Functional properties of *Boesenbergia pandurata* and *Murraya paniculata*: A review

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**Abstract.** Indonesia is a tropical country which cause so many types of herbs and spices can grow, such as Fingerroot (*Boesenbergia pandurata*) and orange jessamine (*Murraya paniculata*). These two herbs are widely used in traditional medicines by Indonesian local inhabitants. Based on the literature studies that have been carried out on several scientific journals, it can be concluded that fingerroot plants possess functional properties like antioxidant, anti-inflammatory, anti-microbial, anti-carcinogenic, anti-aging, anti-obesity, and inhibition of melanogenesis and tyrosinase activities, while orange jessamine leaves have antioxidant, anti-inflammatory, anti-microbial, anti-nociceptive, and anti-diarrheal activities.

**Keywords:** Functional properties, bioactivities, Indonesian plants, *Boesenbergia pandurata*, *Murraya paniculata*.

1. **Introduction**

*Boesenbergia pandurata* Roxb. (Zingiberaceae) is a monocotyledonous plant with a bush-like appearance that grows to a maximum height of 50 cm. This plant has a flowering terminal on pseudostem like ferns 10–15 cm long with an aromatic odor, leaf blades are green on both surfaces, shapes vary from ovate to wide lanceolate, measuring 12–50 cm to 5–17 cm, hairy, with several parallel veins raised at the top and white spots at the bottom [1].

Fingerroot is one of the ginger plants found in Southeast Asia. In Indonesia, this plant grows wildly in a forest and is cultivated anywhere. Fresh rhizomes from fingerroot have been widely used as spices, sliced rhizomes which are chewed together with areca nut (*Areca catechu*) can treat dry cough and aphtha, a mixture of rhizomes and *Pimpinella anisum* which is made into porridge used to treat distended stomach and as a diuretic for children, while the mixture with coconut milk is used as an anti-anthelmintic [2]. In addition, fresh rhizomes are used in cooking and traditional medicine to treat diarrhea, dermatitis, dry cough, and thrush [3].

*Orange jessamine* (*Murraya paniculata*) is one of many herbs that is often used in cooking in tropical countries such as Indonesia and Malaysia. It has a bush-like appearance that grows upright and spreads of medium size as high as 8-12 feet (244–366 cm). This plant has white flowers that bloom throughout the year and green leaves that grow alternately arranged in branches less than 2 inches (5 cm) long [4].

*M. paniculata* is believed able to cure orchitis, bronchitis, urinary tract infections, gonorrhea, vaginal discharge, and as a body slimming [5]. This plant can also be used to reduce blood cholesterol levels with the main content of flavonoids and tannins [6]. In addition, yuehchukene compounds which have only been isolated from plants with the genus *Murraya*, especially *Murraya paniculata*, have been shown to have anti-fertility and estrogenic activity [7].
Both fingerroot and orange jessamine have different levels of functional properties that usually stated in half maximal inhibitory concentration (IC\textsubscript{50}), half maximal effective concentration (EC\textsubscript{50}), minimum inhibitory concentration (MIC), and minimum bactericidal concentration (MBC) values. The IC\textsubscript{50} value shows the amount of particular inhibitory substances needed to reduce the initial concentration of biological components or to inhibit the biological process by 50%. The biological components could be enzymes or microorganisms, while biological process could be oxidation, inflammation, or many other processes. The EC\textsubscript{50} value shows the amount of particular drugs, antibody, or toxicant needed to reach 50% of effectiveness. The EC\textsubscript{50} value is usually used to measure drug’s potency. Both lower IC\textsubscript{50} and EC\textsubscript{50} values indicate the better substances power.

The MBC value is complementary to the MIC value, while the MIC value indicates the lowest level of antimicrobial agent that greatly inhibits growth of microorganisms, the MBC indicates the lowest level of antimicrobial agent resulting in microbial death. Antimicrobial agents are usually regarded as bactericidal if the MBC is no more than four times the MIC. MIC value can be determined by culturing microorganisms in liquid media or on plates of solid growth medium with various concentrations [8]. Then, the MBC test is carried out by sub-culturing to agar plates that do not contain the test agent [9]. Both lower MIC and MBC values indicate the better antimicrobial activity the agents possessed.

