

Antimicrobial activity of polyisoprenoids of sixteen mangrove species from North Sumatra, Indonesia

SUMARDI¹, MOHAMMAD BASYUNI^{2,3,*}, RIDHA WATI²

¹Faculty of Pharmacy, Universitas Tjut Nyak Dhien. Jl. Rasmi No. 28, Medan 20123, North Sumatra, Indonesia

²Departement of Forestry, Faculty of Forestry, Universitas Sumatera Utara. Jl. Tri Dharma Ujung No. 1, Medan 20155, North Sumatra, Indonesia.
Tel./fax.: +62-61-820-1920. *email: m.basyuni@usu.ac.id

³Mangrove and Bio-Resources Group, Center of Excellence for Natural Resources Based Technology, Universitas Sumatera Utara. Medan 20155, North Sumatra, Indonesia

Manuscript received: 25 April 2018. Revision accepted: 5 June 2018.

Abstract. Sumardi, Basyuni M, Wati R. 2018. Antimicrobial activity of polyisoprenoids of sixteen mangrove species from North Sumatra, Indonesia. *Biodiversitas* 19: 1243-1248. Mangroves including those that are distributed in the coast of North Sumatra contain polyisoprenoid with varying levels of polyprenol and dolichol constituents. Differences in polyisoprenoid levels were closely related to the salinity of sea but the information about their biological activities is scarce. The present study aimed to describe the biological activities, antimicrobial, antioxidant, and antifungal effects of polyisoprenoid extracts from sixteen mangrove species of North Sumatra, Indonesia. Polyisoprenoids were isolated from mangrove leaves and tested for their antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans*. Meanwhile, their antioxidant activity was represented by their capacity in scavenging DPPH (2,2-diphenyl-1-picrylhydrazyl) free-radical agents. The most predominant polyisoprenoids found in sixteen mangrove leaf extracts was dolichols (75%). Polyprenols-dominant species, *Acacia auriculiformis*, *Hibiscus tiliaceus*, *Pongamia pinnata*, and *Ricinus communis*, and dolichols-dominant species, *Avicennia lanata*, *Av. marina*, *Av. officinalis*, *Barringtonia asiatica*, *Bruguiera gymnorhiza*, *Calophyllum inophyllum*, *Nypa fruticans*, and *Pandanus odoratissimus*, inhibited the growth of *E. coli* and *S. aureus*. However, the antioxidant activity of those sixteen mangrove species was of a weak category. Surprisingly, all other mangroves polyisoprenoid extracts did not inhibit *C. albicans* growth. This study suggested that polyisoprenoids in mangroves have potential antibacterial properties to be developed further.

Keywords: Antioxidant, antibacterial, antifungal, mangrove leaves, nonsaponifiable lipid

INTRODUCTION

Mangroves exist widely in the tropics and subtropics where 75% of them are distributed in 15 countries while 22.6% of the global mangrove was found in Indonesia (Giri et al. 2010). Mangrove forest in North Sumatra mainly existed in the eastern coast of Sumatra island and occupied 37,132.62 ha in 2015 (Basyuni and Sulistiyono 2018). Mangroves play an important role in the socio-economic development of surrounding communities, especially in the region of North Sumatra (Basyuni et al. 2018a, 2018b). Mangroves are used as firewood and charcoal, as well as for traditional medicine (Bandaranayake, 1998). Mangroves are well known to produce secondary metabolites that have promising health benefits, lipid input into estuarine, and biomarkers for organic matters (Basyuni et al. 2007; Patra and Thatoi 2010; Koch et al. 2011).

The enormous potential of mangrove' bioactive compounds is not fully utilized. In this context, mangroves can be used for pharmaceutical, especially antimicrobial (Patra and Thatoi 2010). The antimicrobial development has a role of important because of the crisis of antibiotic resistance. They have played in medicine, surgery and chemotherapy. Beside that continuous use of them cause side effects on the degenerative therapy (Ventola 2015).

Polyisoprenoid alcohols were a group of compounds that have an essential role in living things, including in mangrove plants that are firmly related to the biosynthesis of secondary metabolites of isoprenoid (Basyuni et al. 2007, 2016, 2017a, 2018c). Isoprenoid and polyisoprenoid compounds are the most diverse plant secondary metabolites (Basyuni et al. 2007, 2012, 2016, 2017a; Skorupinska-Tudek et al. 2008; Koch et al. 2011). These compounds were encoded by oxidosqualene cyclase (OSC) gene (Basyuni et al. 2012; Lodeiro et al. 2007). The OSC and salt tolerance genes play an important role in adaptation to salinity tolerance (Basyuni et al. 2012; Basyuni and Sumardi 2017c). The content of isoprenoids and polyisoprenoids have opposed seawater stress in mangrove leaves (Basyuni et al. 2012, 2017d; Basyuni and Sumardi 2017b).

