Antimicrobial of tropical fruit and vegetable waste extract for food-borne pathogenic bacteria

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Abstract

Tropical fruit and vegetable wastes become great potential natural resources of bioactive compounds for antimicrobial. The aim of the study was to determine the effect of antimicrobial extracted from tropical fruit and vegetable waste to inhibit food-borne pathogenic bacteria (Aeromonas hydrophila, Bacillus cereus, Escherichia coli, Listeria monocytogenes, Salmonella Typhimurium, Staphylococcus aureus, Vibrio para-haemolyticus). A total of six tropical fruit waste (peel of pineapple, jackfruit, durian, coffee, mangosteen, and cacao pods) and five tropical vegetable waste (stem of sembukan, lamtora pods, jengkol shell, bitter bean pods, Indian marsh fleabane leave) was extracted by using maceration method. The antimicrobial activity of extracts was carried out by using disc diffusion assay and Minimum Inhibitory Concentration. The flavonoids in extract were identified and quantified by using Liquid Chromatography-Mass Spectrometry. The highest antimicrobial activity against Gram-positive bacteria (B. cereus, L. monocytogenes and S. aureus) was shown by jengkol, bitter bean, and mangosteen waste extract in the range of 0.00038 to 4.2% for MIC. The highest antimicrobial activity inhibits Gram-negative bacteria (A. hydrophila, E. coli, S. Typhimurium and V. para-haemolyticus) was shown by jengkol, bitter bean, mangosteen, sembukan, and lamtora waste extract in the range of 0.00038 to 3.1% for MIC which have apigenin, catechin, coumaric acid, gallic acid, genistein, hydroxybenzoic acids, luteolin, myricetin, naringenin dan quercetin as bioactive compounds. Total phenol of those waste extracts was in the range of 0.663 to 4.441 mg GAE/g. Jengkol, bitter bean, mangosteen, sembukan, and lamtora waste extract shown to be a potential natural antimicrobial to inhibit food-borne pathogenic bacteria.

Introduction

Tropical fruits and vegetables have a significant role for food, and hence the demand for fruit, vegetables and their processed products has significantly increased as a consequence of a rapidly growing human population. Furthermore, huge waste of food commodities, food components and by-products occurred due to improper food handling along the food chain at every step of post-harvest before it is consumed. This is the unintended impact on food supply and production as a result of eating habits and legal framework. The utilization of tropical fruit and vegetable waste and losses as natural resources of bioactive compounds can increase the potential of the wastes and provide great benefit for food industry which can be used in food and pharmaceutical industries as natural antimicrobial (Sagar et al., 2018).

Natural antimicrobials are getting more attention from consumers and the food industry due to increasing consumer awareness of the negative impact of artificial preservatives on human health compared to natural additives (Gyawali and Ibrahim, 2014). The natural antimicrobial could be extracted from fruit and vegetable (Wijngaard et al., 2009). The natural antimicrobial can be applied in food production with the potential of the growth of food-borne pathogenic bacteria (Fancello et al., 2019).

The food-borne pathogenic bacteria such as Aeromonas hydrophila, Bacillus cereus, Escherichia coli, Listeria monocytogenes, Salmonella Typhimurium, Staphylococcus aureus, Vibrio para-haemolyticus has been detected in various food and food products (Budiani et al., 2016, Simonaviczen et al., 2021). Currently, there is a need to develop antimicrobial to maintain food safety that meets the needs of consumers in natural and safe food products. However, the study of natural antimicrobial extracted from tropical fruit and vegetable waste is still limited. The aim of this study was to determine the effect of antimicrobial extracted from tropical fruit and vegetable waste to inhibit food-borne pathogenic bacteria (A. hydrophila, B. cereus, E. coli, L. monocytogenes, S. Typhimurium, S. aureus, V. para-haemolyticus).

Materials and Methods

Material

A total of six tropical fruit waste (pineapple peel, jackfruit peel, durian peel, coffee peel, cacao pods, mangosteen peel) and five tropical vegetable waste (stem of sembukan, lamtora pods, jengkol shell, bitter bean pods, Indian marsh fleabane leave) was collected from local farm and local market. The materials were cut into small pieces, freeze dried and powdered.

