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INNOVATION OF ULTRAFILTRATION MEMBRANES WITH A COMBINATION OF METAL- ORGANIC FRAMEWORK AND NATURAL ORGANIC MATTER FOR MEDICAL WASTE TREATMENT APPLICATIONS

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Abstrak

Limbah medis dalam keadaan cair mengandung bahan kimia yang bereaksi cepat dan harus ditangani langsung. Jika medis limbah di cairan membentuk adalah bukan diperlakukan pertama, dia akan menjadi patogen dan sebab masalah bagi kesehatan dan lingkungan. Oleh karena itu, perlu untuk mengobatinya secara efektif dan efisien untuk mengolah limbah cair medis. Oleh karena itu, penelitian ini berfokus pada manufaktur Membran ultrafiltrasi berbasis PES dengan kerangka logam organik yang dimodifikasi (MOF) dan bahan organik alami (NOM) untuk pengolahan air limbah medis dan mempelajari efeknya menambahkan MOF dan NOM pada kinerja membran. Kinerja membran akan dievaluasi melalui sebuah bersih air permeabilitas uji, porositas uji, kontak sudut uji, anti-fouling uji dengan BSA, antibakteri uji, dan pertunjukan uji. Sementara itu, itu selaput morfologi akan dikarakterisasi dengan Scanning Electron Microscope (SEM) dan FTIR untuk menyelidiki adanya bahan anti-fouling dan MOF alami pada permukaan membran. Berdasarkan analisis hasil, itu puncak pada itu selaput tanpa kolagen adalah lebih kecil dibandingkan itu selaput dengan itu tambahan dari kolagen. Di tambahan, itu tambahan dari kolagen juga meningkat -nya efektivitas di menyaring partikulat dari air limbah medis. Ukuran kapasitas penyimpanan air di itu selaput adalah juga terpengaruh oleh itu porositas terbentuk, dan ini porositas adalah secara langsung sebanding dengan fluks air murni dan BSA. Pada uji sudut kontak, penambahan kolagen mengakibatkan peningkatan sudut kontak dan penurunan hidrofilisitas itu selaput permukaan. Itu tambahan dari kolagen bisa juga mengubah itu properti dari itu membran menjadi antibakteri. Berdasarkan hasil penelitian, dapat disimpulkan bahwa penambahan kolagen dapat meningkatkan kemampuan membran untuk memisahkan partikel, dan lebih halus membran morfologi dan lebih kuat strukturnya.

Kata Kunci: medis cairan limbah, selaput, polietersulfon, ultrafiltrasi.

Abstract

Medical waste in a liquid state contains chemicals that react quickly and must be handled immediately. If medical waste in liquid form is not treated first, it will be pathogenic and cause problems for health and the environment. Thus, it is necessary to treat it effectively and efficiently to treat medical liquid waste. Therefore, this research focuses on manufacturing PES-based ultrafiltration membranes with a modified metal organic framework (MOF) and natural organic matter (NOM) for medical wastewater treatment and studies the effect of adding MOF and NOM on membrane performance. The membrane performance will be evaluated through a pure water permeability test, *porosity test, contact angle test, anti-fouling test with BSA, antibacterial test, and performance test. Meanwhile, the membrane morphology will be characterized by Scanning Electron Microscope (SEM) and FTIR to investigate the presence of natural anti-fouling and MOF material on the membrane surface. Based on the analysis results, the peak on the membrane without collagen is smaller than the membrane with the addition of collagen. In addition, the addition of collagen also increases its effectiveness in filtering out particulates from medical wastewater. The size of the water storage capacity in the membrane is also influenced by the porosity formed, and this porosity is directly proportional to the flux of both pure water and BSA. In the contact angle test, the addition of collagen resulted in an increase in the contact angle and a decrease in the hydrophilicity of the membrane surface. The addition of collagen can also change the properties of the membrane to be antibacterial. Based on the results of the study, it can be concluded that the addition of collagen can increase the ability of the membrane to separate particles, and the smoother the membrane morphology and the stronger the structure.*

Keywords: *medical liquid waste, membrane, polyethersulfone, ultrafiltration*

Introduction

Medical liquid waste contains chemicals, both organic and inorganic, which are generally measured by parameters BOD, COD, TSS, and pH. The waste is likely to contain pathogenic microorganisms or hazardous toxic chemicals that can cause infectious diseases and can be spread to the environment (Mallongi, 2018). With the rapid development of urbanization and industrialization, membrane separation technology is increasingly becoming one of the most effective methods for water treatment and purification in fields such as engineering, environment, energy, and chemical industry. Ultrafiltration (UF) is one of the commercial membrane industrial technologies that provide higher separation efficiency and also high water quality (Ramdhani & Kiswanto, 2020). Polyethersulfone (PES) is one of the best polymer materials widely used in the microfiltration membrane industry due to its chemical, mechanical and thermal properties. Various nanomaterials can be used, such as metal- organic MOFs which are used as nanofillers for polymer membranes (Kiswanto, 2020). MOFs are considered attractive for separation applications because their chemical functions can be adjusted and designed, provide selective solute transport. MOFs have been studied extensively for separating gases and organic mixtures (Jeoung et al., 2020) and water treatment applications.