Mangrove plants are commonly used for medical purpose, but there is still little information about the biological activity of the polyisoprenoid of the plants. Study on mangrove polyisoprenoid compounds, especially in light of their function as antimicrobial, antioxidant, and antifungal agents, is required for pharmaceutical and medicinal purpose. We are interested in providing complete information for the utilization of the compounds in the field of medicine, food, industry, and others. Therefore, our current study aimed to describe the antimicrobial,

antioxidant and antifungal activities of polyisoprenoid extract from sixteen mangrove species in North Sumatra, Indonesia.

MATERIALS AND METHODS

Sample collection

Leaves from sixteen mangrove species were collected from Lubuk Kertang and Pulau Sembilan mangrove forest, Langkat, North Sumatra, Indonesia. These species are *Acacia auriculiformis* (Fabaceae), *Avicennia alba* (Acanthaceae), *A. lanata* (Acanthaceae), *A. marina* (Acanthaceae), *A. officinalis* (Acanthaceae), *Barringtonia asiatica* (Lecythidaceae), *Bruguiera gymnorrhiza* (Rhizophoraceae), *Calophyllum inophyllum* (Calophyllaceae), *Ceriops tagal* (Rhizophoraceae), *Hibiscus tiliaceus* (Malvaceae), *Nypa fruticans* (Arecaceae), *Pandanus odoratissimus* (Pandanaceae), *Pongamia pinnata* (Fabaceae), *Ricinus communis* (Euphorbiaceae), *Rhizophora mucronata* (Rhizophoraceae), and *Stachytarpheta jamaicensis* (Verbenaceae). The leaves were dried at 60-75°C for two days for further analysis.

Polyisoprenoid extraction

Polyisoprenoid extraction method was performed as described previously (Sagami et al. 1992; Basyuni et al. 2016, 2017a, 2018c). The dried leaves (3-7 g) were first ground and extracted with 30 mL of chloroform-methanol (2: 1, v: v) for 48 h. The insoluble cell wall debris was removed following the method of Basyuni et al. (2016). The lipid extract of leaves was saponified with 4 mL 2 M KOH in 50% ethanol solution at 60°C for 24 h. The nonsaponifiable lipids (NSL) were then regarded as polyisoprenoids and partitioned into n-hexane. The extracted polyisoprenoids were applied for antimicrobial, antifungal, and antioxidant activity tests.

Antimicrobial and antifungal activities

The antibacterial and antifungal activity tests were done as previously reported by Okigbo and Mmeka (2008). Tests were done on two organisms, *S. aureus* and *E. coli*. The antibacterial test was performed on nutrient agar plates prepared by dissolving 28 g of nutrient agar in 1 L of water. The antifungal test against *C. albicans* was done on sabour and dextrose agar prepared by dissolving 64 g in 1 L of water. The media culture to be poured into a petri dish and made wellbore with a diameter 6 mm. Media were sterilized in an autoclave at 121°C for 15 min (Okigbo and Mmeka, 2008).

One hundred (100) mg/mL extracts were prepared in dimethyl sulfoxide (DMSO): ethanol (1: 2, v: v) solution. The extract was placed on culture plates in triplicate (Okigbo and Mmeka, 2008). The culture was incubated in an incubator for 24 h for antibacterial assay and 48 h for the antifungal test at 37°C, respectively. The zone of inhibition of plant extracts was observed and measured. The solvent was used as negative control.

Antioxidant activity

Antioxidant activity assay was carried out based on the modification of standard DPPH (2,2-diphenyl-1-picrylhydrazyl) method (Mustarichie et al. 2017). DPPH solution was prepared with a concentration of 60 µg/mL. DPPH maximum wavelength and the specified operating time of DPPH in methanol were determined. Its absorbance was measured using UV-Vis spectrophotometer every min for two h. Each of polyisoprenoid was prepared in methanol: n-hexane (4: 1, v/v) and made in three various concentrations. Each 0.2 mL of test solution was mixed with 1 mL DPPH and 3.8 mL methanol: n-hexane (4: 1, v/v). The mixture was incubated for two h at room temperature, then measured using UV-Vis spectrophotometry at maximum wavelength 517 nm. Percentage of inhibition, regression curves, and the linear equation were applied to calculate the IC₅₀ as previously reported (Sebaugh 2011).

RESULTS AND DISCUSSION

In this study, isolation of polyisoprenoid from 16 species of mangrove plants was performed using a previously described protocol (Basyuni 2016, 2017a, 2018c). As displayed in Table 1, polyisoprenoid in the form of polyprenol is predominantly detected in four species of mangroves, *Ac. auriculiformis*, *H. tiliaceus*, *P. pinnata*, and *R. communis*. Meanwhile, dolichols predominantly (more than 90%) compose the polyisoprenoids in the 12 mangrove species tested.

