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

Titik Budiati,[1] Wahyu Suryaningsih,[1] Titania Nur Bethiana[2]

[1]Food Engineering Department, Politeknik Negeri Jember, Jember, East Java, Indonesia; [2]Chemical and Biomolecular Engineering Department, Johns Hopkins University, Baltimore, MD, USA

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 hydrophilla, Bacillus cereus, Escherichia coli, Listeria monocytogenes, Salmonella* Typhimurium, *Staphylococcus aureus, Vibrio parahaemolyticus*). 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, lamtoro 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. hydrophilla, E. coli, S.* Typhimurium and *V. parahaemolyticus*) was shown by jengkol, bitter bean, mangosteen, sembukan and lamtoro 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 and 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 lamtoro 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 consequent 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. These are 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 pharmaceuticals 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 to inhibit the growth of food-borne pathogenic bacteria (Fancello *et al*., 2019).

The food-borne pathogenic bacteria such as *Aeromonas hydrophilla, Bacillus cereus, Escherichia coli, Listeria monocytogenes, Salmonella* Typhimurium, *Staphylococcus aureus, Vibrio parahaemolyticus* has been detected in various food and food products (Budiati *et al*., 2016, Simonavičienė *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 vegetables 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. hydrophilla, B. cereus, E. coli, L. monocytogenes, S.* Typhimurium, *S. aureus, V. parahaemolyticus*).

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, lamtoro pods, jengkol sheel, 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. hydrophilla* ATCC 7966, *B. cereus* ATCC 10876, *E. coli* ATCC 25922, *L. monocytogenes* ATCC 7644, *S.* Typhimurium ATCC 14028, *S. aureus* ATCC 25923, *V. Parahaemolyticus* 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

Correspondence: Titik Budiati, Food Engineering Department, Politeknik Negeri Jember, Mastrip PO Box 164 Jember, 68101, East Java, Indonesia.
E-mail: titik_budiati@polije.ac.id

Key words: Antimicrobial; Fruit, Tropical, Vegetable, Waste.

Contributions: The authors contributed equally.

Conflict of interest: The authors declare no conflict of interest.

Funding: This work was supported by PNBP Research (grant number 496/17.4/PG/2020).

Availability of data and material: Data and materials are available by the authors.

Received for publication: 12 April 2022.
Revision received: 21 August 2022.
Accepted for publication: 1 September 2022.

Italian Journal of Food Safety 2022; 11:10510
doi:10.4081/ijfs.2022.10510

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 cultured 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 aliquot was swabbed in 3 different directions onto Mueller Hinton Agar (Oxoid, England). A sterile 6 mm filter paper disc was aseptically placed on Mueller Hinton Agar surfaces. A total of 15 µl crude extract was added on to discs and was incubated at 37°C for 24±2 hours. The inhibition zones were measured in 4 different directions of diameter and recorded as millimetre. The experiment was done in triplicate. A 15 µl aliquot of 10% DMSO was dropped onto a sterile paper disc as a negative control. Penicillin G (10 unit/ml) was used as positive control for *S. aureus B. cereus* and *L. monocytogenes*. 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 cultured 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 10^8 CFU / mL. About 20 µL aliquot was pipetted onto 180 µL of different concentration of Mueler 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 10^7 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.*

Quantification of total phenol

Total phenol quantification was done by the method of Vala and Maitreya (2019). About 1 mL tropical fruit and vegetable extract was pipetted and added with 0,4 mL reagent of Folin Ciocalteau. The mixture was shaken and let for 4-8 min followed by adding 4 mL Na_2CO_3 7%. Aquadest was added until reach 10 mL and let for 2 hours in room temperature. Measuring the absorbance with the wavelength of 744,8 nm. Gallic acid (Sigma, USA) was used as a standard. Total phenol was calculated as mg equivalent gallic acid/gram extract.

