BIOPROSPECTION OF ENGGANO MACROSCOPIC FUNGI AS ANTIBACTERIAL AND ANTIOXIDANT AGENTS
[Bioprospeksi Jamur Makroskopis Enggano Sebagai Antibakteri dan Antioksidan]

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ABSTRACT
Macrofungi in Indonesia have not been widely studied for their pharmacological activity, especially as a source of antibacterial and antioxidant properties, even though Indonesia as a tropical country has quite a high diversity of macrofungi. This study aims to reveal the potential of macrofungi from the Enggano forest as a source of antibacterial and antioxidant compounds. Four types of macrofungi were collected and their metabolites were extracted using four types of organic solvents. Antibacterial and antioxidant activity assay of the extract was carried out using the TLC Bioautography method. From the sixteen macrofungal extracts, there is one extract that has the strongest antibacterial activity compared to the others, namely n-hexane Coriolopsis polyzona. It showed moderate antibacterial activity against Staphylococcus aureus and Escherichia coli with MIC values of 256–128 μg/mL, respectively. Meanwhile, the antioxidant activity of the macrofungal extracts showed weak activity with IC50 values of 3080–7370 μg/mL (AAI values of 0.033–0.079).

Key words: Macrofungi, Enggano, antibacterial, antioxidant, Coriolopsis polyzona

INTRODUCTION
The increasing number of antibiotic-resistant bacteria drives the development of more effective antibiotics. In the presence of antibiotics, bacteria gradually become immune and these resistant bacteria begin to replicate (Dandawate et al., 2019). As a result, novel anti-biotic agents derived from various biological sources are constantly searched. Furthermore, the discovery of antioxidant agents is also important for protecting against chronic degenerative diseases. Fungi have received a lot of attention because they are recognized to possess bioactive compounds that are effective against microbial organisms.

The fungi have long been known to thrive in humid conditions that encourage the development of pathogenic microorganisms. They have developed certain defensive mechanisms to survive in their environment by producing antibacterial and antifungal compounds (Lindequist et al., 2005). Fungi are medicinal foods that are widely used in the treatment of diet-related diseases, the prevention of chronic diseases, and to slow down the aging process (Khatun et al., 2012). The medicinal properties of fungi are due to the presence of a diverse variety of secondary metabolites of high therapeutic potential (Ogidi and Oyetayo, 2015). Polysaccharides and glycoproteins derived from the fungi, such as lentinan, krestin, and schizophyllan, have been used as a stimulant of the body in the treatment of cancer in Asia (Wasser, 2002).

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Macrofungi are a fascinating fungi group because of their potential. Most macrofungi belong to Basidiomycota and Ascomycota (Hibbett et al., 2007). Metabolites from macrofungi have antibacterial, antioxidant, antifungal, anti-tumor, antiviral, anti-inflammatory, antiatherogenic, hypoglycemic, hepatoprotective, immunomodulatory, anti-Alzheimer's, anti-diabetic, antimalarial, and hypocholesterolemic activity (Suay et al., 2000, 2005; Reis et al., 2011; Ren et al., 2012). The fungi can be a potential source of medicinal raw materials because of their abundance in nature, with a variety of potential activities. Fungi are the second-largest organism in existence, behind terrestrial plants, with about 3-5 million organisms (Blackwell, 2011). Indonesia, which is rich in animal and plant diversity, also has a high diversity of fungi. This is due to the humidity and tropical temperatures in Indonesia, which promote the growth of fungi, and it is estimated that Indonesia has 200,000 species of fungi (Dewi et al., 2019). Nevertheless, only a limited percentage of the overall number of fungi species found in the wild has been described.

Enggano Island is one of the outermost islands in Indonesia, located in Bengkulu Province. The information about Enggano Island’s biodiversity is still limited. Thirtyone species of macrofungi were identified from the village in Enggano Island. Those species belong to Basidiomycota and Ascomycota. The nine new species were identified as new record named as Phellinus gilvus, Fomitella supina, Flaviporus liebmannii, Coriolopsis polyzona, Flabelliphora sp., Trichaptum byssogenum, Stecherrinum sp., Stereum cf. pergameneum, and Trametes cf. villosa. On the other hand, two species, namely Cookeina cremeirosea and Fomitella supina are known to be a new record for macrofungi in Indonesia. Fungi Phellinus gilvus was reported as a harmful parasite for rubber plantation, while edible mushrooms were described as Pleurotus ostreatus, Volvariella volvacea, Schizophyllum commune, Auricularia auricula- juda, Lentinus major-caja, and Panus neostrigosus. According to previous use, two species Favolus grummocephalus and Panus neostrigosus are known as therapeutic agents (Susan and Retnowati, 2017).