The result of polyisoprenoid extracts inhibitory test against *E. coli* and *S. aureus* as representatives of gram-negative and gram-positive bacteria, respectively, were shown in Table 2 and Figure 1. *N. fruticans* and *C. tagal* had the largest and smallest diameter of inhibition area against *E. coli*, respectively. Meanwhile, *C. tagal* and *R. communis* had the largest and smallest diameter of inhibition area against *S. aureus*, respectively. Determination of antioxidant activity of the mangrove extract followed a previously reported method (Marjoni and Zulfisa, 2017). Meanwhile, determination of antimicrobial effectivity followed a method described by Herni et al. (2016). Interestingly, the mangrove species containing polyprenols, *Ac. auriculiformis*, *H. tiliaceus*, *P. pinnata*, and *R. communis*, and eight species with predominant dolichols content, *Av. lanata*, *Av. marina*, *Av. officinalis*, *B. asiatica*, *B. gymnorrhiza*, *C. inophyllum*, *N. fruticans*, and *P. odoratissimus*, inhibited the growth of *E. coli* and *S. aureus* (Table 2).

The inhibitory test against *C. albicans* fungi was shown in Table 2. All the mangroves did not show an inhibitory effect on *C. albicans* culture growth. Antioxidant activity of polyisoprenoid extracted from each mangrove was shown in Table 3. The antioxidant assay for a natural substance using DPPH radical agents has been established (Milardović et al. 2006). A high degree of DPPH scavenging indicates an excellent antioxidant activity.

Acacia auriculiformis showed weak antioxidant activity with an IC₅₀ of 17100 µg/mL, but the polyisoprenoid from

this species was able to inhibit the growth of *E. coli* and *S. aureus* with inhibitory diameter 13.7 and 12.29 mm, respectively, while no activity against *C. albicans*. This result suggests that the polyisoprenoid of *Ac. auriculiformis* may not have antifungal property. Polar extract such as saponins in *Ac. auriculiformis* has been reported to inhibit *Bacillus megaterium*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa* (Mandal et al. 2005).

Avicennia alba is one of the medicinal plants traditionally used by communities. Polar extract of *Av. alba* Bark are able to inhibit the culture of bacterial bacteria but that n-hexane extract of the plant was not active against the bacteria (Vadlapudi and Naidu 2009). Polyisoprenoid of *Av. alba* moderately impedes the growth of *S. aureus* with a diameter of inhibition of 9.24 mm (Table 2). In contrast, dolichols family compounds did not show significant inhibitory effect against to *E. coli* and *C. albicans* (Table 1).

Table 1. Polyisoprenoid profile of sixteen mangroves species

Species	Polyisoprenoid (%)	
	Polyprenol	Dolichol
<i>Ac. auriculiformis</i> ^c	100	0
<i>Av. alba</i> ^b	0	100
<i>Av. lanata</i> ^b	0	100
<i>Av. marina</i> ^a	4.2	95.8
<i>Av. officinalis</i> ^b	0	100
<i>B. asiatica</i> ^c	8	92
<i>B. gymnorhiza</i> ^a	0	100
<i>C. inophyllum</i> ^c	0	100
<i>C. tagal</i> ^b	0	100
<i>H. tiliaceus</i> ^a	100	0
<i>N. fruticans</i> ^b	0	100
<i>P. odoratissimus</i> ^c	0	100
<i>P. pinnata</i> ^c	100	0
<i>R. communis</i> ^c	100	0
<i>R. mucronata</i> ^b	9.8	90.2
<i>S. jamaicensis</i> ^c	0	100

Note: ^a Basyuni et al. (2016), ^b Basyuni et al. (2017), ^c Basyuni et al. (2018)

Table 2. Antibacterial and antifungal activities of polyisoprenoid in 16 mangrove leaves

Sampel	Diameter of Inhibition (mm)		
	<i>E. coli</i>	<i>S. aureus</i>	<i>C. albicans</i>
<i>Ac. auriculiformis</i>	13.17±4.63	12.29±0.87	na
<i>Av. alba</i>	na	9.24±0.22	na
<i>Av. lanata</i>	10.19±0.01	13.25±0.32	na
<i>Av. marina</i>	10.85±0.58	10.52±0.38	na
<i>Av. officinalis</i>	12.66±0.71	8.85±0.56	na
<i>B. asiatica</i>	12.83±0.58	9.6±0.51	na
<i>B. gymnorhiza</i>	10.16±1.02	11.645±0.67	na
<i>C. inophyllum</i>	9.65±0.74	8.66±0.38	na
<i>C. tagal</i>	9.14±0.01	13.48±3.10	na
<i>H. tiliaceus</i>	10.52±0.59	11.57±1.31	na
<i>N. fruticans</i>	14.48± 1.17	11.66±0.33	na
<i>P. odoratissimus</i>	12.49±0.58	12.38±0.72	na
<i>P. pinnata</i>	10.19±0.01	10.96±0.10	na
<i>R. communis</i>	10.16±1.02	8.23±0.06	na
<i>R. mucronata</i>	na	11.09±0.86	na
<i>S. jamaicensis</i>	9.99±0.80	11.35±0.18	na

Note: na: not active

Even though the polyisoprenoid of *Av. lanata* showed a weak scavenging activity toward DPPH but the extract inhibited the growth of the pathogenic bacteria (Table 2 and 3). *S. aureus* was inhibited more strongly than *E. coli* by the *Av. lanata* extract. The polar extract of *Avicennia* has been reported to have antimicrobial, antidiarrhoeal, analgesic and antipyretic, antiulcer, antinociceptive, anti-inflammatory, diuretic and neuropharmacological activities (Thatoi et al. 2016).