2. Boesenbergia pandurata

2.1. Antioxidants

Several studies have proven the presence of antioxidant activity found in fingerroot. The panduratin A compound has the ability to protect against oxidative damage caused by reactive compounds, proven by its ability to protect hepatocyte damage in human hepatoma cells (HepG2) induced by tert-butylhydroperoxide (t-BHP) by reducing the formation of MDA [10]. Meanwhile, with the pre-treatment of panduratin A can also increases (or restores) the level of glutathione (GSH) that is damaged by t-BHP. The results can be seen in Table 1.

| Table 1. Effects of pre-treatment panduratin A on HepG2 cell induced with 250 \( \mu \text{M} \) t-BHP |
|---------------------------------------------------------------|
|                | MDA equivalent            | GSH                |
|                | (nmol/mg protein)         | (nmol/mg protein)  |
| Control        | 3.49                      | 23.76              |
| t-BHP          | 8.05                      | 16.31              |
| t-BHP+ panduratin A |
| 1 \( \mu \text{M} \) | 7.98                      | 16.43              |
| 5 \( \mu \text{M} \) | 7.79                      | 18.34              |
| 10 \( \mu \text{M} \) | 6.12                      | 20.41              |
| 15 \( \mu \text{M} \) | 4.80                      | 19.78              |
| Positive control |
| t-BHP+silybin  |
| 1 \( \mu \text{M} \) | 7.94                      | 15.40              |
| 5 \( \mu \text{M} \) | 7.92                      | 16.85              |
| 10 \( \mu \text{M} \) | 5.56                      | 19.94              |
| 15 \( \mu \text{M} \) | 5.02                      | 21.81              |

Source: Sohn, Han, Lee, & Hwang [10]

In addition, Boesenbergin A compounds showed antioxidant activity against oxygen radicals with ORAC test results of 20 \( \mu \text{g/ml} \) (or equivalent to 11.91 \( \mu \text{M} \) Trolox) [11]. Cardamonin compounds, 2', 6'-dihydroxy-4'-methoxychalcone, pinostrobin, pinocembrin, panduratin A, and 4-hydroxyanduratin A also exhibit inhibitory activity against lipid peroxidation and neuroprotective effects on the toxicity of L-Glutamate in mouse brain cells N18-RE-105 with IC\textsubscript{50} and EC\textsubscript{50} values showed in Table 2.
Table 2. IC\textsubscript{50} value of lipid peroxidation inhibition and EC\textsubscript{50} value of neuroprotective effects against L-Glutamate toxicity on mice brain cells N18-RE-105

| Name                                                        | IC\textsubscript{50} (µM) | EC\textsubscript{50} (µM) |
|-------------------------------------------------------------|---------------------------|----------------------------|
| Cardamonin (2',4'-dihydroxy-6'-methoxy chalcone)            | 38                        | 48                         |
| 2',6'-dihydroxy-4'-methoxy chalcone                         | 70                        | 37                         |
| Pinostrobin (5-hydroxy-7'-methoxyflavanone)                 | 230                       | -                          |
| Pinocembrin (5,7-dihydroxyflavanone)                        | 210                       | -                          |
| Panduratin A                                                | 15                        | 13                         |
| 4-hydroxy panduratin A                                      | 4.5                       | 14                         |
| Control                                                     | (-)-catechin              | 17                        | 160                        |

Source: Shindo, Kato, Kinoshita, Kobayashi & Koike [12]