The bioactivities of macrofungal extracts as antimicrobials and antioxidants need to be investigated because antibacterial and antioxidant compounds play an important role in protecting and improving the quality of human existence. Therefore, this research aims to evaluate the antibacterial and antioxidant activity of macrofungal extracts from Enggano Island.

**MATERIALS AND METHODS**

**Sample collection**

Macrofungi were collected from Enggano Island, Bengkulu. Identification was carried out at the Herbarium Bogoriense, Research Center for Biology-Indonesian Institute of Sciences, Cibinong, Bogor.

**Sample extraction**

As much as 10 g of macrofungi fruiting bodies were extracted with 100 mL ethanol for 3 x 24 hours by changing ethanol every 24 hours, then successively partitioned with 100 mL of each solvent (n-hexane, dichloromethane, ethyl acetate, and methanol) respectively for 3 x 24 hours. To obtain a crude extract, the filtrates of each solvent were gathered and dried using a rotary evaporator at 35 °C.

**Thin Layer Chromatography (TLC) analysis of chemical compounds**

TLC was used to analyze the chemical compounds in macrofungal extracts. The dried extract was created at a concentration of 10 mg/mL. The macrofungal extract was transferred (10 μL) to TLC silica plates (GF 254, Merck) at the prepared concentration. n-hexane extract was eluted with an eluent system of hexane:ethyl acetate (3:1), dichloromethane, and ethyl acetate extracts were eluted with an eluent system of dichloromethane: methanol (10:1), and methanol extract was eluted with an eluent system of dichloromethane:methanol (4:1). Under UV light at 254 and 366 nm, eluted chemical compounds were visualized before being sprayed with coloring reagent (1% vanillin-sulfuric acid and 1% cerium (IV) sulfate) (Praptiwi et al., 2018).

**Antibacterial activity assay by TLC-bioautography**

The antibacterial activity of the macrofungal extract was evaluated qualitatively using TLC-bioautography-guided screening (Dewanjee et al., 2015) against Staphylococcus aureus InaCC B4 and Escherichia coli InaCC B5. 10 μL of extract (10 mg/mL) were transferred to a TLC plate and dipped in Mueller-Hinton Broth (MHB) containing 10^8 CFU/mL of bacterial inoculants. The plates were incubated at 37 °C for 18 hours. The incubated plates were sprayed with p-iodonitrotetrazolium 4 mg/mL (Sigma-Aldrich) solution to observe bacterial growth. As a positive control, chloramphenicol solution (Sigma-Aldrich) was used. Bacterial growth inhibition is implied by the existence of a white zone around the extract on a purple background (Das et al., 2010).
**Determination of Minimum Inhibitory Concentration (MIC) value**

The MIC of both extracts and the reference antibiotic, chloramphenicol, were determined by serial microdilution using a 96-well microplate. The extracts of the macrofungi and the reference antibiotic were prepared in dimethylsulfoxide (DMSO, Merck) at a concentration of 20480 μg/mL. The Mueller-Hinton broth (MHB, Merck) and extracts were applied to the 96-well microplate, and serial dilutions were conducted to achieve final concentrations of 1024, 512, 256, 128, 64, 32, 16, and 8 μg/mL in that order, and then 100 μL of bacterial suspension (S. aureus and E. coli) (10⁵ CFU/mL) was added to each well. After incubating the microwell plate at 37 °C for 18 hours, 10 μL of 4 mg/mL INT was applied to each well. The MIC value is the lowest concentration of extract needed to inhibit bacterial growth, as determined by the well that does not change color after the addition of INT (Pessini et al., 2003).

**Antioxidant activity assay by TLC-bioautography**

The TLC-bioautography-guided screening was used to assess the antioxidant efficacy of macrofungal extract and positive control, (+)-catechin against 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Wang et al., 2012). 10 μL of extract (10 mg/mL) and (+)-catechin were transferred to a TLC plate and sprayed with a solution of 1 mM DPPH (Sigma-Aldrich) in methanol. After spraying with DPPH reagent, the yellow spot against the purple background revealed antioxidant activity.