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 × 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	0,38±0^{b}	0,85±0,78^{a}	1,1±0,1^{b}	0±0^{a}	0±0^{a}	0,8±0,19^{b}	1±0^{b}
Jackfruit	Peel	0,375±0^{b}	2,17±0,29^{b}	3,33±0,58^{d}	0±0^{a}	0,17±0,29^{a}	0,46±0,07^{a}	0,67±0,29^{ab}
Durian	Peel	0,02±0^{a}	0,9±0,85^{a}	4,33±0,58^{de}	0±0^{a}	0±0^{a}	1,42±0,29^{c}	1,33±0,58^{bc}
Coffee	Peel	0,5±0,29^{b}	1,33±0,29^{a}	2,1±0,1^{c}	1±0^{b}	0,67±0,58a^{b}	0,38±0,21^{a}	0,67±0,29^{ab}
Cacao	Pods	1,25±0,58^{bc}	0,83±0,29^{a}	0,27±0,23^{a}	0±0^{a}	0,67±0,58^{ab}	0,58±0,38^{ab}	5±0^{e}
Mangosteen	Peel	1,33±0,58^{bc}	2,33±0,29^{b}	3,33±0,58^{d}	1,3±0,6^{d}	3,33±0,58^{c}	2,83±0,29^{d}	0,5±0^{a}
Sembukan	Stem	1,5±0^{c}	1,04±0,59^{a}	2,13±0,12^{c}	1±0^{b}	0±0^{a}	0,42±0,14^{a}	1,67±0,58^{c}
Lamtoro	Pods	1,5±0^{c}	1,72±0,14^{b}	3,07±0,06^{d}	3,3±0,6^{c}	1,33±0,58^{b}	0,71±0,29^{ab}	0,5±0^{a}
Jengkol	Sheel	2,25±0^{d}	3,17±0,14^{c}	5,33±0,58^{f}	6,3±0,6^{d}	2,67±0,58^{c}	1,25±0,7^{b}	3±0^{d}
Bitter bean	Pods	2,33±0,58^{cd}	2,75±0,43^{bc}	4,33±0,58^{e}	3,3±0,6^{c}	7±1d	4,18±0,12^{e}	0,5±0^{a}
Indian Marsh Fleabane	Leaf	1,25±0,58^{bc}	1,13±0,22a	0,83±0,29^{b}	1±0^{b}	0±0^{a}	0,67±0,14^{ab}	0,5±0^{a}

^{a,d}Different alphabet means significant different at P<0.05 in the same column of MIC value. *Pineapple = *ananas comosus*; jackfruit = *Artocarpus heterophyllus*; durian = *Durio*; coffee = *Coffea arabica*; mangosteen = *Mangifera;* sembukan = *Paederia foetida*; lamtoro = *Leucaena leucocephala*; jengkol = *Archidendron pauciflorum*; bitter bean = *Parkia speciosa*; indian marsh fleabane = *Pluchea 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 2,33±0,58 mm (Table 1). The highest antimicrobial activity was shown by the extract of jengkol waste, bitter bean waste lamtoro 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. paramaemolyticus* 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 lamtoro waste extract and sembukan waste extracts. The extracts were composed by apigenin, hesperetin, kaempferol, luteolin dan quercetin (Table 4). Total phenol of those extracts was observed for 2,727 and 0,663 mg GAE/g, respectively.

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.

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	0,024±0^{b}	50±0^{d}	50±0^{d}	3,1±0^{b}	25±0^{d}	50±0^{c}	50±0^{d}
Jackfruit	Peel	0,024±0^{b}	0,00038±0^{a}	25±0^{c}	50±0^{e}	50±0^{d}	50±0^{c}	25±0^{c}
Durian	Peel	0,38±0^{c}	50±0^{d}	25±0^{c}	25±0^{d}	25±0^{d}	33,3±14,43^{b}	50±0^{d}
Coffee	Peel	0,38±0^{c}	6,25±0^{b}	50±0^{d}	3,1±0^{b}	12,5±0^{c}	16,7±7,22^{b}	12,5±0^{b}
Cacao	Pods	1,56±0^{d}	25±0^{c}	100±0^{e}	12,5±0^{c}	6,25±0^{b}	33,3±14,43^{b}	25±0^{c}
Mangosteen	Peel	0,00019±0^{a}	0,00038±0^{a}	0,78±0^{a}	25±0^{d}	1±0,13^{a}	6,25±0^{a}	25±0^{c}
Sembukan	Stem	0,00038±0^{a}	6,25±0^{b}	25±0^{c}	25±0^{d}	25±0^{d}	50±0^{c}	3,125±0^{a}
Lamtoro	Pods	0,00038±0^{a}	0,0015±0^{a}	25±0^{c}	12,5±0^{c}	12,5±0^{c}	16,7±7,22^{b}	25±0^{c}
Jengkol	Sheel	0,00038±0^{a}	0,00038±0^{a}	0,78±0^{a}	0,4±0^{a}	6,25±0^{b}	4,2±1,8^{a}	25±0^{c}
Bitter bean	Pods	0,00038±0^{a}	0,00038±0^{a}	3,13±0^{b}	0,4±0^{a}	6,25±0^{b}	4,7±2,71^{a}	50±0^{d}
Indian Marsh Fleabane	Leaf	12,5±0^{e}	6,25±0^{b}	50±0^{d}	25±0^{d}	12,5±0^{c}	33,3±14,43^{b}	50±0^{d}