Table 3. Antioxidant activity of polyisoprenoid from 16 mangrove leaves

Sample	Conc. (µg/mL)	% Inhibition	Regression equation	IC ₅₀ (µg/mL)
<i>Ac. auriculiformis</i>	4800	25.75	y = 0.002x + 15.80	17100
	480	17.92		
	48	14.89		
<i>Av. alba</i>	2720	32.53	y = 0.002x + 25.50	12250
	272	26.78		
	27.2	25.07		
<i>Av. lanata</i>	3460	17.28	y = 0.003x + 5.958	14681
	346	8.56		
	34.6	4.75		
<i>Av. marina</i>	2800	17.03	y = 0.003x + 9.316	13561
	280	18.46		
	28	1.86		
<i>Av. officinalis</i>	3260	46.37	y = 0.004x + 31.94	4515
	326	33.44		
	32.6	32.05		
<i>B. asiatica</i>	6000	59.14	y = 0.003x + 36.72	4427
	600	41.03		
	60	35.08		
<i>B. gymnorhiza</i>	4860	11.62	nc	nc
	486	14.17		
	48.6	8.22		
<i>C. inophyllum</i>	2260	60.05	y = 0.012x + 32.44	1463
	226	35.15		
	22.6	32.77		
<i>C. tagal</i>	3240	45.41	y = 0.002x + 38.64	5680
	324	40.21		
	32.4	37.92		
<i>H. tiliaceus</i>	3240	56.83	y = 0.005x + 39.91	2018
	324	40.43		
	32.4	41.14		
<i>N. fruticans</i>	2680	54.51	y = 0.015x + 13.43	2438
	268	18.85		
	26.8	12.67		
<i>P. odoratissimus</i>	4580	0.72	nc	nc
	458	1.45		
	45.8	4.43		
<i>P. pinnata</i>	7660	64.83	y = 0.003x + 34.70	5100
	766	39.00		
	76.6	33.85		
<i>R. communis</i>	4860	42.23	y = 0.002x + 31.61	9195
	486	32.92		
	48.6	31.50		
<i>R. mucronata</i>	6920	31.35	y = 0.001x + 22.38	27620
	692	22.00		
	69.2	23.62		
<i>S. jamaicensis</i>	200	30.06	y = 0.026x + 24.75	971
	20	25.25		
	2	24.84		

Note: nc: not calculated

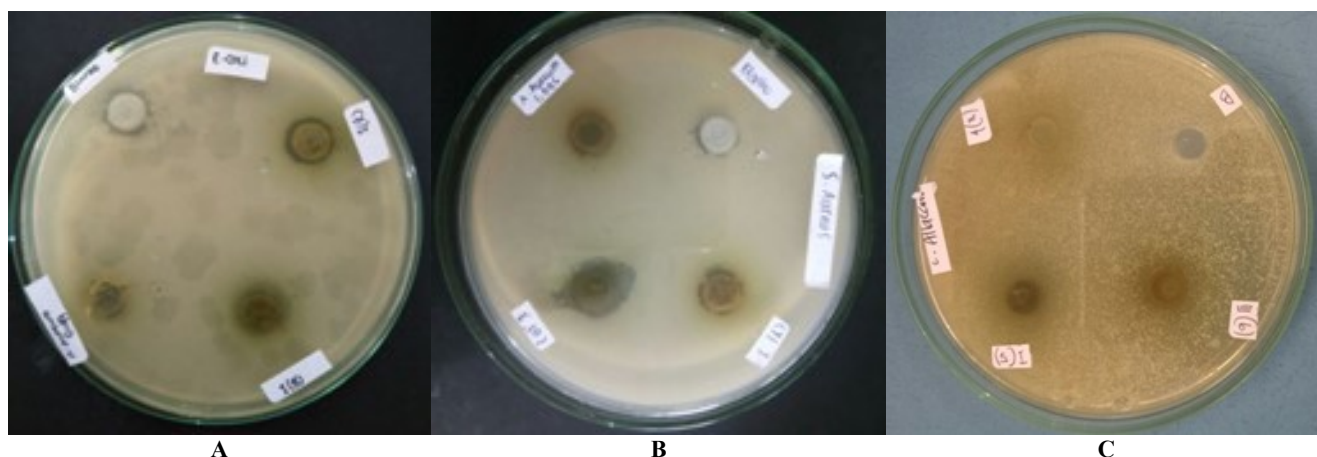


Figure 1. Zones of microbe growth inhibition produce by polyisoprenoid in leaves of the mangrove. A. *S. aureus*, B. *E. coli* , C. *C. albicans*

Avicennia marina had an IC_{50} of 13.561 $\mu\text{g/mL}$ indicating the antioxidant activity of its polyisoprenoid was of a weak category. The polyisoprenoid extract of *Av. Marina* inhibited *E. coli* and *S. aureus* with an inhibition area diameter of 10.85 mm and 10.52 mm, respectively while no inhibition zone observed in *C. albicans* culture.

