 cm pellets. Then, the initial weight of the sample is weighed and immersed in water for 1 minute. The formula is found in equation (2).

$$\text{Water } (\%) = \left[\frac{W-Wo}{Wo}\right] \times 100\% \quad (2)$$

Details:

A = water absorption (%)

Wo = original weight (gram)

W = test weight after immersion (gram) [37]

2.14.5 Compressive Power

The compressive force acting on one unit of surface area subjected to compressive force using a mass cylinder as a mass weight. Using 6 x 2 cm as an experimental sample, the calculation uses units of gr and MPa.

3. RESULT AND DISCUSSION

Results and discussion using seven stages of research, as follows;

3.1. Characterization of Nano Cellulose - TiO_2 NPs

3.1.1 Durian Peel Processing Process

Durian peels are cut smaller, washed and dried in an oven at 120°C, then the durian peels are ground to produce durian peel powder and stored in a clean, dry, and closed package.

3.1.2 Durian Peel Cellulose Extraction Process

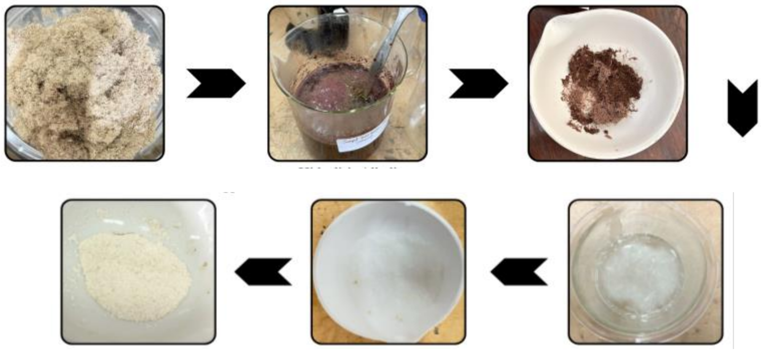
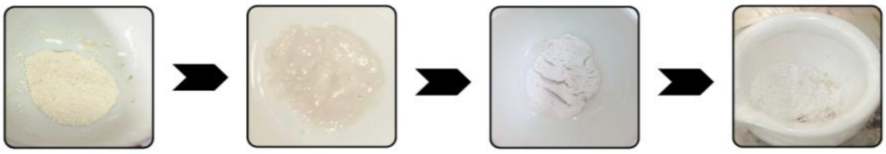


Figure 4. Research samples. (a) durian peel powder, (b) 4M NaOH alkaline hydrolysis, (c) alkaline hydrolysis, (d) 2.5% NaCl bleaching, (e) heating, (f) cellulose powder

Cellulose extraction goes through the stages of alkaline hydrolysis and bleaching, to remove compounds other than cellulose. Get the final result of cellulose powder as much as 30 grams.

3.1.3 Transformation of Cellulose Extract into Nanoparticles



(a) (b) (c) (d)

Figure 5. Research samples. (a) cellulose powder, (b) cellulose nano liquid, (c) and (d) cellulose nano powder

The cellulose powder was resized into nanoparticles using centrifugation and sonication, resulting in 5 g of nanocellulose.

3.1.4 Measurement Table

Durian Skin Powder	Alkaline Hydrolysis	Wet Bleaching	Dry Bleaching	Cellulose Nano Precipitate	Nanocellulose
100 g	70 g	50 g	30 g	15 g	5 g

The formula for the ratio of nano cellulose extract (MOH, 2000) is as follows.

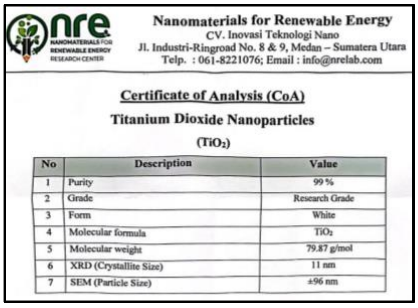
$$\boxed{\frac{Extract\ weight}{Raw\ material\ weight} \text{ x } 100\%}$$

↓

Durian Skin Powder	Alkaline Hydrolysis	Wet Bleaching	Dry Bleaching	Cellulose Nano Precipitate	Nanocellulose
71,42%	70%	71,42%	60%	50%	33,33%