Organisms and cultures

Typical bacterial contaminants used in this study were A. hydrophila ATCC 7966, B. cereus ATCC 10876, E. coli ATCC 25922, L. monocytogenes ATCC 7644, S. Typhimurium ATCC 14028, S. aureus ATCC 25923, V. Para-haemolyticus ATCC 17802 (MBRIO, Indonesia). Bacterial culture is cultured on nutrient agar slants (Merck, Germany). For a period of one month, the culture was stored at 4 °C and refreshed to maintain bacterial viability.

Chemicals and instruments

LC-ESI-MS/MS (Shimadzu, Japan) was used to identify and quantify the
phenolic of fruit and vegetable waste extract. The standard of coumaric acid (≥97%), kaempferol (≥97%), and quercetin (≥97%) were purchased from Sigma (USA). HPLC grade methanol was purchased from Merck (USA).

**Extraction of waste of fruit and vegetables**

Waste of tropical fruit and vegetable (50 g) was extracted with methanol in maceration method. A total 500 ml of 96% aqueous methanol was added and shaken using orbital shaker at 200 RPM for 24 hours. The mixture was filtered using Whatman Paper no. 1 and re-extracted twice using fresh methanol (500 ml). Waste of fruit and vegetables extracts were evaporated using vacuum rotary evaporator and air dried at 40°C. Stock solutions of crude extract were diluted with 10% dimethyl sulfoxide (DMSO) solution for concentration of 400 mg/ml.

**Disc diffusion assay**

Antimicrobial activity was done by using disc diffusion assay as the method of Bauer (1966). The culture was cultivated for 16 hours in the TSB medium (TSB, Merck, Germany) and incubated at 37°C. The overnight culture was diluted to reach 0.5 of the McFarland scale for the turbidity. The culture was standardized to have a concentration about 10⁶ CFU/mL. About 20 µL aliquot was pipetted onto 180 µL of different concentration of Mueller Hinton Broth (MHB, Oxoid, United Kingdom) in the 96-wells plate impregnated by tropical fruit and vegetable waste extract. The final concentration of bacteria was approximately 10⁷ CFU/mL. At the concentration of 100% there was 180 µL pure tropical fruit and vegetable waste extract. The concentration was reduced for 50% gradually by adding MHB to a total 180 µL (v/v) and incubated at 37°C for 24 hours. The plate was agitated, and the growth of bacteria was observed by using UV-Vis microplate spectrophotometer at 620 nm (Agilent-USA). The absorbance values were subtracted from those observed before incubation. MIC value was recorded at the lowest concentration for the growth of bacteria. A 15 µl aliquot of 10% DMSO was dropped onto Mueller Hinton Broth as a negative control. Penicillin G (10 unit/ml) was used as positive control for B. cereus, L. monocytogenes and S. aureus. Trimethoprim-sulfamethoxazole 10 unit/ml was used as positive control for A. hydrophilla, E. coli, S. Typhimurium, V. Parahaemolyticus.

**Minimum Inhibitory Concentration (MIC)**

The culture was cultivated for 16 hours in the TSB medium (TSB, Merck, Germany) and incubated at 37°C was done as method of Garcia (2010). The overnight culture was diluted to reach 0.5 of the McFarland scale for the turbidity. The culture was standardized to have a concentration about 10⁶ CFU/mL. About 20 µL aliquot was pipetted onto 180 µL of different concentration of Mueller Hinton Broth (MHB, Oxoid, United Kingdom) in the 96-wells plate impregnated by tropical fruit and vegetable waste extract. The final concentration of bacteria was approximately 10⁷ CFU/mL. At the concentration of 100% there was 180 µL pure tropical fruit and vegetable waste extract. The concentration was reduced for 50% gradually by adding MHB to a total 180 µL (v/v) and incubated at 37°C for 24 hours. The plate was agitated, and the growth of bacteria was observed by using UV-Vis microplate spectrophotometer at 620 nm (Agilent-USA). The absorbance values were subtracted from those observed before incubation. MIC value was recorded at the lowest concentration for the growth of bacteria. A 15 µl aliquot of 10% DMSO was dropped onto Mueller Hinton Broth as a negative control. Penicillin G (10 unit/ml) was used as positive control for B. cereus, L. monocytogenes and S. aureus. Trimethoprim-sulfamethoxazole 10 unit/ml was used as positive control for A. hydrophilla, E. coli, S. Typhimurium, V. Parahaemolyticus.