2.2. Anti-inflammation

Study conducted by Tuchinda et al. [13] showed that the application of rat ear pretreatment with panduratin A and 4-hydroxy panduratin A significantly inhibited the formation of edema in TPA-induced rat ears with ID\textsubscript{50} values of 84 and 12 µg/ear, respectively. Other studies have shown the inhibitory activity of NO production in RAW264.7 cells treated with lipopolysaccharide (LPS) inflammation [14]. Cardamonin, panduratin A, and 4-hydroxy panduratin A compounds have been shown to show strong effects in inhibiting NO production compared to other compounds (see Table 3). In this study, it was also found that panduratin A and 4-hydroxy panduratin A compounds could inhibit PGE2 production with IC\textsubscript{50} values of 10.5 and 12.3 µM and the inhibition of TNF-α production with IC\textsubscript{50} values of 60.3 and 57.3 µM [14]. In addition, the Boesenbergin A compound was also shown to be able to inhibit NO production in RAW264.7 cells treated with IFN-γ / LPS from NO 36.68 to 25.69 at a dose of 50 µg/ml without finding any toxicity effects on cells [11].

Table 3. NO production inhibition on RAW264.7 cells induced with LPS from isolated compounds of Fingerroot rhizome

| Compounds                              | IC\textsubscript{50} (µM) |
|----------------------------------------|---------------------------|
| Panduratin C                           | 67.8                      |
| Panduratin A                           | 5.3                       |
| Hydroxy panduratin A                   | 13.3                      |
| Helichrysetin                          | 62.3                      |
| 2',4',6'-Trihydroxyhydrochalcone       | 96.2                      |
| Uvangoletin                            | 74.7                      |
| Cardamonin                             | 24.7                      |
| Control                                |                           |
| L-Nitroarginine (L-NA)                 | 61.8                      |
| Caffeic acid phenethylester (CAPE)      | 5.6                       |

Source: Tewtrakul, Subhadhirasakul, Karalai, Ponglimanont, & Cheenpracha [14]

2.3. Anti-microbial: antibacterial, antifungal, anti-parasitic and antiviral activities

Many studies have proven the antimicrobial activity in fingerroot, such as antibacterial, antifungal, antiparasitic, and antiviral. These activities are present in plant extracts, essential oils contained, and purified compounds that have been successfully isolated from fingerroot plants. Ethanol extracts and essential oils from this plant were proven to inhibit the growth of pathogenic bacteria in food, such as Listeria monocytogenes and Salmonella typhimurium which results can be seen in Table 4 [15].
Table 4. MIC value of ethanol extract and essential oils from *Fingerroot* against *L. monocytogenes* and *S. typhimurium*

| Strain          | MIC (%, v/v) | Ethanol 50% extracts | Essential oils |
|-----------------|--------------|----------------------|----------------|
| *L. monocytogenes* |              |                      |                |
| 101             | 5            | 0.3                  |                |
| 108             | 5            | 0.2                  |                |
| 310             | 10           | 0.4                  |                |
| Scott A         | 10           | 0.4                  |                |
| V7              | 10           | 0.4                  |                |
| *S. typhimurium DT104* |          |                      |                |
| 2380            | >10          | 0.7                  |                |
| 2486            | >10          | 0.5                  |                |
| 2576            | >10          | 0.6                  |                |
| 2582            | >10          | 0.6                  |                |

*Source:* Thongson, Davidson, Mahakarnchanakul, & Vibulsresth [15]

Isopanduratin A compounds play a role in the antibacterial activity of methanol extracts of fingerroot plants on the growth of *Streptococcus mutans* with antibacterial activity that is comparable to several antimicrobial agents, such as chlorhexidine, vancomycin, hexamedine, sanguinarine, green tea extract, carvacrol, thymol, isoeugenol, and eucalyptol as shown in Table 5 [16]. Isopanduratin A compounds are also active in inhibiting the growth of other oral microorganisms, such as *Streptococcus salivarius* KCCM 40412, *Streptococcus sanguis* ATCC 35105, *Streptococcus sobrinus* ATCC 27351, *Lactobacillus acidophilus* KCCM 32820, *Lactobacillus casei* KCCM 35465, and *Anctinomycyes viscosus* ATCC 15987 with MIC ranging from 4–500 mg/l and MBC ranging from 6–750 mg/l [16].