3.1.5 Titanium Dioxide Nanoparticles (TiO_2 NPs)

Figure 6. TiO_2 NPs



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Certificate of Analysis (CoA)

Titanium Dioxide Nanoparticles

(TiO_2)

No	Description	Value
1	Purity	99 %
2	Grade	Research Grade
3	Form	White
4	Molecular formula	TiO_2
5	Molecular weight	79.87 g/mol
6	XRD (Crystallite Size)	11 nm
7	SEM (Particle Size)	±96 nm

Figure 7. Analysis of TiO_2 NPs

Certificate of Analysis (COA); 99% purity, grade; research grade, molecular weight: 79.87g/mo, Crystallite Size (XRD): 11 nm, Particle Size (SEM): 96 nm.

3.1.6 Proses Nanocomposite (Nano Selulosa–TiO_2 NPs)

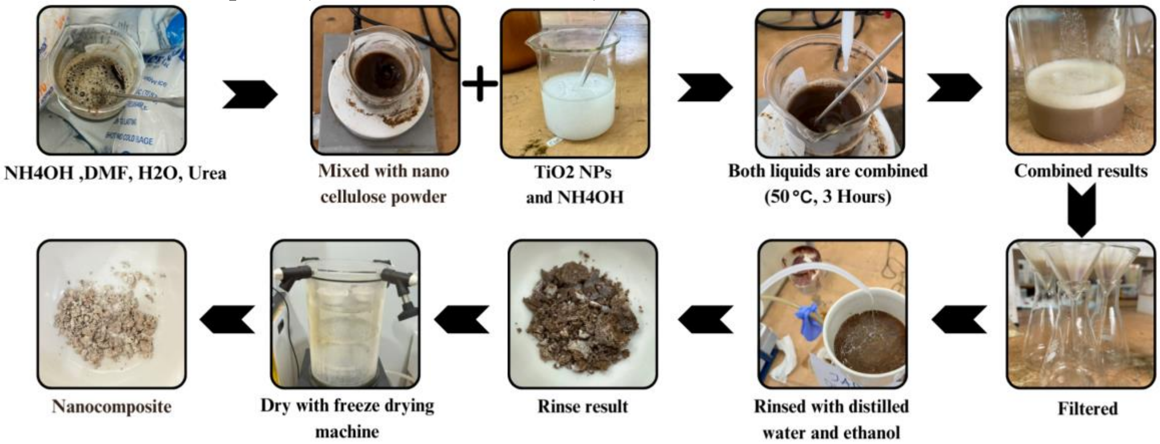

Figure 9. Nanocomposite process

The nanocomposite process combines TiO_2-NH_4OH liquid with nanocellulose. Followed by the process of filtering, rinsing, and drying using freeze drying. The final result is a nanocomposite, as much as 2 gr [5].