**Identification and quantification of compounds**

The phenolic compounds were performed qualitative and quantitative as method of Bouhafsoun et al. (2018) by using a model Shimadzu UHPLC coupled to a tandem MS instrument. This was operated by using SIL-20AC autosampler, DGU-20A3R, CTO-20A column oven and LC-20AD binary pumps. The separation of chromatographic was carried out by using C18 reversed-phase Inertsil ODS-4 (150 mm x 4.6 mm, 3 µm) analytical column. The temperature of column was set at 40°C. The elution gradient was done by using two types of mobile phase namely mobile phase A (water, 5 mM ammonium formate and 0.1% formic acid) and mobile phase B (methanol, 5 mM ammonium formate and 0.1% formic acid). Four microliter of solvent was set for injection volume. The flow rate of solvent was maintained at 0.5 mL/min. Quantification of compound was calculated as part per million (ppm).

**Table 1. Inhibition zone of different tropical fruit and vegetable waste extract on food-borne pathogenic bacteria.**

| Tropical fruit and vegetable* | Waste | A. hydrophilla (mm) | B. cereus (mm) | E. coli (mm) | L. monocytogenes (mm) | S. Typhimurium (mm) | S. aureus (mm) | V. Parahaemolyticus (mm) |
|-------------------------------|-------|--------------------|----------------|--------------|-----------------------|-------------------|---------------|-------------------------|
| Pineapple                     | Peel  | 0.3±0              | 0.85±0.28     | 1.1±0.1     | 0±0                   | 0±0               | 0.8±0.19      | 1±0                     |
| Jackfruit                     | Peel  | 0.37±0             | 2.17±0.29     | 3.33±0.58   | 0±0                   | 0.17±0.29        | 0.46±0.07     | 0.67±0.29***          |
| Durian                        | Peel  | 0.02±0             | 0.9±0.5      | 4.33±0.58   | 0±0                   | 0±0               | 1.42±0.29     | 1.33±0.58**           |
| Coffee                        | Peel  | 0.5±0.29           | 1.33±0.29     | 2.1±0.10    | 1±0                   | 0.67±0.58        | 0.38±0.21     | 0.67±0.29**           |
| Cacao                         | Pods  | 1.25±0.58**        | 0.83±0.29     | 2.27±0.23   | 0±0                   | 0.67±0.58        | 0.58±0.38     | 5±0                     |
| Mangosteen                    | Peel  | 1.3±0.58**         | 2.33±0.29     | 3.33±0.58   | 1.3±0.61              | 3.33±0.58       | 2.83±0.29     | 0±0                     |
| Sembukai                      | Stem  | 1.5±0             | 1.04±0.59     | 2.13±0.12   | 1±0                   | 0±0               | 0.42±0.14     | 1.67±0.58              |
| Lamtoro                       | Pods  | 1.5±0             | 1.72±0.14     | 3.07±0.56   | 3.3±0.6               | 1.33±0.58       | 0.71±0.29     | 0.5±0                   |
| Jengkol                       | Sheel | 2.25±0.1           | 3.17±0.14     | 5.33±0.58   | 6.3±0.6               | 2.67±0.58       | 1.25±0.7      | 3±0                     |
| Bitter bean                   | Pods  | 2.33±0.58          | 2.75±0.43     | 4.33±0.58   | 3.3±0.6               | 7±1.4            | 4.18±0.12     | 0.5±0                   |
| Indian Marsh Firebane         | Leaf  | 1.25±0.58          | 1.13±0.22     | 0.83±0.29   | 1±0                   | 0±0               | 0.67±0.14     | 0.5±0                   |

*Different alphabet means significant different at P<0.05 in the same column of MIC value. *Pinapple = Ananas comosus; jackfruit = Artocarpus heterophyllus; durian = Durio zibethinus; coffee = Coffea arabica; mangosteen = Mangifera; sembukan = Pueraria montana; lamtoro = Leucaena leucocephala; jengkol = Archidendron pauciflorum; bitter bean = Parkia speciosa; indian marsh firebane = Plancha indica.
Statistical analysis

The differences of disc diffusion assay and MIC value observed from different tropical fruit and vegetable waste extract were determined by using one-way ANOVA (SPSS version 13.0) at a significance level of P<0.05.