**Antioxidant Activity Index (AAI) and IC₅₀ value determination**

Determination of the IC₅₀ value of the extract was carried out by the serial microdilution method using a 96-microwell plate (Takao et al., 2015). The first wells were prepared with a 100 μL methanol solution, while the remaining wells were prepared with 50 μL methanol. 100 μL of extracts (10000 mg/L) were added to the first wells and thoroughly mixed. Serial dilutions were performed to obtain final concentrations of 10000–78.125 mg/L. After diluting, 80 μL DPPH (1mM) was applied to each well.

The microplates were incubated for 90 minutes at room temperature in dark conditions. The absorbance of the extracts was measured at 517 nm using a microplate reader (Varioscan flash, Thermo scientific). The IC₅₀ value was calculated using the extract concentration and the IC values from the linear regression equation. The Antioxidant Activity Index (AAI), which is formulated as follows, was used to classify antioxidant activity (Scherer and Godoy, 2009; Praptiwi et al., 2018):

$$\text{AAI} = \frac{\text{The final concentration of DPPH in the reaction (μg/ml)}}{\text{IC₅₀ (μg/ml)}}$$
Figure 1. Chromatograms of macrofungal extracts from Enggano developed with an eluent system of n-hexane:ethyl acetate (3:1) (no.1–4), dichloromethane:ethanol (10:1) (no.5–12), and dichloromethane:ethanol (4:1) (no.13–16). The chromatogram was observed under the following conditions: (a) UV 254 nm, (b) UV 366 nm, (c) sprayed with 1% cerium (IV) sulfate, and (d) 1% vanillin-sulphuric acid. (Kromatogram ekstrak jamur makro dari Enggano dielusi dengan sistem pelarut n-heksana:etil asetat (3:1) (no.1-4), diklorometana:metanol (10:1) (no.5-12), dan diklorometana:metanol (4:1) (no.13-16). Kromatogram diamati pada kondisi: (a) UV 254 nm, (b) UV 366 nm, (d) disemprot dengan 1% serium (IV) sulfat, dan (d) 1% vanillin-sulfat).

Figure 2. Bioautogram of antibacterial activity of macrofungi extracts from Enggano against (a) *S. aureus* and (b) *E. coli*. Extracts no. 1–16 refer to Table 1. K+: chloramphenicol. (Bioautogram aktivitas antibakteri ekstrak jamur makro dari Enggano terhadap (a) *S. aureus* dan (b) *E. coli*. Ekstrak no. 1-16 sesuai dengan Tabel 1. K+: kloramfenikol).
The dehydrogenase enzyme in living microorganisms converts INT into purple formazan, resulting in the development of a purple stain on the TLC plate after being sprayed with INT solution (Silva et al., 2005). The extract of macrofungi that inhibited bacterial growth was then quantitatively tested. The microdilution approach was used to assess the MIC value of each extract in a quantitative study of macrofungal extract from Enggano Island (Table 1).

Table 1. MIC values of macrofungal extract from Enggano (Nilai KHM ekstrak jamur makro dari Enggano)

<table>
<thead>
<tr>
<th>No.</th>
<th>Macrofungal extracts</th>
<th>MIC value Nilai KHM (μg/mL)</th>
<th>S. aureus</th>
<th>E. coli</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>n-hexane <em>Pycnoporus sanguineus</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>n-hexane <em>Lentinus sajor-caju</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>n-hexane <em>Coriolopsis polyzona</em></td>
<td>256</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>n-hexane <em>Earliella scabrosa</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Dichloromethane <em>Pycnoporus sanguineus</em></td>
<td>512</td>
<td>&gt; 512</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dichloromethane <em>Lentinus sajor-caju</em></td>
<td>512</td>
<td>512</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Dichloromethane <em>Coriolopsis polyzona</em></td>
<td>NT</td>
<td>&gt; 512</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Dichloromethane <em>Earliella scabrosa</em></td>
<td>NT</td>
<td>&gt; 512</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Ethyl acetate <em>Pycnoporus sanguineus</em></td>
<td>512</td>
<td>512</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Ethyl acetate <em>Lentinus sajor-caju</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Ethyl acetate <em>Coriolopsis polyzona</em></td>
<td>NT</td>
<td>512</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Ethyl acetate <em>Earliella scabrosa</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Methanol <em>Pycnoporus sanguineus</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Methanol <em>Lentinus sajor-caju</em></td>
<td>512</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Methanol <em>Coriolopsis polyzona</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Methanol <em>Earliella scabrosa</em></td>
<td>NT</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Chloramphenicol</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

*NT: not tested, a qualitative assay revealed poor antibacterial activity. (TD: tidak diuji, pengujian kualitatif menunjukkan aktivitas antibakteri yang lemah).