3.1.7 Fourier-Transform Infrared Spectroscopy (FTIR)

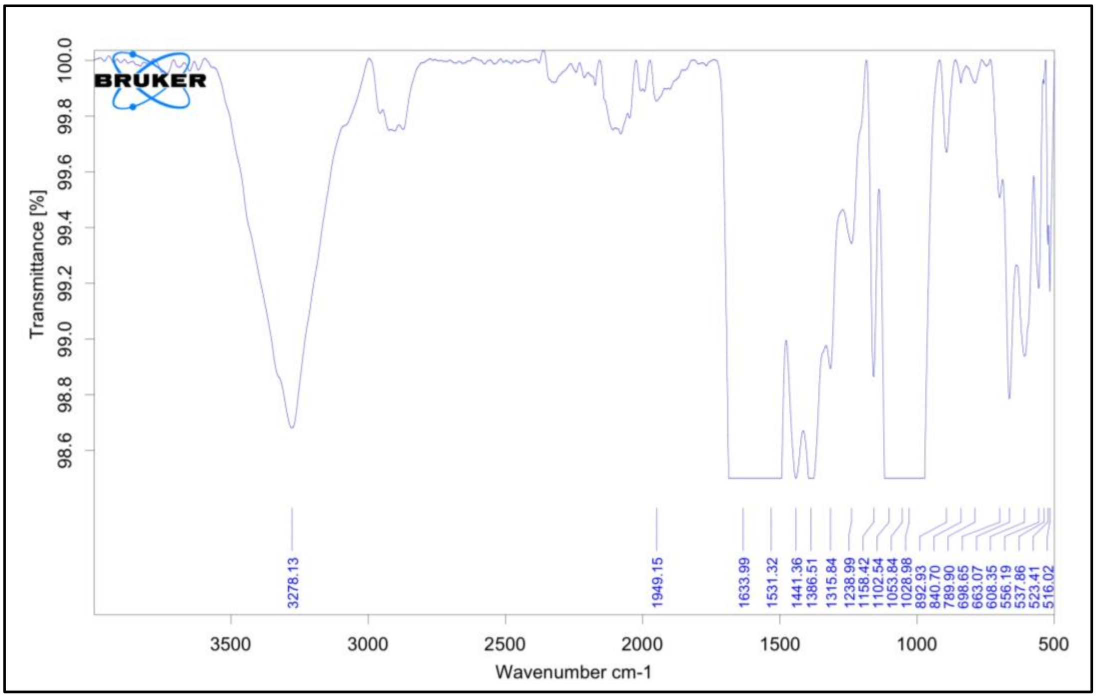

Figure 10. Analysis of FTIR Transmittance (98.6-100)

The FTIR spectrum of the nanocomposite shows various peaks as seen in Figure 10. There is a peak at 698.65 cm^{-1} for the TiO_2 NPs and 1633.99 cm^{-1} is O-H. This value is close to the TiO_2 NPs peak value of 690.52 cm^{-1} and 1631.78 cm^{-1} for the O-H bending vibration, which represents water as water vapor [39].

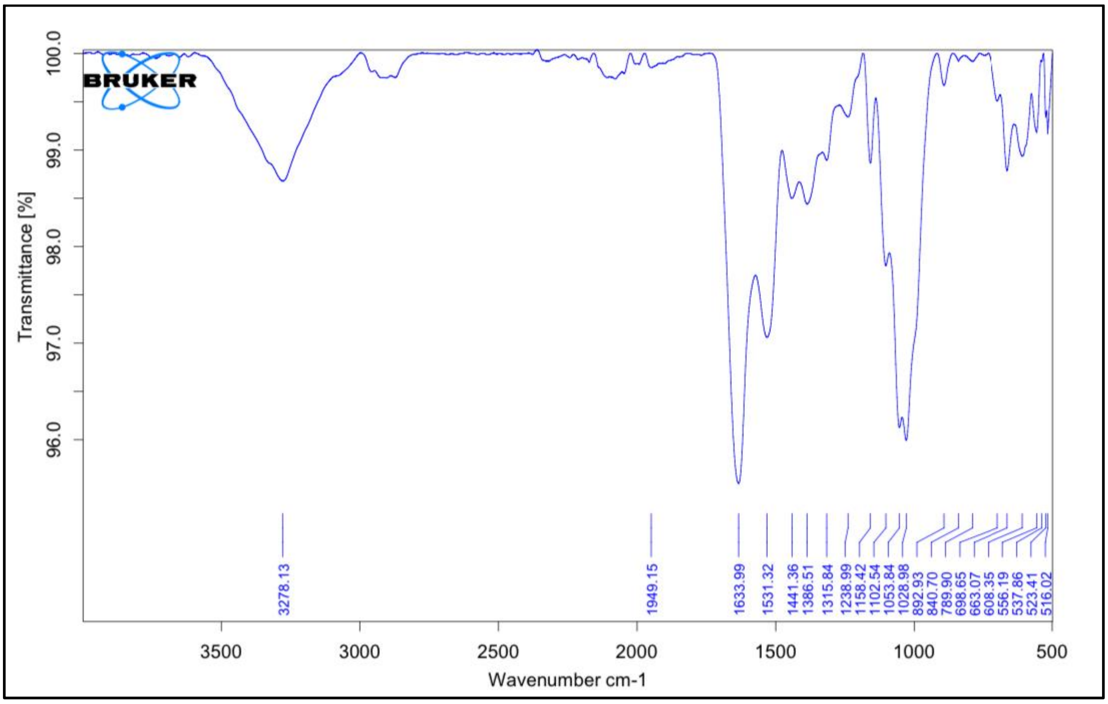

Figure 11. Analysis of FTIR (96-100)