Research methods

Materials

The materials used in this study include polyethersulfone (PES), metal-organic framework in the form of MIL, natural organic matter in the formation of collagen, and n-methyl pyrrolidone (NMP), bovine serum albumin (BSA) solution, and Mueller Hinton agar.

Membrane preparation

The membrane solution was made by mixing 13% PES powder (50-gram basis) with NMP solvent according to the changing variables. The mixture is then stirred until homogeneous, indicated by the dissolved polymer. Stirring was performed for 1 hour with a stirring speed of 1000 rpm. The same treatment was carried out to make membranes with different variations. The result of stirring is in the form of a clear solution, from now on referred to as dope PES/NMP. Before printing, the mixture was allowed to stand until it reached room temperature. Then the dope is poured onto a glass plate for the printing process and smoothed over the entire surface of the glass using a casting knife. The tin film formed was left at room temperature for 15 seconds to evaporate the solvent. Furthermore, the layer still attached to the surface of the glass is immersed in a coagulation bath containing a settling medium in the form of distilled water which functions as a non-solvent in the precipitation process. This process is left until the membrane layer is separated from the glass plate. Then the membrane was oven-dried at 60ºC for 24 hours, with the membrane positioned already covered with tissue and held in place using a glass plate. In this study, the membranes made there were four variables, namely type 1 (13% PES, 0.1% MIL, 1% collagen, 42.95 g NMP), type 2 (13% PES, 0.1% MIL, 3% collagen, 41.95 g NMP), type 3 (13% PES, 0.1% MIL, 5% collagen, 40.95 NMP), and type 4 (13% PES, 0.1% MIL, 43.45 g NMP) with a base of 50 grams.

Membrane characterization

The membranes that have been made were characterized, including pure water permeability test, porosity test, contact angle test, anti-fouling test with BSA, antibacterial test, and performance test. Meanwhile, the membrane morphology will be characterized by Scanning Electron Microscope (SEM) and FTIR to investigate the presence of natural anti-fouling and MOF materials on the membrane surface.

Scanning electron microscope

This analysis aims to determine the changes in membrane morphology. The tool used is a Scanning Electron Microscope (SEM).

Fourier transform infrared

FT-IR was carried out to investigate the surface chemistry to confirm the presence of natural antifouling and MOF material on the membrane surface.

Contact angle test

The contact angle was used to investigate the hydrophilicity of the membrane surface. The tool used is the Coordinate Measuring Machine Contact Angle Meter.

Porosity test

The porosity test was carried out to see the effect of the coagulation temperature on the resulting membrane pores that will affect the performance of the membrane in determining the value of the water flux. The equation calculates the percentage of membrane porosity:

$$\%\ \text{Membrane porosity} = \frac{(m_1 - m_0)/\rho_{water}}{\pi r^2 L}$$

where m1 is the mass of the membrane after immersion (g), m0 is the mass of the membrane before immersion (g), ρwater is the density of water (1 g/cm3), r is the radius of the membrane (cm), and L is the thickness of the membrane (cm).

Pure water permeability test

The value of the permeability of pure water is obtained by measuring the flux of pure water through the membrane by the equation:

$$J = \frac{V}{A\ x\ t}$$

Where J is flux value, t is time, V is permeate volume, and A is membrane surface area.

Anti-fouling test with BSA

Anti-fouling tests are carried out to prevent fouling or reduce the growth of organisms.

Antibacterial test

The antibacterial test on the membrane was carried out using the inhibition zone method with the aim of measuring the diameter of the clear zone formed around the membrane.

Performance test

Performance tests were carried out by applying the membrane with a synthetic solution made with a composition resembling medical waste.

Hasil dan Pembahasan

Effect of addition of MIL and collagen concentrations on membrane porosity

The porosity test is carried out to determine the amount of substances or components that can be absorbed by the membrane. The porosity test is usually carried out on water, so it can be seen the amount of water that can be absorbed by the membrane (Humairo, 2015).