The antibacterial activity of the extract is classified as follows: MIC values of < 100 μg/mL (strong), 100 < MIC ≤ 625 μg/mL (moderate), and MIC values > 625 μg/mL (weak) (Kuete and Efferth, 2010). Based on the classification of antibacterial activity, it can be concluded that extract no. 3, 6, 9, and 11 have moderate activity in inhibiting the growth of *S. aureus* and *E. coli*, while extract no. 5 was only moderately effective in inhibiting *S. aureus* growth. The antibacterial activity of n-hexane extract of *Coriolopsis polyzona*, is the highest among the macrofungal extracts, both against *S. aureus* and *E. coli*.

Antioxidant activity

The antioxidant activity of macrofungal extracts against the free radical DPPH was evaluated qualitatively using the TLC-bioautography method. The formation of a yellow zone around the extract in the qualitative assay indicated that only twelve extracts have the potential to scavenge DPPH radicals (Figure 3).

The formation of yellow color on the plate after being sprayed with DPPH is caused by the antioxidants in the extract donate electrons or hydrogen atoms to the DPPH, causing DPPH to be reduced and the color change from purple to yellow. The strength of the yellow color showed the
antioxidant potential. Because DPPH is a stable free radical, it is the most widely used to assess antioxidant activity. Furthermore, twelve extracts were quantitatively evaluated using a 96-microwell plate to determine the IC₅₀ and AAI values (Table 2). The IC₅₀ value is defined as the extract concentration needed to reduce DPPH free radicals by 50% (Molyneux, 2004).

Figure 3. Bioautogram of antioxidant activity of macrofungal extracts from Enggano. Extracts no. 1–16 refer to Table 1. C+: (+)-catechin. (Bioautogram aktivitas antioksidan ekstrak jamur makro dari Enggano. Ekstrak no. 1-16 sesuai dengan Tabel 1. C+: (+)-katekin).

The classification of antioxidant activity for extracts is described as follows: AAI < 0.5 (weak), AAI 0.5–1.0 (moderate), AAI 1.0–2.0 (strong), and AAI > 2 (very strong) (Scherer and Godoy, 2009). The results in table 2 revealed that twelve extracts were classified as having weak antioxidants, while (+)-catechin as a positive control exhibited very strong antioxidant properties.

Table 2. IC₅₀ and AAI values of macrofungi extract from Enggano (Nilai IC₅₀ dan IAA ekstrak jamur makro dari Enggano)

<table>
<thead>
<tr>
<th>No.</th>
<th>Macrofungi extracts (Ekstrak jamur makro)</th>
<th>IC₅₀ value (μg/mL)</th>
<th>AAI value (Nilai IAA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>n-hexane <em>Pycnoporus sanguineus</em></td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>2</td>
<td>n-hexane <em>Lentinus sajor-caju</em></td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>3</td>
<td>n-hexane <em>Coriolopsis polyzona</em></td>
<td>4670</td>
<td>0.052</td>
</tr>
<tr>
<td>4</td>
<td>n-hexane <em>Earliella scabrosa</em></td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>5</td>
<td>Dichloromethane <em>Pycnoporus sanguineus</em></td>
<td>3390</td>
<td>0.072</td>
</tr>
<tr>
<td>6</td>
<td>Dichloromethane <em>Lentinus sajor-caju</em></td>
<td>7370</td>
<td>0.033</td>
</tr>
<tr>
<td>7</td>
<td>Dichloromethane <em>Coriolopsis polyzona</em></td>
<td>7070</td>
<td>0.034</td>
</tr>
<tr>
<td>8</td>
<td>Diklorometana <em>Earliella scabrosa</em></td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>9</td>
<td>Ethyl acetate <em>Pycnoporus sanguineus</em></td>
<td>5060</td>
<td>0.048</td>
</tr>
<tr>
<td>10</td>
<td>Ethyl acetate <em>Lentinus sajor-caju</em></td>
<td>7360</td>
<td>0.033</td>
</tr>
<tr>
<td>11</td>
<td>Ethyl acetate <em>Coriolopsis polyzona</em></td>
<td>3080</td>
<td>0.079</td>
</tr>
<tr>
<td>12</td>
<td>Ethyl acetate <em>Earliella scabrosa</em></td>
<td>3810</td>
<td>0.064</td>
</tr>
<tr>
<td>13</td>
<td>Methanol <em>Pycnoporus sanguineus</em></td>
<td>4520</td>
<td>0.054</td>
</tr>
<tr>
<td>14</td>
<td>Methanol <em>Lentinus sajor-caju</em></td>
<td>3340</td>
<td>0.073</td>
</tr>
<tr>
<td>15</td>
<td>Methanol <em>Coriolopsis polyzona</em></td>
<td>5410</td>
<td>0.045</td>
</tr>
<tr>
<td>16</td>
<td>Methanol <em>Earliella scabrosa</em></td>
<td>3770</td>
<td>0.064</td>
</tr>
<tr>
<td>17</td>
<td>(+)-Catechin</td>
<td>2.03</td>
<td>15.18</td>
</tr>
</tbody>
</table>