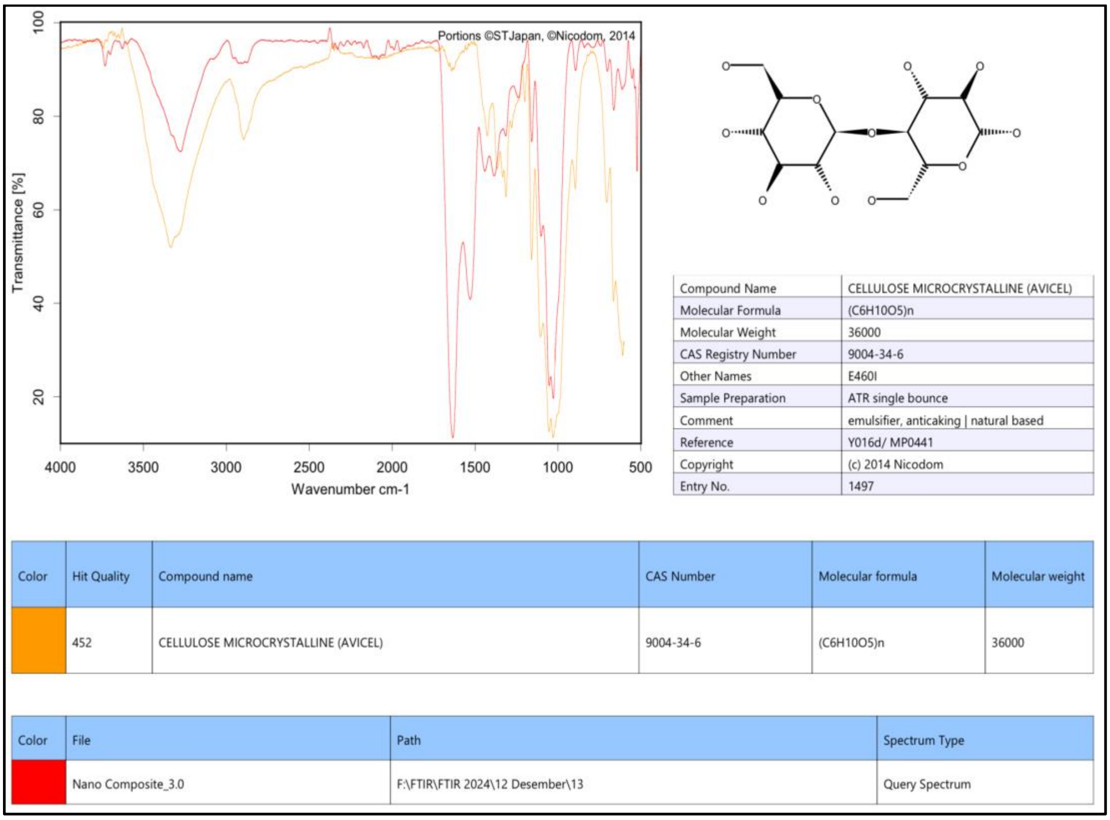

Figure 12. Cellulose in nanocomposite

In the nanocomposite there is a spectrum that is similar to cellulose which indicates the content of cellulose in the nanocomposite, as seen in Figure 12. There is a peak at 1028.98 cm^{-1} as C-O and 1158.42 cm^{-1} is C-O-C as seen in Figure 11. This value is similar to the peak of C-O and C-O-C functional groups of cellulose at 980 cm^{-1} and 1160 cm^{-1} [21].

3.1.8 Particles Size Analyzer (PSA)

Table 2. PSA Analysis with 3 parameters by intensity number and volume

Cumulant Results		Distribution Results	Size (d.nm):	% Vol	σ	%Pd	Undersize Results	
							Dv (%)	Size (d.nm):
Z-Avg (nm):	569.1							
Pd Index:	0.518	Peak 1:	459.9	100.0	115.6	25.1	10	313
Pd (nm):	409.7	Peak 2:	0.000	0.0	0.000	0.0	50	449
%Pd:	72.0	Peak 3:	0.000	0.0	0.000	0	90	627
Derived kcps:	3746.7						100	955