$^{a-e}$Different alphabet means significant different at P<0.05 in the same column of inhibition zone. *Pineapple = *ananas comosus*; jackfruit = *Artocarpus heterophyllus*; durian = *Durio*; coffee = *Coffea arabica*; mangosteen = *Mangifera;* sembukan = *Paederia foetida*; lamtoro = *Leucaena leucocephala*; jengkol = *Archidendron pauciflorum*; bitter bean = *Parkia speciosa*; indian marsh fleabane = *Pluchea indica.*

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	Molecul weight (g/mol)	Pineapple Pericarp	Jackfruit Pericarp	Durian Pericarp	Coffee Pericarp	Cacao Pericarp	Mangosteen Pericarp	Sembukan Stem	Lamtoro Pericarp	JengkolBitter bean Pericarp	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 aicd	194,2	-	-	-	-	-	-	-	-	-	-	+
11	Gallic Acid	170,1	-	+	+	+	+	+	-	+	+	+	-
12	Gallocetehins	306,3	-	-	-	-	-	-	-	+	-	-	-
13	Genistein	270,2	-	-	-	-	+	-	-	-	-	-	-
14	Hesperetin	302,3	+	+	-	+	+	+	+	+	+	+	+
15	Hydroxybenzoic Acids	138,1	-	-	-	-	-	-	-	-	-	-	-
16	Kaempfenol	286,2	+	+	+	+	+	+	+	+	+	+	+
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 = *Durio*; coffee = *Coffea arabica*; mangosteen = *Mangifera;* sembukan = *Paederia foetida*; lamtoro = *Leucaena leucocephala*; jengkol = *Archidendron pauciflorum*; bitter bean = *Parkia speciosa*; indian marsh fleabane = *Pluchea 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-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 hydroxyl 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 antimicrobial 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.

References

Agourram A, Ghirardello D, Rantsiou K, Zeppa G, Belviso S, Romane A, Oufdou K, Giordano M, 2013. Phenolic content, antioxidant potential, and antimicrobial activities of fruit and vegetable by-product extracts. Int J Food Propert 16:1092-104.

Altemimi A, Lakhssassi N, Baharlouei A, Watson D, Lightfoot D, 2017. Phytochemicals: Extraction, isolation, and identification of bioactive compounds from plant extracts. Plants 6:42.

Bakar RA, Ahmad I, Sulaiman SF, 2012. Effect of Pithecellobium jiringa as antimicrobial agent. Bangladesh J Pharmacol 7:131-4.

Bashyal P, Parajuli P, Pandey RP, Sohng JK, 2019. Microbial Biosynthesis of Antibacterial Chrysoeriol in Recombinant Escherichia coli and Bioactivity Assessment. Catalysts 9:112.

Bauer A, Kirby W, Sherris J, Turck M, 1966. Antibiotic susceptibility testing by a standardized single disc method. Am J Clin Pathol 45:493

Bouhafsoun A, Yilmaz MA, Boukeloua A, Temel H, Harche MK, 2018. Simultaneous quantification of phenolic acids and flavonoids in Chamaerops humilis L. using LC–ESI-MS/MS. Food Sci Technol 38:242-7.

Budiati T, Rusul G, Wan-Abdullah WN, Chuah LO, Ahmad R and Thong KL, 2016. Genetic relatedness of Salmonella serovars isolated from catfish (Clarias gariepinus) and tilapia (Tilapia mossambica) obtained from wet markets and ponds in Penang, Malaysia. J Food Protect 79:659-65.

Dzoyem JP, Hamamoto H, Ngameni B, Ngadjui BT, Sekimizu K, 2013. Antimicrobial action mechanism of flavonoids from Dorstenia species. Drug Discov Therapeut 7:66-72.

Eumkeb G, Siriwong S, Phitaktim S, Rojtinnakorn N, Sakdarat S, 2012. Synergistic activity and mode of action of flavonoids isolated from smaller galangal and amoxicillin combinations against amoxicillin□resistant Escherichia coli. J Appl Microbiol 112:55-64.

Eumkeb G, Chukrathok S, 2013. Synergistic activity and mechanism of action of ceftazidime and apigenin combination against ceftazidime-resistant Enterobacter cloacae. Phytomedicine 20:262-9.