Results

Antimicrobial activity of tropical fruit and vegetable waste extract to inhibit food-borne pathogenic bacteria

By using disc diffusion assay A. hydrophilla was inhibited by bitter bean extract with inhibition zone diameter of 2.3±0.58 mm (Table 1). The highest antimicrobial activity was shown by the extract of jengkol waste, bitter bean waste lambotoro waste and sembukan waste extract at MIC concentration of 0.00038±0%. The highest inhibition zone of B. cereus was observed on jengkol waste extract with inhibition zone diameter of 3.17±0.14 mm. By using MIC, the highest antimicrobial for B. cereus was found on jengkol waste, bitter bean waste and mangosteen waste extract at MIC concentration of 0.00038±0%. The growth of E. coli and L. monocytogenes was also inhibited by jengkol waste extract with inhibition zone diameter of 5.33±0.58 mm and 6.3±0.6 mm, respectively. By using MIC, E. coli and L. monocytogenes were inhibited by jengkol waste at MIC concentration of 0.78±0% and 0.4±0%, respectively. Mangosteen waste extract showed to be the highest antimicrobial activity on S. Typhimurium with inhibition zone diameter of 3.33±0.58 mm. V. parahaemolyticus was shown to be inhibited by sembukan waste extract with inhibition zone diameter of 1.67±0.58 mm. The highest antimicrobial to inhibit S. aureus was shown by bitter bean waste extract (4.18±0.12 mm) by using disc diffusion assays (Table 1). Jengkol waste extract was observed to be the highest antimicrobial for the growth of S. aureus at MIC concentration of 4.2±1.8% (Table 2). Bitter bean and jengkol waste extract seem to be potential natural antimicrobial to against S. aureus.

Contents of phenolic compounds

In this present study, antimicrobial activity to inhibit Gram-positive and Gram-negative bacteria was shown mostly by the extract of bitter bean waste, jengkol waste and mangosteen waste. Bioactive compounds of the extracts were apigenin, catechin, coumaric acid, gallic acid, genistein, hydroxybenzoic acids, luteolin, myricetin, naringenin dan quercetin (Table 3). Total phenol in those extract was in the range of 4.419 to 4.441 mg GAE/g. The content of kaempferol, coumaric acid and quercetin of bitter bean extract and jengkol waste extract was found for 0.241 and 0.472 ppm, 0.476 and 0.735 ppm, 11.043 and 17.541 ppm, respectively (Table 4).

Gram-negative bacteria (A. hydrophilla and V. parahaemolyticus) were inhibited by lambotoro waste extract and sembukan waste extracts. The extracts were composed by apigenin, hesperetin, kaempferol, luteolin dan quercetin (Table 4). Total phenol of those extract was observed for 2.727 and 0.663 mg GAE/g, respectively.

Table 2. Minimum Inhibitory Concentration (MIC) of different tropical fruit and vegetable waste extract on food-borne pathogenic bacteria.