Size d.nm	Mean Volume Percent	Std Dev Volume Percent	Size d.nm	Mean Volume Percent	Std Dev Volume Percent	Size d.nm	Mean Volume Percent	Std Dev Volume Percen
0.4000	0.0		13.54	0.0		458.7	21.9	
0.4632	0.0		15.69	0.0		531.2	18.9	
0.5365	0.0		18.17	0.0		615.1	11.7	
0.6213	0.0		21.04	0.0		712.4	4.4	
0.7195	0.0		24.36	0.0		825.0	0.8	
0.8332	0.0		28.21	0.0		955.4	0.0	
0.9649	0.0		32.67	0.0		1106	0.0	
1.117	0.0		37.84	0.0		1281	0.0	
1.294	0.0		43.82	0.0		1484	0.0	
1.499	0.0		50.75	0.0		1718	0.0	
1.736	0.0		58.77	0.0		1990	0.0	
2.010	0.0		68.06	0.0		2305	0.0	
2.328	0.0		78.82	0.0		2669	0.0	
2.696	0.0		91.28	0.0		3091	0.0	
3.122	0.0		105.7	0.0		3580	0.0	
3.615	0.0		122.4	0.0		4145	0.0	
4.187	0.0		141.8	0.0		4801	0.0	
4.849	0.0		164.2	0.0		5560	0.0	
5.615	0.0		190.1	0.0		6439	0.0	
6.503	0.0		220.2	0.4		7456	0.0	
7.531	0.0		255.0	2.4		8635	0.0	
8.721	0.0		295.3	6.8		1.000e4	0.0	
10.10	0.0		342.0	13.2				
11.70	0.0		396.1	19.4				

PSA analysis of nanocellulose–TiO_2 NPs nanocomposite, shows the conjugation of nanocellulose with TiO_2 NPs produces ultra structure (nanocellulose–TiO_2 NPs) with a size range of 220.2 - 825.0 nm with 458.7 nm as the most dominant size. Can be interpreted; nanocomposite size 458.7nm that will interact with bacteria.

3.1.9 Physical Characteristics Test

a. Thickness Test

The average thickness measurement results, obtained from 5 points on Durio Nano-Pack measuring 3 x 3 cm have a value of 4.542 cm. Calculation of measurement error on the thickness of Durio Nano-Pack 4.542 cm + 0.207 cm.

Table 3. Thickness of Durio Nano-Pack

Number	Thickness Value	X^2
1	4,97	24,7
2	4,43	19,625
3	3,99	15,92
4	5,22	27,248
5	4,10	16,81
Σ	22,71	104,303

Average $\bar{x}$ $\frac{\Sigma Xi}{n} = \frac{22,71}{5} = 4,542$ cm

$$\frac{1}{n}\sqrt{\frac{n\Sigma X1^2-(\Sigma X1)^2}{n-1}} = \frac{1}{5}\sqrt{\frac{5(104)-515,7}{4}} = 0,207$$

Accuracy of Measurement Value = 4,542 $\pm$ 0,207

Table 4. Styrofoam thickness

Number	Thickness Value	X^2
1	4,1	16,81
2	5,38	28,94
3	5,2	27,04
4	4,46	19,89
5	5,10	26,01
Σ	24,24	118,69

Average $\bar{x}$ $\frac{\Sigma Xi}{n} = \frac{24,24}{5} = 4,848$ cm

$$\frac{1}{n}\sqrt{\frac{n\Sigma X1^2-(\Sigma X1)^2}{n-1}} = \frac{1}{5}\sqrt{\frac{5(119)-587,6}{4}} = 0,0272$$

Accuracy of Measurement Value = 4,848 $\pm$ 0,0272

b. Density

The sample size was 3 x 3 cm. Durio Nano-Pack 0.0051372 gr/cm³, Styrofoam 0.001312 gr/cm³

Durio Nano-Pack

$$\frac{0{,}21}{3 \times 3 \times 4{,}542} = 0{,}0051372$$

Styrofoam

$$\frac{0{,}14}{3 \times 3 \times 4{,}848} = 0{,}001312$$

c. Tensile Test

When Durio Nano-Pack is given a force of 5 - 30 N (0.0125 - 0.075 MPa) the condition is good. This is opposite when given a force of 35 N (0.0875 MPa) getting bad or damaged conditions. Styrofoam with a force of 5 N (0.0125 MPa) is in good condition, when given a force of 5.5 N - 8 N (0.01375 - 0.02 MPa) the condition is damaged.