Avicennia officinalis is a mangrove and medicinal plant that is distributed in Bangladesh, India, Indonesia, Malaysia, Brunei, Myanmar, Vietnam and southern Papua New Guinea (Thatoi et al. 2016)). The extract of ethyl acetate from *Av. officinalis* leaves was able to inhibit the growth of *E. coli* and *S. typhi* and has good IC_{50} in reducing DPPH free radical (Khushi et al. 2016; Bhimba et al. 2010). In line with those previous reports, in this study, polyisoprenoids extracted from *Av. officinalis* inhibited the growth of *E. coli* and *S. aureus* even though its antioxidant activity was weak. This difference in activity was due to the solubility of active phenol compounds dissolved in a polar or semi-polar solvent, i.e., lipids tend to dissolve in a nonpolar solvent.

Barringtonia asiatica extract had a stronger inhibition effect towards *E. coli* than against *S. aureus*. However, it did not inhibit the growth of *C. albicans*. Furthermore, its ability to reduce free radical DPPH was relatively weak with an IC_{50} of 4427 $\mu\text{g/mL}$. In a previous study conducted, it has been reported that *B. asiatica*'s crude methanol extract and its fractions had high antibacterial and antifungal activities (Khan and Omoloso 2002). Our result showed that the nonpolar portion of *B. asiatica* has less potential antimicrobial and antioxidant activity that compared with its polar fraction

Bruguiera gymnorrhiza is one of mangroves plants that have economically valuable fruits (Rudiyanto 2016). Polyisoprenoids of *B. gymnorrhiza* moderately inhibited the growth of *E. coli* and *S. aureus* whereas it did not exhibit scavenging activities towards DPPH free radical. In a study conducted, it has been reported that the ethanol extract, but not the chloroform extract, of *B. gymnorrhiza*, had inhibitory activity against pathogenic bacteria (Haq et al. 2011).

Calophyllum inophyllum is a medicinal plant for skin diseases including itches, skin allergy, burns and mild wounds (Girardi et al. 2015). *C. Inophyllum* seeds extract in chloroform: methanol (2:1) was able to inhibit the growth of *S. aureus* culture (Léguillier et al. 2015). In this study, we showed that *C. inophyllum* was able to inhibit the growth of *E.coli* and *S. aureus* cultures but not that of the *C. albicans* (Table 2).

Cerriops tagal is a medicinal plant that has been reported to have efficacy to treat infected wounds, obstetric, hemorrhagic, sores, malignant ulcers and malaria (Zhang et al. 2005; Bamroongrugs 1999; Wang et al. 2012; Yang et al. 2015;). In this study, we found that polyisoprenoid compounds of *C. tagal* inhibited the growth of gram-positive bacteria *S. aureus* better than that of the gram-negative bacteria *E. coli*, but not that of the *C. albicans* (Table 2). Previously, have reported that the ethanol extract of *C. tagal* and its partition did not show antimicrobial and antifungal activities. Lipid compounds in *C. tagal* have an antimicrobial property in comparison to the polar component (Bulbul et al. 2017).

Hibiscus tiliaceus has been used as a traditional medicine by Indonesian and Bangladeshi as a cough, bloody/slimy diarrhea, and tonsillitis medicines. In addition to having an inhibitory effect against pathogenic bacteria, surprisingly, the polar extract of the plant shows good cytotoxicity against cancer cell culture (Shaikh et al. 2009; Wong et al. 2010; Ramproshad et al. 2012). The polyisoprenoid of *H. tiliaceus* in this study showed a moderate inhibitory effect against *E. coli* (inhibition zone diameter 10.52 mm), and *S. aureus* (11.57 mm) while has a relatively weak antioxidant activity (Table 2 and 3).

Polyisoprenoid of *N. fruticans* showed an IC_{50} of 2438 $\mu\text{g/mL}$, indicating a weak antioxidant activity. At a concentration of 100 mg/mL, *N. fruticans* extract could inhibit the growth of *E. coli* and *S. aureus* but not that of the fungus *C. albicans* (Table 2). Yusoff et al. (2015) reported the ethyl acetate-soluble part of *N. fruticans* showed a potent antioxidant activity whereas the water

extract was able to improve blood sugar levels in streptozotocin-induced diabetic rats.

Pandanus odoratissimus has been traditionally known as one of the Indian Ayurvedic medicines for a headache, rheumatism, spasm, cold, flu, epilepsy, wounds, boils, scabies, leucoderma, ulcers, colic, hepatitis, smallpox, leprosy, syphilis, cancer, dysuric, as well as a cardiogenic, antioxidant, and aphrodisiac (Adkar et al. 2014). The ethanol extract from leaves of *P. odoratissimus* contains glycosides, flavonoids, alkaloids, saponins, flavonoids dan polyphenol were considered responsible for the effect of therapy (Gurmeet and Amrita. 2015). The polyisoprenoid extract from *P. odoratissimus* in this study showed moderate inhibition of *E. coli* and *S. aureus* (Table 2). However, the extract did not show any antioxidant activity (Table 3).