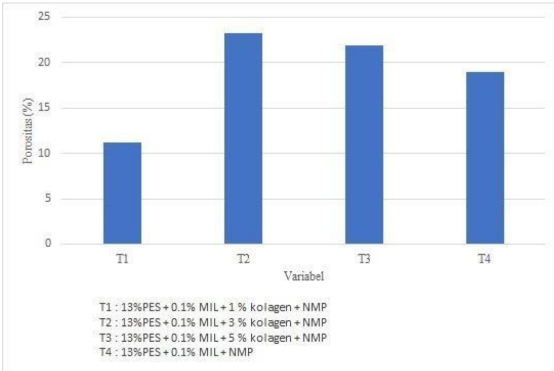

Fig. 1. The value of membrane porosity in each variable

The graph above illustrates the value of membrane porosity which is displayed in the form of a ratio value (%) to the addition of collagen. The porosity values of T1, T2, T3, and T4 membranes were 11.21%; 23.21%; 21.89%; and 18.92%. At T1 with a

collagen concentration of 1%, it shows the lowest porosity value. The highest porosity value is found in T2 which has a concentration of 3% collagen. At T3 and T4 showed a decrease in the value of the porosity which the collagen concentration was 5% and 0%. The data obtained indicated that the addition of collagen increased the porosity of the membrane. However, the addition of too much collagen will reduce the value of membrane porosity.

The porosity of the T layer has the lowest value (11.21%). This happens because the resulting membrane is less porous. Porosity increases with the addition of collagen concentration. However, the addition of too much collagen will reduce the value of membrane porosity. The expansion ability of the membrane is influenced by the porosity value. The size of the water storage capacity of the membranes is influenced by the number of voids or porosity formed (Fadli et al., 2021). Membrane porosity indicates the number of areas that are porous on the membrane. The higher the porosity of a membrane, the more the number of porous surface on the membrane so that the amount of permeate that can be passed at one time is also greater (Zulfi et al., 2014).

Based on research conducted by Zulfi et al. (2014), of the four membranes that have been tested, membrane B with a collagen ratio of 1.5 has the largest average flux compared to the other three membranes because membrane B has the largest pore size and porosity. Membrane porosity indicates the number of areas that are porous on the membrane. The higher the porosity of a membrane, the more the number of porous surfaces on the membrane so that the amount of permeate that can be passed at one time is also greater. The porosity values of membranes A, B, C, and D respectively were 69.68 %; 87.79%; 75.17%, and 87.63%. The presence of other metals in the waste plays a role in the blockage of the membrane pores so that more and more membrane pores are closed at one time which causes the membrane porosity to decrease. As the porosity of the membrane decreases, the amount of waste that can be passed will decrease with time. The phenomenon of fouling on the membrane affects the efficiency and effectiveness of the performance of a membrane(Qaisrani & Samhaber, 2011). If there is a layer formed on the surface of the membrane which is indicated by the blockage of the membrane pores, the porosity of the membrane decreases so that the amount of feed that can be filtered will decrease and the membrane operating time will be shorter.

Effect of addition of MIL and collagen concentration on flux test

Flux or permeate velocity is one of the parameters that determine the performance of the membrane. The flux value determines the amount of permeate that can be passed by the membrane per unit area per unit time (Zulfi et al., 2014).

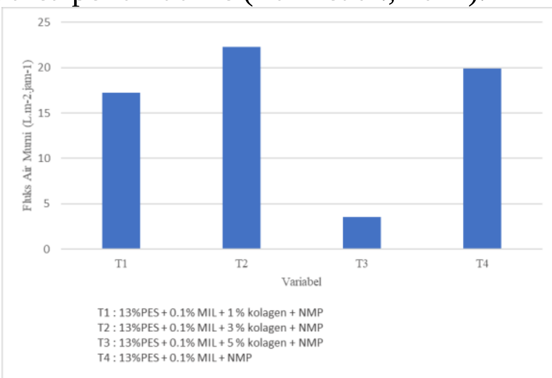

Fig. 2. The value of the membrane flux in each variable

The flux values T1, T2, T3, and T4 show the values respectively are 17.24 (L/.m2.hour); 22,3 (L/.m2.hour); 3.54 (L/.m2.hour) and 19.91 (L/.m2.hour). At T3 shows the lowest flux value consisting of PES of 13%, MIL of 0.1%, collagen of 5% and NMP. The highest flux value was at T2 which consisted of PES of 13%, MIL of 0.1%, collagen of 3% and NMP. At T1

shows a decrease in flux value whose composition consists of PES by 13%, MIL by 1%, collagen by 1% and NMP, while at T4 the composition consists of PES by 15%, MIL by 0.1%, NMP and without the addition of collagen.

The value of flux in the four membranes has a different ratio value (L/.m2.hour) because each membrane has a value of permeate volume (L), time (hours), and membrane surface area (m2) which varies so that the dividing factor (L/.m2.hour) is not the same. This variable flux ratio value indicates that the composition of the addition of MIL and collagen affects the characteristics of the membrane. T2 membrane has the highest ratio (L/.m2.hour) while T3 membrane has the lowest flux ratio value, because T2 membrane has the largest pore size and T3 membrane has the smallest pore size. The pore size greatly affects the flux value, the larger the membrane pore, the greater the amount of permeate that is passed in a given time so that the flux value is higher and vice versa if the pore size is getting smaller. The phenomenon of decreasing membrane flux is commonly known as membrane fouling. The occurrence of fouling begins with concentration polarization, namely an increase in the local concentration of a solute on the membrane surface, so that the dissolved material gathers to form a gel layer which is getting thicker over time. In this situation the membrane begins to experience blockage so that the amount of permeate that is passed is decreasing (Zulfi et al., 2014).