Table 5. Durio Nano-Pack tensile test

Force	Compressive	Condition
5 N	0,0125 MPa	Good
10 N	0,025 MPa	Good
15 N	0,0375 MPa	Good
20 N	0,05 MPa	Good
25 N	0,0625 MPa	Good
30 N	0,075 MPa	Good
35 N	0,0875 MPa	Broken

Table 6. Styrofoam tensile test

Force	Compressive	Condition
5 N	0,0125 MPa	Good
5,5 N	0,01375 MPa	Broken
6 N	0,015 MPa	Broken
6,5 N	0,01625 MPa	Broken
7 N	0,0175 MPa	Broken
7,5 N	0,01875 MPa	Broken
8 N	0,02 MPa	Broken

d. Absorptive Capacity

Shows that 2 x 2 cm Durio Nano-Pack has 400% absorbency and Styrofoam has 100%.

Durio Nano-Pack

$$\frac{0{,}5 \times 0{,}1}{0{,}1} \times 100\% = 400\%$$

Styrofoam

$$\frac{0{,}6 \times 0{,}3}{0{,}3} \times 100\% = 100\%$$

e. Compressive Strength

When the sample is given a mass of 100 g -700 gr or 0.0125 MPa - 0.0875 MPa, it is still in good condition. Contrary when given a mass of 800 gr or 0.1 MPa get a condition that is not good or damaged.

Table 7. Durio Nano-Pack Compressive Power Test Test

Mass	Pressure	Condition
100 gr	0,0125 MPa	Good
200 gr	0,025 MPa	Good
300 gr	0,0375 MPa	Good
400 gr	0,05 MPa	Good
500 gr	0,0625 MPa	Good
600 gr	0,075 MPa	Good
700 gr	0,0875 MPa	Good
800 gr	0,1 MPa	Broken

Table 8. Styrofoam Compressive Strength

Mass	Pressure	Condition
100 gr	0,0125 MPa	Good
200 gr	0,025 MPa	Good
300 gr	0,0375 MPa	Good
400 gr	0,05 MPa	Good
500 gr	0,0625 MPa	Good
600 gr	0,075 MPa	Good
700 gr	0,0875 MPa	Good
800 gr	0,1 MPa	Good
900 gr	0,1125 MPa	Good
1000 gr	0,125 MPa	Good

f. Resistance Test of Nano Cellulose-TiO_2 NPs

1. Disc Diffusion and Well Diffusion

Cellulose-TiO_2 nanocomposite showed no inhibition zone against *E. coli* wild type strain ATCC 35218 and resistance strain. By considering the size of the cellulose-TiO_2 nanocomposite, it can be explained that the size of the nanocomposite can affect the diffusion of the nanocomposite through the agar. The smaller the size of the nanocomposite, the easier the nanocomposite diffuses through the agar pores. The large size of the nanocellulose–TiO_2 NPs nanocomposite will affect the inhibitory activity in disc diffusion and well diffusion.

Therefore it is important to know the size of the nanocellulose–TiO_2 NPs nanocomposite to adjust the antibacterial testing method performed.

2. Microdilution

The MIC value of nanocellulose–TiO_2 NPs nanocomposite is more than 5 mg/ml for E. coli wild type strain ATCC 35218 and resistance strain. There is no growth intervention due to the presence of 5% DMSO which indicates no effect of antibacterial activity of 5% DMSO on E. coli bacteria. The use of 50% DMSO to dissolve the nanocellulose–TiO_2 NPs nanocomposite tested on E. coli. The results of microdilution show that the size of the nanocellulose–TiO_2 NPs nanocomposite affects the interaction between nanocellulose–TiO_2 NPs nanocomposite with bacteria, it has been studied previously that, the size of nanoparticles will affect the penetration ability of nanoparticles to bacterial cells [21]. The smaller the size of nanoparticles will make it easier for nanoparticles to enter bacterial cells, causing metabolic disorders in bacteria, such as oxidative stress or inactive enzymes so that metabolism in bacteria does not run properly. Based on the tests carried out, the formulation of the postulate is as follows; 2 bio compounds both nanoparticles and non nanoparticles, each of which is can reduce its antibacterial activity if combined and produce a larger ultra structure that disrupts the efficiency of the penetration ability of the bio compound (cellulose-TiO_2 nanocomposite). Previous research conducted by [5], stated that nanocellulose–TiO_2 NPs nanocomposites showed antibacterial activity against S.aureus and E. coli bacteria tested. The inhibition zone results (14 mm and 13 mm), prove that the nanocomposite produced has effective antibacterial activity against S.aureus rather than E. coli.