*NT: not tested, a qualitative assay revealed poor antioxidant activity. (TD: tidak diuji, engujian kualitatif menunjukkan aktivitas antioksidan yang lemah).
DISCUSSION

Based on morphological characteristics, four types of macrofungi collected from Enggano Island in Bengkulu were identified as *Pycnoporus sanguineus*, *Lentinus sajor-caju*, *Coriolopsis polyzona*, *DanEarliella scabrosa*. The four types of these macrofungi belong to Basidiomycota. *Pycnoporus sanguineus* is white-rot basidiomycetes widely studied because of its ability to produce bioactive compounds and valuable enzymes (Rohr et al., 2013). This macrofungus is widely used for wound and skin lesion therapy, as well as antiviral, antibacterial, pigment-producing, lignin cellulose-producing enzymes, antioxidants, and antifungals (Smánia et al., 2003; Hwang et al., 2004; Lomascolo et al., 2011). Based on the research of Achenbach and Blum (1991), this macrofungi produced red pigment, which contains alkaloids such as phenoxazin-3-one, which acts as an active compound. Smania et al., (1995) reported that fraction B of *P. sanguineus* had antibacterial activity against several bacteria with MIC values of 190–1250 µg/mL. Cinnabar, a bioactive compound isolated from *P. sanguineus* had antibacterial activity against several bacteria with MIC values of 62.5–4000 µg/mL (Smania et al., 1998). Antibacterial activity of low-molecular-weight secondary metabolite subfractions from cultures of *P. sanguineus* grown at 30 °C against *S. aureus* with MIC value of 120 µg/mL, meanwhile the IC50 value for DPPH assay was 51.46 µg/mL (Jaszek et al., 2015).

Meanwhile, *Earliella scabrosa* is a polypore fungus that can be found in rainforests. This fungus has been used as an antioxidant and free radical scavenger (Zmitrovich et al., 2017). In other studies, it was stated that water and methanol extracts of *E. scabrosa* and *P. sanguineus* were active against several wood-degrading fungi with MIC values of 100–5000 µg/mL (Teoh et al., 2011; Peng and Don, 2013). *E. scabrosa* contains triacetin, furanone derivative, and pyran derivative, while *P. sanguineus* contains 4H-pyranone derivatives that have been shown to inhibit the growth of several wood-degrading fungi (Teoh et al., 2011; Peng and Don, 2013). The bioactive compound such as isocoumarin is successfully used in cancer therapy (Zmitrovich et al., 2017).

While other macrofungi, *L. sajor-caju* or *Pleurotus sajor-caju* is a type of macrofungi that is most commonly found in Indonesia (Susan and Retnowati, 2017). It has antioxidant, antibacterial, and nutritive properties (Singdevsachan et al., 2013). The aqueous and organic solvent extracts of *L. sajor-caju* or *P. sajor-caju* had antibacterial activity against several pathogenic bacteria with inhibition growth zone diameter of 12–22 mm (Tambekar et al., 2006). Based on the research of Mossebo et al., (2020), the MIC value of crude extract of *L. sajor-caju* was 6.25 mg/mL for *S. aureus* and 12.5 mg/mL for *E. coli*.

Macrofungi *Coriolopsis polyzona* has been known as lignin-modifying enzyme, based decolorization of olive mill wastewaters (Jauan et al., 2006), and the methanolic extract had antibacterial against several positive and negative-Gram bacteria, and antifungal activity against some fungi with inhibition zone diameter of 10–25 mm (Al-Fatimi et al., 2012).