These results are in accordance with

research conducted by Zulfi et al. (2014), which states that the water flux in membrane B has the highest J/Jw ratio, while in membrane C the flux ratio is the smallest, because membrane B has the

largest pore size of 2.58 m and membrane C has the smallest pore size of 0.12 m.

Effect of addition of MIL and collagen concentration on contact angle test

The contact angle is the angle measured conventionally through a liquid, where the vapor-liquid interface meets a solid surface(Song & Fan, 2021). This contact angle test aims to investigate the hydrophilicity of the membrane surface.

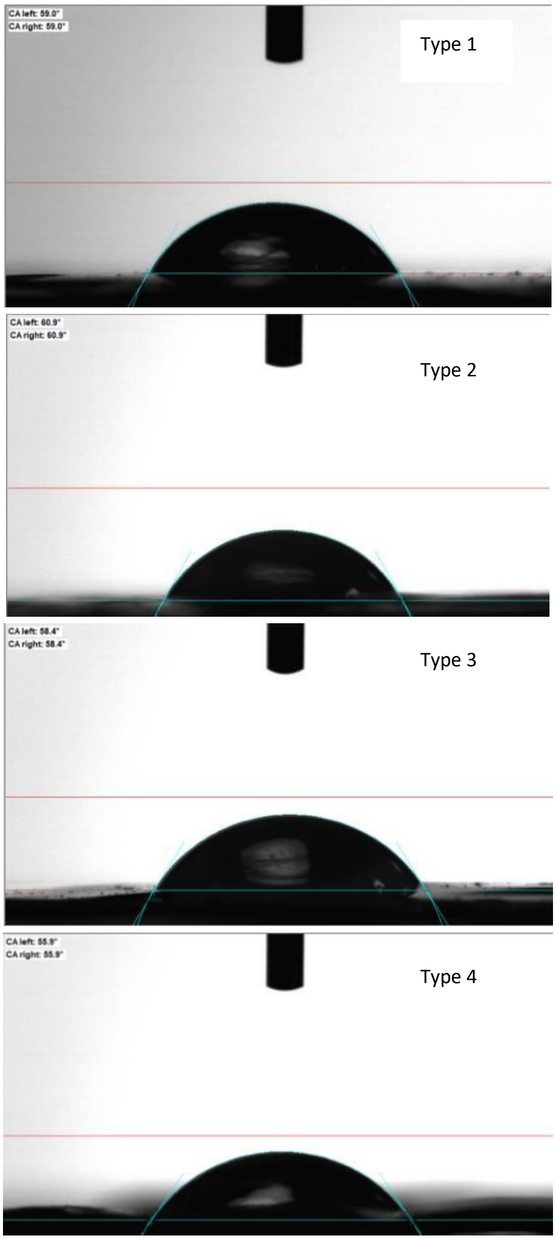

Fig. 3. Contact angle test results

Fig. 3. shows the contact angle between polyethersulfone membranes as a result of immersion in aquadest in type 1 with the addition of 1% collagen showing a value of 59.0º. In type 2 with the addition of 3% collagen, it shows a value of 60.9º. In type 3 with the addition of 5% collagen, it shows a value of 58.4º. Meanwhile, in type 4 without the addition of collagen, it shows a value of 55.9º. From these data, it can be seen that the contact angle on the polyethersulfone membrane is relatively larger with the addition of collagen.

The value of the contact angle on the membrane is closely related to the permeability of the membrane(Chan & Ng, 2018). The greater the contact angle on the membrane, the smaller the membrane permeability will be. The membranes with types 1, 2, and 3 have relatively large contact angles, so the permeability is low. This is caused by the formation of a fouling layer on the surface of the wall on the inside of the membrane, the longer the collagen in the feed solution can become a foulant when trapped in the pore mouth, so that it can cover the entire surface of the membrane (Arahman et al., 2016).

This is in line with the research conducted by Gao et al. (2021) which stated that the addition of collagen at various concentrations resulted in changes in the contact angle from 55.9º to 60.9º. The increase in contact angle occurs along with the increase in the concentration of collagen in the membrane solution. The addition of hydrophobic collagen reduces the surface hydrophilicity of polyethersulfone-based membranes. The higher the concentration of collagen added, the more hydrophobic the membrane surface.