Table 5. MIC and MBC value of isopanduratin A and several antimicrobial agents against *S. mutans*

| Compounds     | MIC (mg/l) | MBC (mg/l) |
|---------------|------------|------------|
| Isopanduratin A | 4          | 8          |
| Control       |            |            |
| Chlorhexidine | 1          | 2          |
| Vancomycin    | 1          | 2          |
| Eucalyptol    | 500        | 500        |

*Source:* Hwang, Chung, Baek, & Park [16]

According to Rukayadi, Lee, Han, Yong, & Hwang [17], the panduratin A compound contained in fingerroot plant has antibacterial activity against the genus *Staphylococcus* bacteria. *Staphylococcus* bacteria tested in this study were 27 methicillin-resistant *S. aureus* (MRSA) isolate with MIC value range from 0.5-1 µg/ml and MBC range from 2-8 µg/ml, 27 methicillin-susceptible *Staphylococcus aureus* (MSSA) isolate with MIC value range from 0.5-2 µg/ml and MBC range from 1-8 µg/ml, 28 methicillin resistant coagulase-negative staphylococi (MRCNS) isolate with MIC value range from 0.125-2 µg/ml and MBC range from 1-8 µg/ml, and 26 methicillin susceptible coagulase-negative staphylococi (MSCNS) isolate with MIC value range from 0.063-2 µg/ml and MBC range from 0.125-4 µg/ml. The antibacterial activity in panduratin A is relatively strong and effective because the results show smaller MIC<sub>50</sub> and MIC<sub>90</sub> values compared to ampicillin and linezolid antibiotics. These smaller MIC<sub>50</sub> and MIC<sub>90</sub> values indicate that the antibacterial activity of the panduratin A compound is stronger than the antibacterial agents. The results also showed that the antibacterial strength in panduratin A was equivalent to the vancomycin antibiotic.

As for the *Enterococci* bacteria, according to Rukayadi, Han, Yong, & Hwang [18], the results showed that the panduratin A compounds contained in fingerroot plants have effective antibacterial activity in inhibiting these bacteria. *Enterococci* bacteria tested in this study were 10 *E. faecalis* isolates with MIC value range from 0.125-2 µg/ml and MBC range from 0.25-8 µg/ml, 13 *E. faecium* isolates with MIC value range from 1-2 µg/ml and MBC range from 4-8 µg/ml, and a total of 23 *E. faecalis* and *E. faecium* isolates with MIC value range from 0.125-2 µg/ml and MBC range from 0.25-
8 µg/ml. The antibacterial activity in panduratin A is very strong because the results show that antibacterial strength is much stronger than the antibiotics ampicillin, linezolid, and vancomycin.

In this study, Staphylococci and Enterococci isolates were shown to have stronger antibacterial activity than antimicrobial agents such as ampicillin, daptomycin, erythromycin, gentamicin, levofloxacin, linezolid, oxacillin, tetracycline, thymol, and vancomycin. However, the data shown are only antibiotics ampicillin, linezolid, and vancomycin because ampicillin is the most commonly used antibiotic, while linezolid and vancomycin have the closest data (equivalent) to the compound panduratin A compared to other antibiotics.

Chloroform extract from fingerroot rhizomes showed strong antifungal activity against clinical isolation of Cryptococcus neoformans and Microsporum gypseum with MIC values of 64 µg/ml, but showed weak results against Candida albicans 3153, 43 and 48 isolation. This result could allow fingerroot rhizomes to be used in the development of drugs for fungal infections in AIDS patients [19]. In addition, ethyl acetate extract from this plant can inhibit the growth of mycelia from Phytophora capsici by 90% (ED$_{50}$) with a concentration about 300 ppm [20]. Ethanol extract of fingerroot plants were also proven to reduce the adhesion of Candida albicans 13803 and clinical isolation strains of C. albicans by 75% with 100 mg/ml pre-treatment [21].

Extracts from fingerroot plants showed anti-giardial activity in the parasite Giardia intestinalis with IC$_{50}$ value of 44.48 µg/ml for chloroform extract and 78.30 µg/ml for methanol extract [22] and anti-amoebaic activity against Entamoeba histolytica with IC$_{50}$ value of 45.8 µg/ml for chloroform extract and 57.6 µg/ml for methanol extract [23].