This study revealed that n-hexane extract of *C. polyzona* had the highest activity in inhibiting the growth of *S. aureus* and *E. coli*. n-hexane has a lower polarity compared to dichloromethane, ethyl acetate, and methanol. The bioactive compounds in n-hexane extract contributed to antibacterial have a lower polarity. The previous study stated that secondary metabolites related to the polarity properties might be attributed to the antimicrobial activity of *C. polyzona* extract. The bioactive compounds as an antimicrobial activity have the following functional groups: hydroxyl (OH), alkyl (C-H), carbonyl (C=O), an aromatic ring (Ogidi and Oyetayo, 2015). The previous study stated this macrofungus is an antifungal, organic polymer degrading, antioxidant, and anticancer agent with secondary metabolites containing saponins, flavonoids, tannins, alkaloids, and steroids in *C. polyzona* extracts (Oyetayo et al., 2013; Ogidi and Oyetayo, 2015). According to another study, these phytochemicals have already been identified to have an antifungal capacity (De Silva et al., 2013).

Moreover, n-hexane *C. polyzona* extract also demonstrated greater antibacterial activity against *E. coli* (a Gram-negative bacteria) compared to *S. aureus* (a Gram-positive bacteria). This is probably related to the capability of antibiotic resistance of *S. aureus* bacteria. These bacteria have been reported to overgrow and succeed because they produce the enzyme coagulase associated with pathogenicity in these bacteria (Elfirta and Sasakiwan, 2020). Pathogenicity is affected by coagulase action, which can coagulate and accumulate fibrin across the bacteria, making it difficult for antibiotics to reach the bacterial cell wall (Kumar et al., 2017).

*P. sanguineus* produces poliporin that has an antibacterial activity (Bose, 1946). *P. sanguineus* also synthesizes an orange pigment called cinnabar that is more active against gram-positive bacteria (Smánia et al., 1998). A study by Rosa et al., (2003) displayed that *P. sanguineus* CCB277 extract could inhibit the growth of *C. kruerl, L. monocytogenes*, and *S. aureus*. Another study also observed a severe disruption of bacterial cells which were treated with low-molecular-weight secondary metabolite subfractions from cultures of *Pycnoporus sanguineus* grown at 30 °C (Jaszek et al., 2015). However, the mechanism of action of these antimicrobial compounds from *P. sanguineus* is still not clear and described in the available reports.
Ngai and Ng (2004) reported that *L. sajor-caju* produces a ribonuclease that is active against *S. aureus* and *P. aeruginosa*. This RNase has an N-terminal sequence that resembles the C-terminal sequence of bacteriocin peptide and also has a similarity to a part of RNA polymerase and an RNA-specific sequence. Hence, this resemblance may play a role in the antibacterial and RNase activities of this *L. sajor-caju*. *C. polyzona* has been reported to have antibacterial and antifungal properties (Oyetayo and Ogidi, 2011; Ogidi and Oyetayo, 2015). However, the underlying mechanisms, as well as the compounds that are responsible for its bioactivities, have not been reported. Liew et al., (2015) reported that crude ethanol extract of *E. scabrosa*, which contained saponin was most active against *Pseudomonas aeruginosa* (MIC = 28.13 μg/mL) and less active against *S. pyogenes, Clostridium difficile, S. aureus,* and *E. coli*. However, further studies are needed as the mode of action as well as the responsible compound for this antibacterial activity are still unclear.

CONCLUSION

Several macrofungal extracts from Enggano Island, including n-hexane extracts (*C. polyzona*), dichloromethane extract (*L. sajor-caju*), ethyl acetate extracts (*P. sanguineus* and *C. polyzona*), have moderate antibacterial activity in inhibiting the growth of *S. aureus* and *E. coli*. Among all tested extracts, n-hexane extract *Coriolopsis polyzona* showed moderate antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* with MIC values of 256 and 128 μg/mL, respectively. Meanwhile, the antioxidant activity of all macrofungal extracts displayed weak activity with IC50 values of 3080-7370 μg/mL (AAI values of 0.033-0.079). Therefore, according to this study, macrofungal extracts from Enggano Island may contain valuable bioactive compounds with antibacterial activity. However, further investigation studies need to be carried out to isolate and characterize the bioactive compounds of the extract.

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