Effect of addition of MIL and collagen concentration on SEM Scanning Electron Microscope (SEM) is a type of electron microscope that draws specimens by scanning them using a high-energy electron beam in a raster pattern scan (Wijayanto and Bayuseno, 2013). SEM has several advantages and has a fairly high magnification of up to 300,000x and even 1000000x.

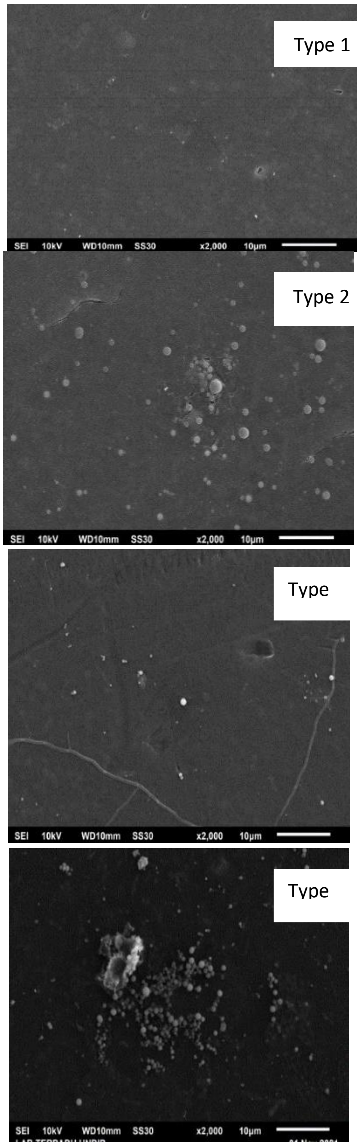

Fig. 4. Characterization of ultrafiltration membranes with SEM instruments before filtration of medical wastewater

Fig. 5. Characterization of ultrafiltration membranes with SEM instruments after filtration of medical wastewater

The figure above shows an illustration of the effect of adding collagen to the membrane produced by SEM instruments with a magnification of 2000x. It can be seen in Fig. 4. the results of the SEM of the membrane before the filtration process. In type 1 (addition of 0.5 g collagen) the membrane surface is quite smooth, but slightly thin. Meanwhile, type 3 (addition of 2.5 g of collagen) showed a fairly smooth and thicker membrane surface. Fig. 5. the results of the membrane SEM after the filtration process using medical liquid waste. It can be seen from the filtration results obtained, in type 3 particulates are captured much more than the other types. The increase in collagen will cause more particulates to be caught.

The results of the SEM analysis showed that the membrane with the addition of more collagen would make the membrane much smoother and thicker and increase its effectiveness in filtering out particulates in medical wastewater. In a study conducted by Arahman (2009), the addition of collagen will increase the membrane yield obtained. Membranes made of PES/NMP with the addition of collagen also produced significantly fewer pores than membranes without collagen(Garcia-Ivars, Iborra-Clar, Alcaina-Miranda, & Van der Bruggen, 2015). The more collagen it will make the ultrafiltration membrane will have fewer pores. However, according to research by Japranata (2016), the addition of excess collagen will make the membrane unable to work optimally, so that the filtered waste is less effective.

Based on the research conducted, the results obtained are in accordance with the theory. In this study, type 3 membrane (addition of 2.5 g collagen) produced a fairly good type of membrane because it can filter dirt from medical liquid waste well, it can be seen in Fig. 4. and Fig. 5. that there is much more dirt attached to the membrane when compared to other types.

Effect of addition of MIL and collagen concentration on FTIR FTIR is a vibrational spectroscopy to obtain the value of the infrared spectrum simultaneously in all wave numbers. The purpose of the characteristics with FTIR (Fourier Transform Infrared Spectroscopy)

is to prove the presence of fouling by looking at the wavelength of the compound groups on the membrane surface (Fadli, 2021).

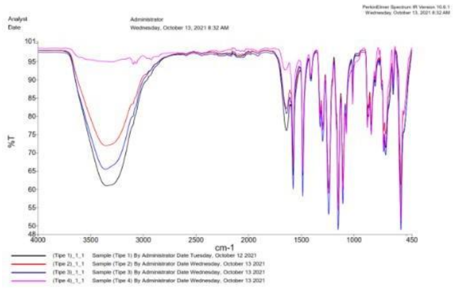

Fig. 6. FTIR spectrum from fresh membrane

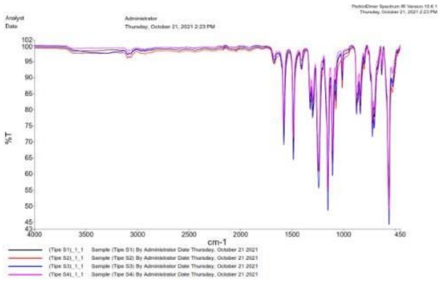

Fig. 7. FTIR spectrum of fouling membranes (aquadest and BSA)