Panduratin A and 4-hydroxypanduratin A compounds isolated from fingerroot plants showed inhibition of the HIV-1 protease virus with IC$_{50}$ values of 18.7 µM and 5.6 µM [24]. Both of these compounds also showed an inhibitory activity of the protease virus DEN-2 NS2B / 3 of more than 65% at a concentration of 80 ppm. However, at smaller concentrations (40 ppm), 4-hydroxypanduratin A compound showed greater inhibitory activity (reaching 50%) compared to panduratin A compound (only 27%) [25]. Pinocembrin compounds showed antiviral activity against HSV-1 with an EC$_{50}$ value of 22.71 µg/ml and did not show any cytoxicity to host cells (Vero E6 cells) at concentrations of ≤95.17 µg/ml. In vivo tests on mice infected with the HSV-1 virus showed that the compound pinostrobin was shown to have its own effect on the development of lesion values at a dose of 50 mg/kg/dose [2].

2.4. Anticarcinogenic and antimutagenic

Various extracts and isolates from fingerroot plants have been proved to have anticancer effects. A total of 20 µg/ml of plant methanol extract is able to inhibit the activation of EBV induced by 20 ng teleocidin in human B-lymphoblastoid (Raji) cells with IE values (inhibitory effect) of more than 70%. Cardamonin compounds found in this plant can inhibit EBV activation with IC$_{50}$ values of 3.1 µM and at concentrations of 25 µM can completely inhibit EBV activation with high cell viability (>90%) [26]. In addition, the compound panduratin A has also been shown to be effective against various cancer cells (see Table 6).

| Cancer cells | Description | Source |
|--------------|-------------|--------|
| Pancreas (PANC-1) | PC$_{100}$ = 2.5 µM | [27] |
| Lungs (A549) | IC$_{50}$ = 4.4008 µg/ml, incubation time of 24h with RTCA method | [28] |
| Lungs (A549) | IC$_{50}$ = 4.4040 µg/ml, incubation time of 24h with MTT method | [28] |
| Lungs (A549) | IC$_{50}$ = 4.3647 µg/ml, incubation time of 48h with RTCA method | [28] |
| Lungs (A549) | IC$_{50}$ = 3.7930 µg/ml, incubation time of 48h with MTT method | [28] |
| Lungs (A549) | IC$_{50}$ = 5.5453 µg/ml, incubation time of 72h with RTCA method | [28] |
| Lungs (A549) | IC$_{50}$ = 4.4190 µg/ml, incubation time | [28] |
of 72h with MTT method

| Compounds            | IC_{50} (µM) |
|----------------------|--------------|
| Breast (MCF-7)       | 3.75 ± 0.4   |
| Prostate (DU145)     | 14.0 ± 0.7   |
| Prostate (PC3)       | 13.5 ± 0.7   |
| Intestine (HT-29)    | 6.56 ± 0.3   |
| Intestine (HT-29)    | 28 ± 0.3     |
| Intestine (HT-29)    | 23 ± 0.3     |
| Intestine (HT-29)    | 13 ± 0.3     |

RTCA = Real time cell analysis
MTT = 3-(4,5-dimethylthiazol-2-yI)-2,5-diphenyltetrazolium bromide