| Tropical fruit and vegetable | Waste | A. hydrophilla (mm) | B. cereus (mm) | E. coli (mm) | L. monocytogenes (mm) | S. Typhimurium (mm) | S. aureus (mm) | V. parahaemolyticus (mm) |
|-----------------------------|-------|---------------------|----------------|-------------|----------------------|-------------------|---------------|-------------------------|
| Pineapple                   | Peel  | 0.02±0              | 50±0           | 50±0        | 3.1±0                | 25±0             | 50±0          | 50±0                    |
| Jackfruit                   | Peel  | 0.02±0              | 0,00038±0      | 25±0        | 50±0                 | 50±0             | 50±0          | 25±0                    |
| Durian                      | Peel  | 0.38±0              | 50±0           | 25±0        | 25±0                 | 25±0             | 33±14,43      | 50±0                    |
| Coffee                      | Peel  | 0.38±0              | 6,25±0         | 50±0        | 3.1±0                | 12,5±0           | 16,77,22      | 12,5±0                  |
| Cacao                       | Pods  | 1,56±0              | 25±0           | 100±0       | 12,5±0               | 6,25±0           | 33,3±14,43    | 25±0                    |
| Mangosteen                  | Peel  | 0,00019±0           | 0,00038±0      | 7,8±0       | 25±0                 | 1±0              | 6,25±0        | 25±0                    |
| Sembukan                    | Stem  | 0,00038±0           | 6,25±0         | 25±0        | 25±0                 | 50±0             | 3,125±0       | 25±0                    |
| Lamtoro                     | Pods  | 0,00038±0           | 0,0015±0       | 25±0        | 12,5±0               | 12,5±0           | 16,7±7,22     | 25±0                    |
| Jengkol                     | Sheel | 0,00038±0           | 0,00038±0      | 0,78±0      | 0,4±0                | 6,25±0           | 4,2±1,8       | 25±0                    |
| Bitter bean                 | Pods  | 0,00038±0           | 0,00038±0      | 3,13±0      | 0,4±0                | 6,25±0           | 4,7±1,7       | 50±0                    |
| Indian Marsh Fleabane       | Leaf  | 12,5±0              | 6,25±0         | 50±0        | 25±0                 | 12,5±0           | 33±14,43      | 50±0                    |

**Different alphabet means significant different at P<0.05 in the same column of inhibition zone.** *A. hydrophilla* = annua commus; *jengkol* = Arctocarpus heterophyllus; *durian* = Durio zibethinus; *coffee* = Coffea arabica; *mangosteen* = Mangifera; *sembukan* = Paederia foetida; *lambotoro* = Leucocarya beecroftii; *jengkol* = Archidendron pascullorum; *bitter bean* = Parkia speciosa; *indian marsh fleabane* = Pluchea indica.

Discussion

Bioactive compounds from plant tissue have been reported to show antimicrobial activity (Altemimi et al., 2017). It was important to be studied as potential sources of novel natural antimicrobial compounds which were effective and safe. Several studies reported the antimicrobial activity of fruit and vegetable by-product such as hazelnut skin, pomegranate peel, apple peel, potato peel, leek leaves, cornelian cherry seed, dog rose seeds, grape marc, dog rose pulp, cornelian cherry pulp, pomegranate pomace, apple pomace, potato pulp (Agourram et al., 2013). Other studies reveal that fruit and vegetable waste contain phenolic compounds such as lemon peel, avocado seed, jackfruit seed, mangoes seed (Soong and Barlow, 2004). This present study found that Gram-positive and Gram-negative bacteria were inhibited mostly by the extract of bitter bean waste, jengkol waste and mangosteen waste. Joshi et al. (2012) reported that flavonoids in fruits and vegetables may show antimicrobial activity. Bakar et al. (2012) reported that jengkol shell showed antimicrobial activity due to the presence of saponin, tannin and flavonoid. Flavonoid is the most component of phenol compound which is effective to inhibit the growth of bacteria. The mechanism of flavonoid occurred by disturbing the cell wall of microorganism. Lipid and amino acid in cell wall were reacted by the presence of alcoholic compound in flavonoid that resulting cell wall damage. The complex of protein will denature the protein in cell membrane and produce cell lysis (Dzoyem, 2013). Xie et al. (20015) revealed flavonoid groups, namely luteolin showed the antimicrobial activity to bacteria.
The cell membrane of Gram positive was constructed by peptidoglycan which susceptible for the antimicrobial properties of flavonoid in jengkol waste extract. Luteolin and apigenin, similar structure compounds, were flavonoid polyphenol group that interfere the DNA of bacteria (Xie et al., 2015).