The graph above illustrates the results of FTIR on ultrafiltration membranes, which can be seen on fresh type 1 membranes (collagen 1%) there are differences in peaks at 3351.19 cm-1; 1485.37cm^{-1}; 1238.31 cm^{-1}; and 552.10 cm-1 then for membrane fouling there is a peak at 3095.69 cm^{-1}; 1578.20 cm^{-1}; 1150.91 cm^{-1}; and 555.40 cm^{-1}. Furthermore, for type 2 (3% collagen) there were differences in peaks at 3352.50 cm^{-1}; 1557 cm^{-1}; 1238.59 cm^{-1}; and 552.42 cm^{-1}, then for membrane fouling there is a peak at 3096.38 cm^{-1}; 1577.89 cm-1; 1150.17 cm^{-1}; and 555.07 cm^{-1}. While for type 3 (collagen 5%) there is a difference in peak at 3368.45 cm-1; 1557.17 cm^{-1}; 1238.67 cm^{-1}; and 716.05 cm^{-1}, and then for membrane fouling there is a peak at 3095.93 cm-1; 1578.13 cm^{-1}; 1150.26 cm^{-1}; and 522.32 cm^{-1}. Finally, for type 4 (without collagen) there are differences in peaks at 3296.46 cm^{-1}; 1557.16 cm^{-1}; 1297.13 cm^{-1}; and 524.51 cm-1 then for membrane fouling there is a peak at 3095.33 cm-1; 1105.91 cm-1; 1150.26 cm-1; and 523.89 cm^{-1}.

FTIR examination was carried out to see the functional groups or compounds of collagen and chitosan. FTIR spectroscopy is a tool to measure the absorption of infrared radiation at a wavelength (Sari et al., 2021).Qualitatively, FTIR spectroscopy can be used to determine the functional groups present in the molecular structure. The data is generated from the FTIR spectrum test. is the peak of the characteristic spectrum described as the transmission curve (%) and the number of waves (cm-1) in the tested sample which will then be analyzed. Analysis of the data generated by infrared spectroscopy requires an international converter table, namely the IR handbook(Katari et al., 2017). Guidelines for using IR to match groups of collagen compounds. From the measurement data obtained, then analyze the probability of the occurrence of chemical compounds or mechanical mixtures.

The results of Zeeshan et al. (2018) research show that the addition of collagen will provide more detailed characterization of the chemical and molecular structure of the membrane. This is in accordance with the results of the characterization of membrane types 1 to 4 where the peak in the membrane without collagen is smaller than the membrane with the addition of collagen.

Effect of addition of MIL and collagen concentration on antibacterial test

Antibacterial activity test can be carried out using the zone of inhibition method by measuring the diameter of the clear zone which is an indication of an inhibitory response to bacterial growth by an antibacterial compound in the membrane.

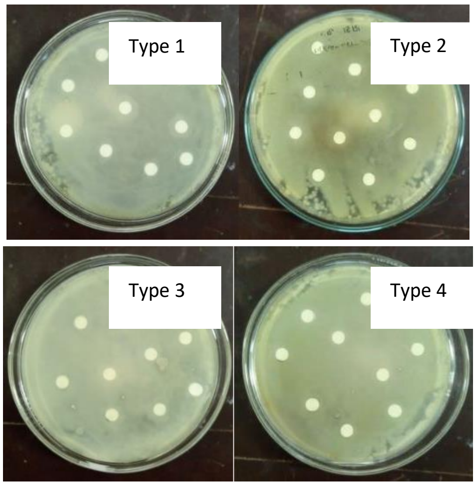

Fig. 8. S. aureus antibacterial test results

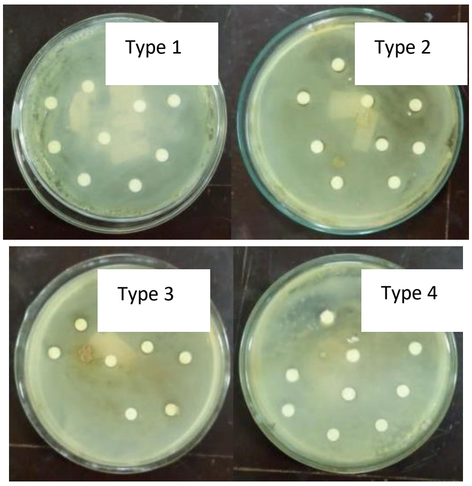

Fig. 9. S. tiphy antibacterial test results

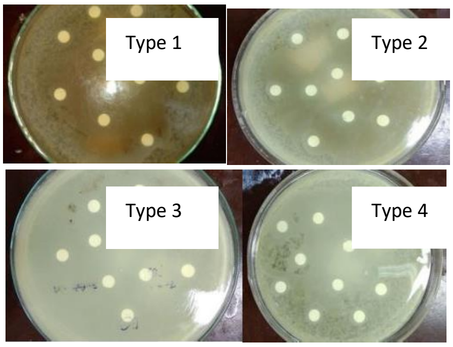

Fig. 10. E. coli antibacterial test results The following is a table of the results of antibacterial activity tests that have been carried out on PES/NMP ultrafiltration membranes.