Other isolates have also been tested for toxicity to PANC-1 cancer cells by Win,Awale,Esumi, Tezuka, & Kadota [27] & Win, Awale, Esumi, Tezuka, & Kadota [31] with PC_{100} value of 2.5 µM for (-)-nicolaioidesin B and Panduratin A, PC_{100} value of 8 µM for (-)-6-geranylpinocembrin and Isopanduratin A1, PC_{100} value of 16 µM for Geranyl-2,4-dihydroxy-6-phenethylbenzoate, 2’4’-Dihydroxy-3’-(1’-geranyl)-6’-methoxychalcone, (1’R,2’S,6’R)-2-Hydroxyisopanduratin A, (-)-hydroxyisopanduratin A, and Isopanduratin A2, PC_{100} value of 64 µM for (±)-6-methoxyisopanduratin A, (2S)-7,8-dihydro-5-hydroxy-2-methyl-2-(4’’-methyl-3’’-pentenyl)-8-phenyl-2H,6H-benzo[1,2-b:5,4-b’]dipyran-6-one, (-)-pinocembrin, Boesenbergin A, and Boesenbergin B, PC_{100} value of 128 µM for (2R)-8-geranylpinostrobin, (2S)-6-geranylpinostrobin, Panduratin B1, Panduratin B2, Panduratin D, Panduratin E, Panduratin G, Panduratin H, and Panduratin I, PC_{100} value of >256 µM for Flavokawain C, Cardamonin, (-)-pinostrobin, (-)-alpinetin, (-)-7,4’-dihydroxy-5-methoxyflavanone, Tectochrysin, 5,6-dehydrokawain, Panduratin C, and Panduratin F.

In addition to the anticancer activity tested from several pure compounds resulting from isolation from fingerroot plants, mutagenic activity is also present in some of these compounds. This antimutagenic activity was tested through the Ames test method for 3-amino-1,4-dimethyl-5H-pyrido [4,3-b] indole (Trp-P-1) in Salmonella typhimurium TA98 with the results shown in Table 7 [32].

Table 7. IC_{50} values of antimutagenic activity in isolated compounds from fingerroot against Trp-P-1

| Compounds             | IC_{50} (µM) |
|-----------------------|--------------|
| Pinocembrin chalcone  | 5.2 ± 0.4    |
| Cardamonin            | 5.9 ± 0.7    |
| Pinocembrin           | 6.9 ± 0.8    |
| Pinostrobin           | 5.3 ± 1.0    |
| 4-hydroxyisopanduratin A | 12.7 ± 0.7   |
| Panduratin A          | 12.1 ± 0.8   |

Source: Trakoontivakorn et al. [32]

2.5. Antiaging

The panduratin A compound showed anti-aging activity in concentrations of 0.001 to 0.1 µM by reducing MMP-1 expression and increasing expression of type-1 procollagen resulting in the reduction of UV radiation in fibroblast cells [33]. The UV radiation was reduced significantly through deactivation of MAPK signaling molecules. Thus, this deactivation resulted in the inhibition of AP-1 DNA binding activity because the c-Fos expression and c-Jun phosphorylation were decreased during the process. Panduratin A compounds and 4-hydroxyisopanduratin A were found to be responsible for this activity [33, 34].

2.6. Anti-obesity

Panduratin A compound (at a dose of 50 mg/kg/day) and plant extract (at a dose of 200 mg/kg/day) can significantly reduce weight gain and fat mass without reducing food intake. The panduratin A compound was found to be able to regulate lipid metabolism. The mechanism was rather complex but the panduratin A was found to work through the activation of LKB1-dependent AMPK signaling [35]. Panduratin A weaken the HFD-induced obesity by increasing the phosphorylation of LKB1, AMPK and ACC in liver and skeletal muscle [35]. Fingerroot plant extracts also apply the same molecular
mechanism as the panduratin A compound, only the extract treatment on MDT 3T3-L1-treated MDI and insulin-induced HepG2 cells decreases the accumulation of triglycerides in both cells by activating AMPK signaling and regulating the expression of proteins related to lipid metabolism [36].

2.7. Melanogenesis and tyrosinase inhibition
Isopanduratin A and 4-hydroxypanduratin A compounds have been shown to have inhibitory activity against melanogenesis and are able to inhibit tyrosinase activity with IC$_{50}$ values shown in Table 8.