Kaempferol, a flavonoid group, showed antimicrobial activity for inhibiting bacteria. Eumkeb et al. (2012) revealed that kaempferide, the 4’-O-methyl derivative of kaempferol, exhibited the activity to inhibit amoxicillin-resistant E. coli. This was also inhibiting peptidoglycan and ribosome synthesis to reverse the resistance. Sanver et al. (2016) reported that quercetin showed to disrupting the lipid monolayer structure and reducing the bilayer thickness. structure. In this present study, the synergy of apigenin, catechin, coumaric acid, gallic acid, genistein, hydroxybenzoic acids, luteolin, myricetin, naringenin dan quercetin in jengkol waste extract, bitter bean waste extract and mangosteen waste extract were effec-

### Table 3. Bioactive compounds of different tropical fruit and vegetable waste extract.

| No | Bioactive compounds | Molecular weight (g/mol) | Pineapple Pericarp | Jackfruit Pericarp | Durian Pericarp | Coffee Pericarp | Cacao Pericarp | Mangosteen Pericarp | Sembukan Stem | Lamtoro Pericarp | Jengkol/Bitter bean Pericarp | Indian Marsh Fleabane Leaf |
|----|--------------------|---------------------------|--------------------|-------------------|-----------------|---------------|---------------|-------------------|----------------|----------------|-----------------------------|---------------------------|
| 1  | Apigenin           | 270.1                     | -                  | +                 | +               | +             | +             | +                 | +             | +             | +                          | +                         |
| 2  | Caffeic acid       | 180.2                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 3  | Catechins          | 290.3                     | -                  | +                 | -               | -             | +             | +                 | +             | +             | -                          | +                         |
| 4  | Coumaric Acid      | 163.0                     | +                  | +                 | -               | -             | -             | +                 | +             | +             | -                          | +                         |
| 5  | Curcumin           | 368.4                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 6  | Cyanidin           | 287.2                     | -                  | +                 | -               | +             | -             | +                 | -             | -             | -                          | -                         |
| 7  | Daidzein           | 254.2                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 8  | Delphinidin        | 303.2                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 9  | Eriodictyol        | 288.3                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 10 | Ferulic acid       | 194.2                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | +                         |
| 11 | Gallic Acid        | 170.1                     | -                  | +                 | +               | +             | +             | -                 | +             | +             | -                          | -                         |
| 12 | Gallocatechin      | 306.3                     | -                  | -                 | -               | -             | -             | -                 | +             | -             | -                          | -                         |
| 13 | Genistein          | 270.2                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 14 | Hesperetin         | 302.3                     | +                  | +                 | -               | +             | +             | +                 | +             | +             | +                          | +                         |
| 15 | Hydroxybenzoic Acids | 138.1                  | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 16 | Kaempferol         | 288.2                     | +                  | +                 | +               | +             | +             | +                 | +             | +             | +                          | +                         |
| 17 | Luteolin           | 286.2                     | +                  | +                 | +               | +             | +             | +                 | +             | +             | +                          | +                         |
| 18 | Malvidin           | 331.3                     | +                  | -                 | +               | -             | -             | -                 | -             | -             | -                          | -                         |
| 19 | Myricetin          | 318.2                     | +                  | +                 | -               | +             | +             | +                 | -             | +             | -                          | +                         |
| 20 | Naringenin         | 272.3                     | +                  | -                 | +               | +             | +             | +                 | -             | +             | -                          | +                         |
| 21 | Pelargonidin       | 271.2                     | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 22 | Petunidin          | 317.3                     | -                  | +                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 23 | Protocatechuic acid | 154.1                 | -                  | -                 | -               | -             | -             | -                 | -             | -             | -                          | -                         |
| 24 | Quercetin          | 302.2                     | +                  | +                 | +               | +             | +             | +                 | +             | +             | +                          | +                         |