Treatment	Diameter (mm)					Inhibition zone category
	1	2	3	Average	Standard Deviation	
EC1	6,5	6,7	7,1	6,76	0,30	Medium
EC2	7,6	7,2	6,7	7,16	0,45	Medium
EC3	7,4	7,1	6,7	7,06	0,35	Medium
EC4	8,5	8,3	7,9	8,23	0,30	Medium
SA1	13,6	12,9	13,3	13,26	0,35	Strong
SA2	8,8	8,3	8,7	8,6	0,26	Medium
SA3	8,2	8,8	9,4	8,8	0,60	Medium
SA4	7,5	9,2	8,8	8,5	0,88	Medium
ST1	7,5	7,4	7,2	7,4	0,30	Medium
ST2	11,5	11,2	10,9	11,2	0,30	Strong
ST3	8,2	8,5	8,0	8,23	0,25	Medium
ST4	7,6	7,8	8,0	7,8	0,35	Medium

Table 1. Results of antibacterial activity tests that have been carried out on PES/NMP ultrafiltration membranes.

From Fig. 8. to Fig. 10. and Table 1. show antibacterial activity in types 1 to 4 with various bacteria, including S. aureus, S. typhy, and E. coli. It can be seen that type 1 membrane has moderate resistance to E. coli and S. typhy bacteria, but has strong resistance to S. aureus bacteria. In type 2, the membrane has a fairly good bacterial resistance to E. coli and S. aureus bacteria, while for S. typhy bacteria it has a very strong resistance. For type 3 and 4, both have fairly good bacterial resistance to E. coli, S. aureus, and S. typhy bacteria.

The presence of collagen in the membrane can function as an antibacterial because collagen can interact with bacterial membranes, causing damage to bacterial membranes which in turn will kill bacteria. Collagen will first attack on the surface of the bacterial membrane, penetrate into the bacteria, and finally change the permeability of the bacterial membrane. This mechanism causes damage to the membrane (Zheng, Xie, Dai, Chen, & Wang, 2018).

This is in line with research conducted by Notriawan et al. (2021) who stated that collagen can cause damage to the membrane and change the permeability of bacterial membranes.

The antibacterial properties of collagen-containing membranes depend on the size, shape, and surface that determine the success in destroying bacterial membranes. Collagen with a small size can interact with the protective lignin layer on bacteria better.

Effect of addition of MIL and collagen concentration on BSA rejection

Bovine Serum Albumin (BSA) at different temperature, pH, circulating flow rate and operating pressure was used as a level solution to study the performance of polyethersulfone (PES) ultrafiltration membranes. Observations focused on flow parameters and membrane rejection factors observed and held by the membrane during the process (Anwar & Lapenia, 2019).

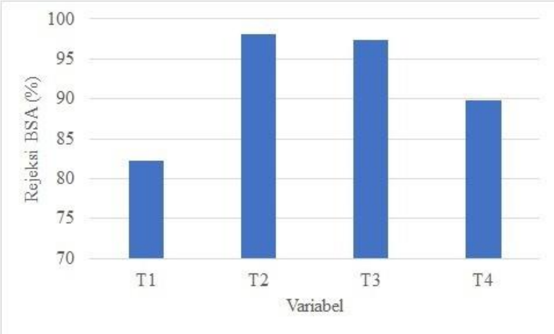

Fig. 11. Rejection graph of BSA

The graph above is a graph of BSA rejection from four types of membranes whose value is the percentage ratio between the BSA concentrations after the cross-flow test compared to the BSA concentration before the cross-flow test. From the experiment, the BSA rejection value in type 1 (collagen addition of 1%) was 82.17%; type 2 (addition of collagen as much as 3%) by 98.08%; type 3 (addition of collagen as much as 5%) by 97.33%; and type 4 (without the addition of collagen) by 89.83%.

Observations focused on the flow parameters and the observed rejection factor of the value of the protein that passed through and was captured by the membrane during this process.

The test results show that temperature, pH of BSA grade solution, circulation rate, and operating pressure can affect membrane performance in terms of flow rate and membrane rejection. High levels will decrease the membrane flux but will increase the membrane rejection coefficient (Thompson et al., 2018). The membrane rejection coefficient will expand and the flux will decrease as the pH of the solution approaches the isoelectric point of the protein. The high pressure of the feed solution will increase the membrane flux but decrease the membrane rejection coefficient. The membrane rejection coefficient decreases and the flow rate increases at low recirculating flow rates.

