Characterization of polyethersulfone (PES) membrane entrapping with ginger extract (GE) as a green additive

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Abstract. The hydrophilicity of the membrane surface plays an essential role in improving membrane filtration performance. Better hydrophilicity could facilitate higher water permeation and prevent fouling phenomena. In this research, a green additive from ginger extract (GE) was employed to improve the polyethersulfone (PES) membrane hydrophilicity. The PES/GE membrane was fabricated via the phase inversion method by dispersing GE powder in PES/NMP solution using sonication followed by mechanical stirred. The influence of ginger extract (GE) on the PES membrane was characterized in terms of hydrophilicity, morphological structure, porosity, water permeation, chemical composition, and mechanical property. Water contact angle measurements showed that PES/GE membrane with 0.1% GE has the highest hydrophilicity. Scanning Electron Microscopy (SEM) indicated a porous finger-like structure on the cross-section membrane after the addition of GE.

1. Introduction
Polymeric ultrafiltration (UF) membrane is widely applied in water purification, wastewater treatment, and chemical engineering process [1]. However, the hydrophobic nature of pristine membranes is one of the significant obstacles that usually hinders membrane applications [2,3]. Fouling phenomena due to the interaction between membrane surface and organic molecules causes a substantial decline of the water permeation, increase in energy consumption, and shorten membrane lifetime [4]. Therefore, the improvement of membrane hydrophilicity is highly necessary.

Hydrophilic groups, such as hydroxyl, carboxyl, and sulfonate groups, are introduced to improve membrane surface hydrophilicity [4,5]. Some plant extracts from Piper betel, Vanilla planifolia, and natural products such as 2(5H)-Furanone that contains aldehyde, hydroxyl, and ether functional groups have been explored to increase membrane hydrophilicity [6]. Ginger (Zingiber Officinale Roscoe) is
another plant derivative with active substances in the form of zingerone, shogaols, gingerols, and volatile oils (essential) [7,8]. The hydroxyl groups are found in the chemical structures of Ginger extract (GE) and potentially improved membrane hydrophilicity. However, the use of ginger extract for enhancement membrane hydrophilicity has not been reported.

In the present study, polyethersulfone (PES) was utilized as the primary membrane polymer because it owes mechanical stability and chemical resistance [9]–[11]. Herein, ginger extract (GE) was explored to enhance membrane hydrophilicity by blending technique. The effect of ginger extract on the morphology, hydrophilic, and mechanical properties of the PES membrane was reported. Besides, the employing plant extract as membrane additive material is a green alternative to produce an appropriate membrane from an environmental point of view.

2. Materials and experimental set up

2.1. Material
Polyethersulfone (PES, Ultrason E6020P) as the main material was purchased from BASF Co. (Ludwigshafen, Germany). N-Methyl Pyrrolidone (NMP) (Wako Pure Chemical Industries, Japan) was directly used as a solvent. Zingiber Officinalis Roscoe extract (purity 100%) (Sciyu bio. Tech, China) was utilized as an antibacterial additive. Distilled water (DI) was used as a non-solvent for the solidification process.

2.2. Membrane fabrication
The phase inversion technique was used to prepare flat sheet membranes. Ginger extract (GE) was initially dissolved in the N-Methyl Pyrrolidone (NMP) by sonication for 10 minutes, followed by 5 minutes stirring. Then, polyethersulfone (PES) was added into the suspension, and the solution was kept to continue stirring until homogeneous. The composition of membrane solutions in this study is shown in Table 1. The membrane solutions were then cast on flat glass with an air gap of 200 μm using a casting knife (Yoshimitsu, YBA-3, Japan). Next, the glass plate is dipped in a water bath to induced the solidification process. The formed membranes are stored in containers containing distilled water to remove any remaining solvents.

| Membrane | PES (wt%) | GE (wt%) | NMP (wt%) |
|----------|-----------|----------|-----------|
| PG1      | 16        | 0        | 84        |
| PG2      | 16        | 0.01     | 83.99     |
| PG3      | 16        | 0.03     | 83.97     |
| PG4      | 16        | 0.05     | 83.95     |

2.3. Characterization
Membrane chemical group composition was identified by attenuated total reflectance (ATR) instrument (Thermo Scientific iD5 ATR–Nicolet iS5 FTIR spectrophotometer, Japan). Hydrophilicity on the membrane surface was measured by contact angle meter (Drop Master 300, Kyowa Interface Science Co., Japan). The membrane morphological structures on surface and cross-sections were visualized using scanning electron microscopy (SEM; JSF-7500F, JEOL Co., Ltd., Japan) at 5.0 kV. The mechanical property was evaluated with a tensile test instrument (Autograph AGS-J, Shimadzu Co., Japan), by following ASTM D 638-14.

3. Result and discussion

3.1. Hydrophilicity
Figure 1 displayed the water contact angle of the formed membranes as a function of hydrophilicity. The water contact angle is evaluated by placing a water droplet on the membrane surface, then the angle
between the droplet and membrane surface is calculated [12]. It means the smaller contact angle facilitates better hydrophilicity.

As shown in Figure 1, the increment of the loading of ginger extract (GE) particles increases PES membrane hydrophilicity. PG4 membrane has the highest hydrophilicity that the other membranes and decreases the PES membrane water contact angle from 68.50° to 58.31. In this case, the hydroxyl groups (−OH) in GE particles play a significant role in improving the hydrophilicity of the membrane surface. IR-spectra confirmed the presence of hydroxyl groups (−OH) in the ginger extract in Figure 2.

![Figure 1. The water contact angle of the PES membrane.](image1)

![Figure 2. IR-Spectra of ginger extract.](image2)

3.2. Morphological structure

Figure 3 showed the cross-section of the formed membranes with a completely finger-like structure. As shown in Figure 3, the increasing concentration of GE particles resulted in higher porosity of membrane indicated by more extensive finger formation. Since GE additive has hydroxyl groups and soluble in water, it can leach out from the membrane during the solidification process leading the creation of porous [13,14]. Furthermore, the increasing finger size in the cross-section membrane is also induced by the fast exchange of solvent and non-solvent due to a closer affinity between membrane solution and water as non-solvent caused by higher hydrophilicity of membrane solution [13–16].
3.3. Mechanical property
The mechanical property of the membranes was investigated using the tensile strength test. As presented in Figure 4, the pristine membrane (PG1) has the most durable mechanical property. The loading of GE particles leads to the decreasing of PES membrane tensile strength from 15.6 to 10.4 Mpa. From the results, the formation of macrovoid in membrane structure affected the tensile strength of the membrane. It weakens the density of the membrane and products in a more fragile form [17].

4. Conclusion
Based on the results, ginger extract (GE) showed a positive impact on enhancing the hydrophilicity of the membrane. The addition of GE particles into the PES membrane matrix also induced the formation of finger-like structures that indicated a more porous membrane. However, the decrease of tensile
strength due to the addition of GE still provides excellent performance of mechanical property; it is above 10 Mpa.

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6. References
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