Pongamia pinnata has been used as a medicinal plant by the Indian for fever, ulcer, skin diseases, piles, bronchitis, etc. (Duke 1983). The extract of petroleum ether and ethyl acetate from leaves of *P. pinnata* did not show an inhibitory effect on *E. coli*, *S. aureus*, and *C. albicans* (Ujwal et al. 2007). In this study, polyisoprenoids from the leaves of *P. pinnata* moderately inhibited the growth of *E. coli* and *S. aureus*, but not that of the *C. albicans* (Table 2). This study suggests that the polyisoprenoid may act as an antibacterial agent and the difference in solvent's polarity may affect the solubility of the active compound.

Ricinus communis is a traditional medicinal plant, and its leaves and seeds were reported to have pharmacological effects, such as anti-inflammatory, immunomodulator, antidiabetic, antiulcer, etc. (Kumar. 2017). Polar extract from *R. communis* leaves and seeds actively inhibited the growth of pathogenic gram-negative and gram-positive bacteria (Naz and Bano. 2012). We found that the polyisoprenoid extract of *R. communis* showed a weak antioxidant activity (Table 3). Nevertheless, it inhibited the growth of *E. coli* and *S. aureus* but not that of the *C. albicans* (Table 2). The polar and non-polar extract of *R. communis* showed synergistic activity in biological effects.

Rhizophora mucronata has been traditionally used to treat diarrhea, dysentery, fever, angina, diabetes, hematuria, and bleeding (Batool et al. 2014). Hexane, chloroform and methanol extracts of leaves and roots of *R. mucronata* have been reported to have high antibacterial and antifungal activity (Kusuma et al. 2011). However, in this study, we found that the polyisoprenoid extract of the plant did not have inhibitory activity against *E. coli* and *C. albicans* while moderately inhibited the growth of *S. aureus*. *S. jamaicensis* has been reported to contain secondary metabolites alkaloids, flavonoids, phenols, steroids, and terpenoids; and has traditionally been used for medicinal purpose in various countries (Putera and Shazura 2010). The active compounds have pharmacological effects as antacid, analgesic, anti-inflammatory, hypotensive, antihelminthic, diuretic, laxative, lactagogue, purgative, sedative, spasmogenic, vasodilator, vulnerary, and vermifuge properties (Liew and Yong 2016). Our study showed that the polyisoprenoid of *S. jamaicensis* had moderate inhibitory effects on the growth of *E. coli* and *S. aureus*.

Overall, this study identifies mangroves whose polyisoprenoid content have the inhibitory effect to *E. coli* and *S. aureus* bacteria, they are *Ac. auriculiformis*, *Av. lanata*, *Av. marina*, *Av. officinalis*, *B. asiatica*, *B. gymnorrhiza*, *C. inophyllum*, *H. tiliaceus*, *N. fruticans*, *P. odoratissimus*, *P. pinnata* and *R. communis*. Information of polyprenol and dolichol compounds that have biological activity is still limited. Some mangroves species have been reported to produce polyprenyl acetone, polyprenol, and dolichol content. They were in different variations of proportion in each mangrove (Basyuni et al. 2017a). The dominant polyprenol content in polyisoprenoid has a significant inhibitory tendency against bacterial growth. The data of the antimicrobial activity of polyisoprenoid compounds was that of the polyprenol only.

In conclusion, we reveal that the polyisoprenoid extracts from the leaves of the twelve mangroves species showed significant antibacterial activities that are potential for antimicrobial drugs development.

ACKNOWLEDGEMENTS

This work was supported financially by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia through Excellent Research for Higher Education Grant (PUPT) 2017 (No. 003/SP2H/LT/DRPM/IV/2017). The authors are grateful to Devi and Aji at Research Laboratory of Faculty of Pharmacy, Universitas Sumatera Utara, Indonesia.