Table 8. IC$_{50}$ values of isolated compounds from Fingerroot

| Compounds               | Melanin Synthesis Inhibition IC$_{50}$ (µM) | Tyrosinase Activity Inhibition IC$_{50}$ (µM) | Source  |
|-------------------------|--------------------------------------------|-----------------------------------------------|---------|
| Isopanduratin A         | 10.64                                      | 10.5                                          | [37]    |
| 4-hydroxypanduratin A   | 23.25                                      | >30                                           | [37]    |
| Panduratin A            | 9.6                                        | 8.2                                           | [38]    |
| Control                 |                                            |                                               |         |
| Phenylthiourea          | 34.32                                      | 47.6                                          | [37]    |
| Arbutin                 | 990                                        | 660                                           | [38]    |
| Kojic acid              | 152                                        | 126                                           | [38]    |

3. Murraya paniculata

3.1. Antioxidant
The antioxidant levels in the M. paniculata ethanol extract have been investigated by Rohman and Riyanto [6] with two different methods, which are the linoleic-thiocyanate and DPPH methods. The results of the linoleic-thiocyanate method show the sequence of antioxidant strength on the M. paniculata are 10% ethanol extract> 1% vitamin E> 5% ethanol extract> 1% ethanol extract. Whereas in the DPPH method the IC$_{50}$ value for the ethanol extract of M. paniculata is 126.17 µg/ml, where this value is 15 times lower than the IC$_{50}$ value of vitamin E which is 8.27 µg/ml. In addition, 100 µg/ml of M. paniculata acetone extract can inhibit 10% of xanthine oxidase (XO) activity and 62% of lipoxygenase (LOX) activity, while 500 µg/ml of leaf acetone extract yellowing can inhibit 72% of tyrosinase activity.

3.2. Anti-inflammation
Based on research conducted by Rahman, Hasanuzzaman, Udin, and Shahid [39], the anti-inflammatory activity of ethanol extracts of dried yellow M. paniculata against carrageenan-induced mouse edema showed a significant inhibitory effect with the highest effect at the third hour of 26.43% for the dose 300 mg/kg and 42.71% for a dose of 600 mg/kg (Table 9).

Table 9. Anti-inflammation activity of Murraya paniculata ethanol extract

| Treatment               | Edema volume $\times$ 1000 (ml) (%) inhibition | 1* | 2* | 3* | 4* | 5* |
|-------------------------|-----------------------------------------------|----|----|----|----|----|
| Control                 | 1% tween 80, 10 ml/kg p.o.                     | 16.65 | 167.80 | 249.10 | 285.30 | 232.70 |
| Positive control        | Aspirin 150 mg/kg p.o.                         | 11.20 | 101.20 | 121.10 | 183.40 | 155.15 |
|                         |                                               | (32.73) | (39.69) | (51.38) | (35.72) | (33.32) |
| Group 1                 | Ethanol extract 300 mg/kg p.o.                 | 13.70 | 131.20 | 183.25 | 229.20 | 191.45 |
|                         |                                               | (17.72) | (21.81) | (26.43) | (19.66) | (17.73) |
| Group 2                 | Ethanol extract 600 mg/kg p.o.                 | 12.15 | 112.10 | 142.70 | 202.10 | 168.50 |
|                         |                                               | (27.03) | (33.19) | (42.71) | (29.16) | (27.59) |

p.o. = per oral; *1 = 1 h after carrageenan injection; *2 = 2 h after carrageenan injection; *3 = 3 h after carrageenan injection; *4 = 4 h after carrageenan injection; *5 = 5 h after carrageenan injection

Source: Rahman, Hasanuzzaman, Udin, & Shahid [39]
3.3. Antimicrobial activity

Chloroform extract from *M. paniculata* showed moderate antifungal activity against clinical isolation of *Cryptococcus neoformans* and *Microsporum gypseum* with MIC values of 256 and 512 µg/ml, but water extracts from these leaves showed weak results against clinical isolation of *Microsporum gypseum* with MIC values of 256 and 512 µg/ml, but water extracts from these leaves showed weak results against clinical isolation of *Microsporum gypseum* with MIC values of 256 and 512 µg/ml. These results could allow *M. paniculata* to be used in the development of drugs for fungal infections in AIDS patients [19].

Chloroform extract from *M. paniculata* showed anti-giardal activity in the parasite *Giardia intestinalis* with IC$_{50}$ value of 144.87 µg/ml [22] and anti-amoebic activity against *Entamoeba histolytica* with IC$_{50}$ value of 116.5 µg/ml [23].