Fancello F, Petretto GL, Marceddu S, Venditti T, Pintore G, Zara G, Mannazzu I, Budroni M, Zara S, 2019. Antimicrobial activity of gaseous Citrus limon var Pompia leaf essential oil against Listeria monocytogenes on ricotta salata cheese. Food Microbiol 103386.

Garcia L, 2010. Preparation of routine media and reagents used in antimicrobial susceptibility testing. Clinical Microbiology Procedures Handbook. 3rd Edn. ASM Press, Washington, DC, pp.181-201.

Gorinstein S, Martın-Belloso O, Park YS, Haruenkit R, Lojek A, Caspi A, Libman I, Trakhtenberg S, 2001. Comparison of some biochemical characteristics of different citrus fruits. Food Chem 74:309-15.

Gyawali R, Ibrahim SA, 2014. Natural products as antimicrobial agents. Food Control 46:412-29.

Haute GV, Caberlon E, Squizani E, de Mesquita FC, Pedrazza L, Martha BA, da Silva Melo DA, Cassel E, Czepielewski RS, Bitencourt S, Goettert MI, 2015. Gallic acid reduces the effect of LPS on apoptosis and inhibits the formation of neutrophil extracellular traps. Toxicol Vitro 30:309-17.

Joshi VK, Kumar A, Kumar V, 2012. Antimicrobial, antioxidant and phytochemicals from fruit and vegetable wastes: A review. Int J Food Ferment Technol 2:123.

Lou Z, Wang H, Rao S, Sun J, Ma C, Li J, 2012. p-Coumaric acid kills bacteria through dual damage mechanisms. Food Control 25:550-4.

Masek A, Chrzescijanska E, Latos M, 2016. Determination of antioxidant activity of caffeic acid and pcoumaric acid by using electrochemical and spectrophotometric assays. Int J Electrochem Sci 11:10644-58.

Meena VCK, Shetty PH, 2015. Quercetin Influences Quorum Sensing in Food Borne Bacteria: In-Vitro and In-

Silico Evidence. PLoS one 10:e0134684.
Paudyal N, Anihouvi V, Hounhouigan J, Matsheka MI, Sekwati-Monang B, Amoa-Awua W, Atter A, Ackah NB, Mbugua S, Asagbra A, Abdelgadir W, 2017. Prevalence of foodborne pathogens in food from selected African countries–A meta-analysis. Int J Food Microbiol 249:35-43.
Sagar NA, Pareek S, Sharma S, Yahia EM, Lobo MG, 2018. Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. Compr Rev Food Sci Food Safety 17:512-31.
Sanver D, Murray BS, Sadeghpour A, Rappolt M, Nelson AL, 2016. Experimental Modeling of Flavonoid–Biomembrane Interactions. Langmuir 32:13234-43.
Simonavičienė I, Zakarienė G, Lozoraitytė A, Zaborskienė G, Gerulis G, Stimbirys A, 2021. Identification and serotyping of Listeria monocytogenes, isolated from various salmon products, sold in retail market in Lithuania. Ital J Food Safety 10:9341.
Soong YY, Barlow PJ, 2004. Antioxidant activity and phenolic content ofselected fruit seeds. Food Chem 88:411–7.
Ulanowska K, Tkaczyk A, Konopa G, Wegrzyn G, 2006. Differential antibacterial activity of genistein arising from global inhibition of DNA, RNA and protein synthesis in some bacterial strains. Arch Microbiol 184:271-8.
Vala M, Maitreya B, 2019. Qualitative analysis, total phenol content (TPC) and total tannin content (TTC) by using different solvant for flower of Butea monosperma (Lam.) Taub. collected from Saurashtra region. J Pharmacognosy Phytochemistry 8:2 902-6.
Vikram A, Jayaprakasha GK, Jesudhasan PR, Pillai SD, Patil BS, 2010. Suppression of bacterial cell–cell signalling, biofilm formation and type III secretion system by citrus flavonoids. J Appl Microbiol 109:515–27.
Wijngaard HH, Rößle C, Brunton N, 2009. A survey of Irish fruit and vegetable waste and by-products as a source of polyphenolic antioxidants. Food Chem 116:202-7.
Xie Y, Yang W, Tang F, Chen X, Ren L, 2015. Antibacterial activities of flavonoids: structure-activity relationship and mechanism. Curr Med Chem 22:132-49.
Yamamoto H, Ogawa T, 2002. Antimicrobial activity of Perilla Seed Polyphenols against Oral Pathogenic Bacteria. Biosci Biotechnol Biochem 66:921-4.