REFERENCES

- Bamroongrugs N. 1999. Bioactive substances from the mangrove resource. Songklanakarin J Sci Technol 21: 377-386.
- Bandaranayake WM. 1998. Traditional and medicinal uses of mangroves. Mangroves Salt Marshes 2 (3): 133-148.
- Basyuni M, Oku H, Baba S, Takara K, Iwasaki H. 2007. Isoprenoids of Okinawan mangroves as lipid input into estuarine ecosystem. J Oceanography 63: 601-608.
- Basyuni M, Baba S, Kinjo Y, Putri LA, Hakim L, Oku H. 2012. Salt-dependent increase in triterpenoids is reversible upon transfer to fresh water in mangrove plants *Kandelia candel* and *Bruguiera gymnorrhiza*. J Plant Physiol 169: 1903-1908.
- Basyuni M, Sagami H, Baba S, Iwasaki H, Oku H. 2016. Diversity of polyisoprenoids in ten Okinawan mangroves. Dendrobiology 75: 167-175.
- Basyuni M, Sagami H, Baba S, Oku H. 2017a. Distribution, occurrence, and cluster analysis of new polyprenyl acetones and other polyisoprenoids from North Sumatran mangroves. Dendrobiology 78: 18-31.
- Basyuni M, Sumardi. 2017b. Bioinformatics approach of salt tolerance gene in mangrove plant *Rhizophora stylosa*. J Phys: Conf Ser 801: 012012.
- Basyuni M, Sagami H, Baba S, Putri LA, Wati R, Oku H. 2017c. Salinity alters the polyisoprenoid alcohol content and composition of both salt-secreting and non-salt-secreting mangrove seedlings. Hayati J Biosci 24: 206-214.
- Basyuni M, Sulistiyono N. 2018a. Deforestation and reforestation analysis from land-use changes in North Sumatran Mangroves, 1990-2015. IOP Conf Ser: Mater Sci Eng 309: 012018
- Basyuni M, Harahap MA, Wati R, Slamet B, Thoha AS, Nuryawan A, Putri LA, Yusriani E. 2018b. Evaluation of mangrove reforestation and the impact to socioeconomic-cultural of community in Lubuk Kertang village, North Sumatra. IOP Conf Ser: Earth Environ Sci 126: 012113.