In addition, only the chloroform extract of *M. paniculata* showed antimicrobial activity against *B. cereus* and *S. cerevisiae* with inhibition zones respectively of 9 mm and 8 mm. Auraptene, trans-gleinesiadiene, 5,7-dimethoxy-8- (3-methyl-2-oxo-butyl) coumarin, and toddalenone compounds were also successfully isolated from extracts of chloroform, petroleum ether, and methanol. However, only trans-gleinadiene compounds that showed antimicrobial activity against *B. cereus* with an inhibition zone of 8 mm. Thus, it can be concluded that the compound trans-gleinadiene, aurapteme, and 5,7-dimethoxy-8- (3-methyl-2-oxo-butyl) coumarin together provide a synergistic effect on the chloroform extract of *M. paniculata*.

3.4. Antinociceptive activity

Ethanol extracts of *M. paniculata* produce antinociceptive activity in certain doses that have been tested in mice that are induced by acetic acid [40]. At doses of 250 and 500 mg/kg, ethanol extract produced about 26.67 and 66.67% writhing inhibition in test animals. The results can be compared with standard diclofenac sodium drugs.

3.5. Anti-diarrheal activity

The antidiarrheal activity of the ethanol extract of *M. paniculata* was tested against rats induced by castor oil by Rahman, Hasanuzzaman, Udin, and Shahid [39]. *M. paniculata* extract can increase the latent period from 0.86 hours to 1.82 hours and is comparable to standard loperamide drugs (Table 10). The latent period is the length of time when diarrhea reappears. At the same dose, the extract was also able to reduce the frequency of bowel movements by an average amount of stool as shown in Table 11.

| Treatment | Dose (/kg p.o.) | Latent period (h) |
|-----------|----------------|------------------|
| Control   | 1% Tween 80    | 10 ml            | 0.86 ± 0.140     |
| Positive control | Loperamide | 50 mg           | 1.98 ± 0.114*    |
| Group 1   | Ethanol extract | 500 mg          | 1.82 ± 0.119*    |

Values are average ± SEM (n=5); *P<0,001; p.o. = per oral

*Source: Rahman, Hasanuzzaman, Udin, & Shahid [39]*

| Treatment | Dose (/kg p.o.) | Period (h) | Total number of stool |
|-----------|----------------|------------|-----------------------|
| Control   | 1% tween-80    | 3.0 ± 0.304| 3.2 ± 0.357           |
|           | 2              | 3.2 ± 0.295|                       |
|           | 3              | 3.0 ± 0.295|                       |
|           | 4              | 3.4 ± 0.364|                       |
|           | 5              | 3.2 ± 0.390|                       |
IOP Conf. Series: Earth and Environmental Science 794 (2021) 012151 doi:10.1088/1755-1315/794/1/012151

Positive control

|                |     |       |
|----------------|-----|-------|
| Loperamide     | 50 mg | 1     |
| 2              | 1.2 ± 0.219* |
| 3              | 1.0 ± 0.320* |
| 4              | 1.0 ± 0.332* |
| 5              | 1.0 ± 0.287* |
| 5              | 1.4 ± 0.224* |
| Ethanol extract| 500 mg| 1     |
| 2              | 1.4 ± 0.357* |
| 3              | 1.0 ± 0.418* |
| 4              | 1.2 ± 0.370* |
| 5              | 1.2 ± 0.327* |
| 5              | 1.4 ± 0.312* |

Values are average ± SEM (n=5); *P<0.01; p.o. = per oral

Source: Rahman, Hasanuzzaman, Udin, & Shahid [39]

Conclusions

Fingerroot plants have functional properties like antioxidant, anti-inflammatory, anti-microbial, anti-carcinogenic, anti-aging, anti-obesity, and inhibition of melanogenesis and tyrosinase activities, while orange jessamine leaves have antioxidant, anti-inflammatory, anti-microbial, anti-nociceptive, and anti-diarrheal activities.

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