### Table 4. Total phenol and other bioactive compounds of different tropical fruit and vegetable waste extract.

| Tropical Fruit and vegetable* | Waste   | Total phenol (mgGAE/g) | Kaempferol (ppm) | Coumaric acid (ppm) | Quercetin (ppm) |
|--------------------------------|---------|------------------------|------------------|---------------------|-----------------|
| Pineapple                      | Peel    | 1.491                  | 0.213            | 0.134               | 11.043          |
| Jackfruit                      | Peel    | 0.948                  | 0.112            | 0.217               | 0.171           |
| Durian                         | Peel    | 1.122                  | 0.225            | 0.21                | 0.251           |
| Coffee                         | Peel    | 4.839                  | 0.211            | 0.349               | 0.182           |
| Cacao                          | Pods    | 1.226                  | 0.117            | 0.277               | 0.161           |
| Mangosteen                     | Peel    | 4.419                  | 0.491            | 0.397               | 0.182           |
| Sembukan                       | Stem    | 0.663                  | 0.055            | 0.096               | 0.109           |
| Lamtoro                        | Pods    | 2.727                  | 0.057            | n.d                 | 1.88            |
| Jengkol                        | Sheel   | 4.423                  | 0.472            | 0.735               | 17.541          |
| Bitter bean                    | Pods    | 4.441                  | 0.241            | 0.476               | 11.043          |
| Indian Marsh Fleabane          | Leaf    | 2.923                  | 0.247            | 0.658               | 14.274          |

nd = not detected. *Pineapple = ananas comosus; jackfruit = Artocarpus heterophyllus; durian = Dario; coffee = Coffea arabica; mangosteen = Mangifera; sembukan = Faideria forfida; lamtoro = Leucaena leucocephala; jengkol = Archidendron pacciiflorum; bitter bean = Parkia speciosa; indian marsh fleabane = Plancha indica.
tive to against gram-positive and gram-negative bacteria. Vikram et al. (2010) reported that apigenin, kaempferol, quercetin and naringenin were antagonist of cell signalling in bacteria. Xie et al. (2015) revealed that luteolin inhibits gram-positive and gram-negative bacteria. Yamamoto and Ogawa (2002) revealed that luteolin and quercetin, a hydroxyl group at the 3' position, showed antimicrobial activity to bacteria. Yamamoto and Ogawa et al. (2002) also reported that apigenin had less antimicrobial activity than luteolin and quercetin. Luteolin, a core flavonoid, has been reported to act on bacteria cell wall and disrupting bacteria cytoplasmic membrane (Bashyal et al., 2019). Other study reported that quercetin, a plant flavonoid group of polyphenols, showed to reduce the quorum sensing-dependent phenotypes, to reduce the exopolysaccharide (EPS) production and to increase the motility of bacteria (Meena and Sheety, 2015). Apigenin, a group of flavonoids, has been reported to inhibit the peptidoglycan synthesis, to inhibit the activity of lactamase enzymes and to alter the outer and cytoplasmic membrane permeabilization, to inhibit on the efflux pump of bacteria (Eumkeb and Chukrathok, 2013). Flavonoid showed three mechanisms of antimicrobial by inhibiting the cytoplasmic membrane function, nucleic acid synthesis, energy metabolism and the porin on the cell membrane, altering the membrane permeability, and attenuating the pathogenicity (Ulanowska et al., 2006).

In this present study, phenolic compound of tropical fruit and vegetables wastes observed was coumaric acid. Coumaric acid has two antimicrobial activity mechanisms by disrupting the bacterial cell membrane and binding the DNA of bacteria. This may disturb the cellular function and cause cell death (Lou et al., 2012). Coumaric acid has one hydroxy group which is similar to caffeic acid (Masek et al., 2016). This present study found that extract of jengkol waste, bitter bean waste and mangosteen waste were composed by gallic acid. Gallic acid, hydroxybenzoic acids group, showed anti-microbial activity by reducing the lipopolysaccharides formation which cause apoptosis cell (Haute et al., 2015). Jengkol waste extract, bitter bean waste extract and mangosteen waste extract might be a potential eco-friendly and natural antimicrobial to inhibit food-borne pathogenic bacteria.

Conclusions

The present work highlights the effect antimicrobial of tropical fruit and vegetable waste to inhibit the growth of food-borne pathogenic bacteria. Jengkol waste extract, bitter bean waste extract and mangosteen waste extract showed antimicrobial activity for Gram-positive and Gram-negative bacteria due to the presence of apigenin, catechin, coumaric acid, gallic acid, genistein, hydroxybenzoic acids, luteolin, myricetin, naringenin dan quercetin. Sembukan and lamtoro waste extract showed to against Gram negative bacteria. Jengkol, bitter bean, mangosteen, sembukan and lamtoro waste extract might be a potential eco-friendly and natural antimicrobial to inhibit food-borne pathogenic bacteria.

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