- Basyuni M, Harahap FK, Wati R, Putri LA. 2018c. Effect of mangrove rehabilitation on socio-cultural of Pulau Sembilan society, North Sumatera, Indonesia. IOP Conf Ser: Earth Environ Sci 126: 012115.
- Basyuni M, Wati R, Sagami H, Sumardi, Baba S, Oku H. 2018d. Diversity and abundance of polyisoprenoid composition in coastal plant species from North Sumatra, Indonesia. Biodiversitas 19: 1-11.
- Batool N, Ilyas N, Shahzad A. 2014. Asiatic mangrove (*Rhizophora mucronata*)-An overview. Eur Acad Res 2 (3): 3348-3363
- Bhimba BV, Meenupriya J, Joel EL, Naveena DE, Kumar S, Thangaraj M. 2010. Antibacterial activity and characterization of secondary metabolites isolated from mangrove plant *Avicennia officinalis*. Asian Pac J Trop Med 3 (7): 544-546.
- Bulbul IJ, Begum Y, Jahan N, Khan MM. 2017. Preliminary phytochemical screening and antimicrobial potentials of different extracts of *Aegicera corniculatum* L. and *Ceriops tagal*. Intl J Sci: Basic Appl Res 36 (3): 86-95.
- Duke JA. 1983. Handbook of energy crops. Available online: https://www.hort.purdue.edu/newcrop/duke_energy/refa-f.html
- Girardi C, Butaud JF, Ollier C, Ingert N, Weniger B, Raharivelomanana P, Moretti. 2015. Herbal medicine in the Marquesas Islands. J Ethnopharmacol 23: 161-200.
- Gurmeet S, Amrita P. 2015. Unique pandanus-flavour, food, and medicine. J Pharm Phytochem 5 (3): 08-14.
- Haq M, Sani W, Hossain ABMS, Taha RM, Monneruzzaman KM. 2011. Total phenolic contents, antioxidant and antimicrobial activities of *Bruguiera gymnorrhiza*. J Med Plants Res 5 (17): 4112-4118.
- Herni TN, Fitri A, Isnaini, Melki. 2016. Screening of *Nypa fruticans* as antibacterial of *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus*. J Maspari 8 (2): 83-90.
- Khan MR, Omoloso AD. 2002. Antibacterial, antifungal activities of *Barringtonia asiatica*. Fitoterapia 73 (3): 255-260.
- Khushi S, Hasan MM, Al-Hossain ASMM, Hossain ML, Sadhu SK. 2016. Medicinal activity of *Avicennia officinalis*: evaluation of phytochemical and pharmacological properties. Saudi J Med Pharm Sci 2 (9): 250-255.
- Koch BP, Souza Filho PW, Behling H, Cohen MC, Kattner G, Rullkötter J, Scholz-Böttcher B, Lara RJ. 2011. Triterpenols in mangrove sediments as a proxy for organic matter derived from the red mangrove (*Rhizophora mangle*). Organic Geochem 42: 62-73.
- Kumar, M. 2017. A Review on phytochemical constituents and pharmacological activities of *Ricinus communis* L. Int J Pharm Phytochem Res 9 (4): 466-472.
- Kusuma S, Kumar PA, Kamala B. 2011. Potent antimicrobial activity of *Rhizophora mucronata*. J Ecobiotech 3 (11): 40-41
- Léguillier T, Bornet ML, Lémus C, Ralliard DR, Lebouvier N, Hnawia E, Nour M, Aalbersberg W, Ghazi K, Raharivelomanana P, Rat P, Léguillier T, Leicsö BM, Lémus C, Rousseau RD, Lebouvier N, et al. 2015. The wound healing and antibacterial activity of five ethnomedicinal *Calophyllum inophyllum* oils: an alternative therapeutic strategy to treat infected wounds. Plos One 10 (9): 0138602
- Liew PM, Yong YK. 2016. *Stachytarpheta jamaicensis* (L.) Vahl: from traditional usage to pharmacological evidence. Evid Based Complement Alternat Med 2016: 7842340
- Lodeiro S, Xiong Q, Wilson WK, Kolesnikova MD, Onak CS, Matsuda SPT. 2007. An oxidosqualene cyclase makes numerous products by diverse mechanism: a challenge to prevailing concepts of triterpene biosynthesis. Journal of the American Chemical Society 129 (36): 11213-11222.
- Mandal P, Sinha BSP, Mandal NC. 2015. Antimicrobial activity of saponins from *Acacia auriculiformis*. Fitoterapia 76 (5): 462-465.
- Marjoni MR and Zulfisa A. 2017. Antioxidant activity of methanol extract/fractions of senggani leaves (*Melastoma candidum* D. Don). Pharm Anal Acta 8: 557.
- Milardović S, Iveković D, Grabarić BS. 2006. A novel amperometric method for antioxidant activity determination using DPPH free radical. Bioelectrochemistry 68 (2): 175-180.
- Naz R and Bano A. 2012. Antimicrobial potential of *Ricinus communis* leaf extracts in different solvents against pathogenic bacterial and fungal strains. Asian Pac J Trop Biomed 2 (12): 944-947.
- Okigbo and Mmeko. 2008. Antimicrobial effects of three tropical plant extract on *Staphylococcus aureus*, *Escherichia coli* and *Candida albicans*. Afr J Trad Compl Altern Med 5 (3): 226-229.
- Patra JK, Thatoi HN. 2010. Metabolic diversity and bioactivity screening of mangrove plants: A review. Acta Physiol Plant 33 (4): 1051-1061.
- Prafulla P, Adkar, Bhaskar VH. 2014. *Pandanus odoratissimus* (Kewda): A review on ethnopharmacology, phytochemistry, and nutritional aspects. Adv Pharmacol Sci 2014: 120895
- Putera I, Shazura AK. 2010. Antimicrobial activity and cytotoxic effects of *Stachytarpheta jamaicensis* (L.) Vahl crude plant extracts. [Thesis]. Universiti Teknologi Malaysia, Skudai, Johor, Malaysia.
- Qin S, Xing K, Jiang JH, Xu LH, Li WJ. 2011. Biodiversity, bioactive natural products and biotechnological potential of plant-associated endophytic actinobacteria. App Microbiol Biotechnol 89 (3): 457-473.
- Ramproshad S, Afroz T, Mondal B, Haque A, Ara S, Khan R, Ahmed S. 2012. Antioxidant and antimicrobial activities of leaves of medicinal plants *Hibiscus tiliaceus* L. Pharmacologyonline 3: 82-87.
- Resmi M, Runadi D, Ramdhani D. 2017. The antioxidant activity and phytochemical screening of ethanol extract, fractions of water, ethyl acetate, and n-hexane from mistletoe tea (*Scurrulaa tropurpurea* Bl. Dans). Asian J Pharm Clin Res 10 (2): 343-347.
- Sebaugh JL. 2011. Guidelines for accurate EC50/IC50 estimation. Pharmaceut Statist 10 (2): 128-134.
- Skorupinska-Tudek KS, Wojcik J, Swiezewska E. 2008. Polyisoprenoid alcohols--recent results of structural studies. Chem Rec 8: 33-45.
- Thatoi H, Samantaray D, Das SK. 2016. The genus *Avicennia*, a pioneer group of dominant mangrove plant species with potential medicinal values: a review. Front Life Sci 9 (4): 267-291
- Ujwal P, Kumar MPM, Naika HR, Hosetti BB. 2007. Antimicrobial activity of different extracts of *Pongamia pinnata*. Med Aromat Plant Sci Biotechnol 1 (2): 285-287.
- Ventola CI. 2015. The antibiotic resistance crisis: Part 1 causes and threats. Pharma Therapeut 40 (4): 277-283.
- Wang H, Li MY, Wu J. 2012. Chemical constituents and some biological activities of plants from the genus *Cerriops*. Chem Biodiv 9: 1-11.
- Wong SK, Lim YY, Chan EWC. 2010. Evaluation of antioxidant, anti-tyrosinase and antibacterial activities of selected *Hibiscus* species. Ethnobot Leaf 14: 781-796.
- Yang Y, Zhang Y, Liu D, Li-Weber M, Shao B, Lin W. 2015. Dolabrane-type diterpenes from the mangrove plant *Cerriops tagal* with antitumor activities. Fitoterapia 103: 277-282.
- Yusoff NA, Yam MF, Beh HK, Abdul RKN, Widyawati T, Mahmud R, Ahmad M, Asmawi MZ. 2015. Antidiabetic and antioxidant activities of *Nypa fruticans* Wurmb. vinegar sample from Malaysia. Asian Pac J Trop Med 8 (8): 595-605.
- Zhang Y, Lu Y, Mao L, Proksch P, Lin W. 2005. Tagalsins I and J, two novel tetraterpenoids from the mangrove plant, *Cerriops tagal*. Org Lett 7: 3037-3040.