In a previous study conducted by Asa et al. (2016) mentioned that their research results showed that the addition of collagen to the membrane affected the structure and morphology of the membrane. The more collagen added, the smoother the membrane morphology and the stronger the structure(Chu et al., 2016). From the table, it can be seen that the addition of collagen up to 3% made the BSA rejection value the highest among the others. In the membrane without the addition of collagen, the results will be less than optimal, while the results for the membrane with the addition of 5% collagen are not as good as type 2. The results obtained in general show that the composition of collagen at a ratio of 3% produces a membrane with a smoother morphology and structure and stronger. The higher the concentration of collagen used increases the ability of the membrane to separate particles(Antman-Passig & Shefi, 2016).

Kesimpulan

1. Program pemberdayaan ekonomi di kelurahan Ciketing Udik adalah salah satu implementasi dari komitmen dan kebijakan CSR PT Indofood Sukses Makmur tbk. Terhadap anjuran kepatuhan pada peraturan dan strategi pengembangan bisnis yang berkelanjutan.
2. Mengacu pada ISO26000 pelaksanaan pemberdayaan ekonomi pada lokus penelitian sejalan dengan subyek inti tata kelola dan pelibatan dan pengembangan masyarakat.
3. Berdasarkan Kompas *Sustainability NEWS*, ditemukan terdapat dampak ekonomi, kesejahteraan dan kemasyarakatan yang signifikan dan masih terbatas dirasakan oleh

penerima manfaat dan keluarganya. Manfaat ekonomi digunakan untuk membiayai pendidikan anak, mengembangkan usaha dan membeli kendaraan.

4. Koperasi telah dibentuk sebagai institusi yang akan menjamin keberlanjutan manfaat atau *exit strategy* program pemberdayaan ekonomi dan sejumlah kecil anggota koperasi memanfaatkan akses bahan baku yang disediakan. Akan tetapi, koperasi belum membagikan sisa hasil usaha disebabkan aktivitas ekonomi yang terhambat pada saat pandemi Covid-19.
5. Belum ditemukan kebijakan yang secara jelas mendukung dan melanjutkan pemberdayaan ekonomi yang dilakukan oleh pemerintah, kendati ditemukan dukungan yang baik dari pemerintahan tingkat kecamatan, kelurahan, RW dan RT dalam membantu memasarkan dan pemanfaatan produk. Situasi ini sangat bergantung pada individu yang memangku jabatan sehingga dukungan keberlangsungan program pemberdayaan ekonomi cenderung kurang optimal.
6. Terdapat tiga aspek jenis efektifitas pelaksanaan kegiatan mencakup pelibatan kader, pemetaan pra-kegiatan dan merangkul aktor pembangunan lainnya. Sementara efisiensi penggunaan sumber daya yang ada ditemukan sebagai tidak boros karena bisa didatangkan dari wilayah sekitar tanpa biaya dan usaha ekstra. Akan tetapi tidak didapatkan bantuan pembiayaan dari pemerintahan setempat sebagai dana perimbangan dari yang telah disalurkan perusahaan.
7. Terdapat tiga kategori kapasitas adaptif yang dimiliki oleh penerima manfaat, pengurus dan pemangku kepentingan mencakup diantaranya 1), kemampuan belajar: pengetahuan dan keterampilan mengolah produk berbahan dasar terigu, gagasan untuk melakukan inovasi, memanfaatkan internet, 2). perubahan yang dilakukan secara mandiri: memasarkan produk melalui *market place online*, pembentukan koperasi, PAUD ABK, dan 3). kepemimpinan - legitimasi, kesempatan yang setara dan responsifitas - mencakup pengakuan akan ketokohan mereka sebagai kader, *trainer*, motivator, kecepatan merespon situasi termasuk dampak covid-19 dan partisipasi perempuan yang baik.
8. Keberlanjutan berhubungan dengan jenis produk yang paling diminati dan kesesuaian kegiatan dengan tujuan keikutsertaan penerima manfaat dan pengurus dan tujuan perusahaan dalam keberlanjutan usaha.
9. Ditemui pola berpikir pengusaha pada sejumlah kecil penerima manfaat yang memiliki visi yang jelas untuk mengembangkan usaha. Akan tetapi sebagian besar cenderung belum punya visi yang jelas dalam pengembangan usahanya.
10. Terdapat indikasi kontribusi program pemberdayaan ekonomi dengan tujuan pembangunan berkelanjutan khususnya indikator 1) Tanpa Kemiskinan,2) Tanpa Kelaparan,3) Kesehatan,4) Pendidikan, 5) Persamaan Gender, 8) Ekonomi dan Lapangan Kerja, 16) Kelembagaan dan 17) Kemitraan untuk Mencapai Tujuan.

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