g. Application of the Durio Nano-Pack

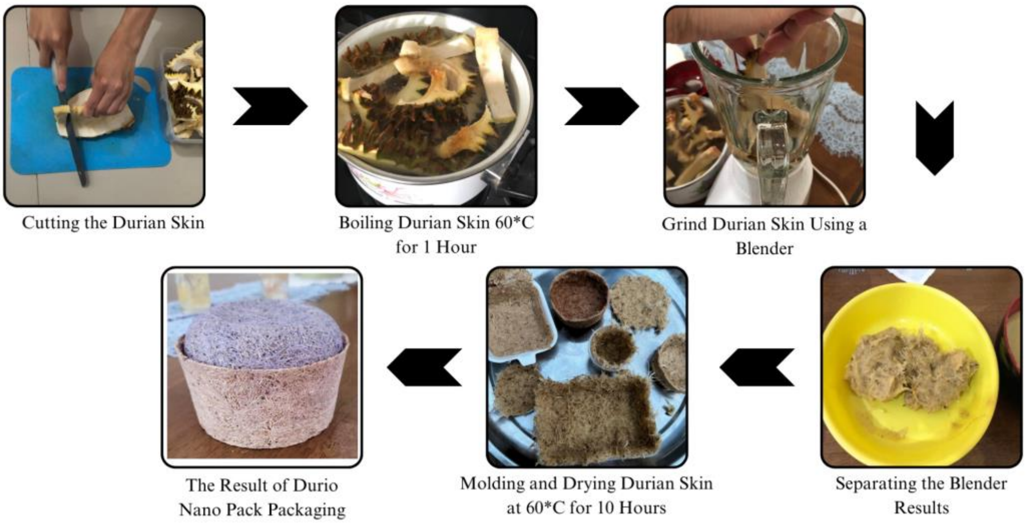

Figure 13. Durio Nano-Pack making

The process of making Durio Nano-Pack uses durian peel fiber as a foundation coated with cellulose-TiO_2 nanocomposite, and printing is carried out, then drying using an oven temperature of 60 ° C until completely dry / hardened.

4. CONCLUSION

Nanocomposite nanocellulose-TiO_2 NPs was successfully manufactured using a 1: 1 ratio and has a particle size of 458.7 nm based on PSA test, which is classified as nano size. The success of nanocomposite synthesis was proven by the results of FTIR analysis with the formation of 698.65 cm-1 and 1633.99 cm^{-1} spectra showing the presence of TiO_2 NPs and O-H functional group peaks on TiO_2 NPs and spectra at 1028.98 cm^{-1} and 1158.42 cm^{-1} showing C-O and C-O-C bonds in cellulose. The antibacterial test performed showed no significant activity in disc diffusion and well diffusion tests against E. coli wild type and resistance. This is likely due to the variation in particle size which is not homogeneous. Physical characteristics test showed that nanocellulose-TiO_2 NPs nanocomposite; density 0.0409 gr/cm³, thickness 4.542 cm $\pm$ 0.207 cm, tensile strength reached 35 N force (0.0875 MPa), absorbency 9.6%, and in the compressive strength test was damaged when given a mass of 800 gr (0.1 MPa). In the tensile strength test (0.075 > 0.0125 MPa) Durio Nano-Pack is superior to styrofoam, but in the compressive strength test (0.125 > 0.875 MPa) shows the opposite. In this study, nanocomposite has a potential novelty that provides good mechanical properties and has multiple functions such as. Further research is needed to improve the homogeneity of the nanocomposite particle size, modify the impregnation method, so that it has the potential to develop multifunctional materials that excel in various applications.

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It is encouraging to use nanocellulose from Durio Zibethinus L. plant and titanium dioxide nanoparticles for potential food packaging with antibacterial activity. However, the product contains large pores, so water can leak out, or soak the container. This limits the material to just dry food package. This project does not offer much chemistry insights.