



Comparative Analysis of Antioxidant and Antimicrobial Properties of Banana and Lime Fruit Peel Extracts

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ABSTRACT

Fruit peels generated during food processing are generally considered as waste and are not further utilized. However, studies conducted on fruit peels have revealed the presence of constituents that could be used for pharmacological or pharmaceutical applications. To evaluate the potential of extracting such health promoting bioactive materials from fruit peels, current study was aimed to determine the polyphenolic content and the antioxidative and antimicrobial activities of methanolic peel extracts of four local banana (*Musa sapientum*) varieties (*Ambul*, *Anamalu*, *Seeni* and *Kolikuttu*) and lime (*Citrus aurantifolia*). The *Folin-Ciocalteu* method was employed to calculate the total phenolic content, and antioxidant capacity was assessed with DPPH, ABTS^{•+} and TBARS assays. The antimicrobial efficacy was determined using agar well diffusion method against *Staphylococcus aureus* and *Escherichia coli*. According to the results, lime and *Anamalu* banana peel exhibited the highest total phenolic content (178.30±2.46 µg GAE/ml, 120.27±0.89 µg AAE/ml and 177.87±3.68 µg GAE/ml, 102.11±1.35 µg AAE/ml respectively). All fruit peel extracts showed high scavenging effects on DPPH and ABTS^{•+} radicals with IC₅₀ values ranging from 51.51%±0.76 to 54.65%±0.11 and 51.56%±0.35 to 67.14%±1.38 respectively. Lime and *Ambul* banana showed the lowest total TBARS content. All tested banana peel extracts showed no antimicrobial activity while the absolute lime peel extracts showed a high zone of inhibition (1.9±0.0 cm) against *E. coli* and (1.8±0.1 cm) *S. aureus*. Current study provides the initial evidence of having antioxidant and antimicrobial properties in banana and lime peel. Thus, a potential exists to extract the bioactive materials responsible for such properties focusing possible applications.

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INTRODUCTION

Fruits are considered as an important part of a healthy and balanced diet. Fruit waste and by-products are formed in great amounts during industrial processing of fruits. These have usually been discarded creating a serious problem on environment. Therefore, it is important to find effective ways to manage or utilize waste materials and by-products formed during fruit processing (Sagar et al., 2018). Extensive researches on utilizing these wastes are being carried out worldwide (Gowe, 2015).

Previous researches have proved the antimicrobial activity of selective varieties of lime and banana peel extracts against some bacterial strains (Mahmud et al., 2009; Aboul-Enein et al., 2016). The peel of citrus fruits is a rich source of flavanones and polymethoxylated flavones that rarely occur in other plants (Nogata et al., 2006). The major components of lime peel essential oil proved to be β -pinene (12.6%), limonene (53.8%), γ -terpinene (16.5%), terpinolene (0.6%), α -terpineol (0.4%) and citral (2.5%) (Dosoky and Setzer, 2018). These are most likely to be associated with the good antimicrobial activity, in particular on gram-positive bacteria such as *Staphylococcus aureus*, *Bacillus subtilis* and *Staphylococcus epidermidis*. The lime peel demonstrated a strongest radical scavenging activity. The most abundant flavonoids found in *C. aurantifolia* extracts were apigenin, rutin, quercetin, kaempferol and nobiletin (Tundis et al., 2012).

Banana peel is a rich source of phenolic compounds (Tsamo et al., 2015). The total amount of phenolic compounds in banana peel has been reported as 0.90 to 3.0 g/100g dry weight. The flavonoids detected in banana peel are as quercetin, myricetin, kaempferol, and cyaniding. These provide health benefits mainly by acting as free radicals including reactive oxygen species (ROS), and reactive nitrogen species (RNS) (Kevers et al., 2007). In bananas the peel can be the major source of obtaining natural antioxidant. Ascorbic acid, tocopherol, beta carotene, phenolic groups, dopamine and gallic acid are antioxidant compounds identified in banana peel. Anthocyanins, delphinidin, cyaniding and catecholamines also contain in ripe banana peel. In addition, carotenoids such as α -carotene, β -carotene and xanthophylls have been discovered in banana peel as well as sterols and triterpenes (Ayala-Zavala et al., 2011). Researchers have demonstrated the antimicrobial activity of banana peel against various gram-positive and gram-negative bacteria including *M. catarrhalis*, *S.*

aureus, *S. pyogenes*, *E. aerogenes* and *K. pneumonia* (Chabuck et al., 2013).

The effects of antioxidants in banana and lime peel extracts in scavenging the free radicals have been reported in previous studies (González-Montelongo et al., 2010; Bocco et al., 1998). In this study, methanolic extracts of peels from four common varieties of banana; *Ambul* Banana (Sour banana or *Musa acuminata*, AA), *Seeni* Banana (Sweet banana or *Musa acuminata* × *Musa balbisiana*, AABB), *Anamalu* Banana (Gros Michel or *Musa acuminata*, AAA), *Kolikuttu* Banana (Latundan or *Musa acuminata* × *Musa balbisiana*, AAB group) and lime, those are commonly consumed in Sri Lanka were obtained and tested for the antioxidant and antimicrobial properties. The results of this study will aid in developing new effective antimicrobial agents as well as natural antioxidant agents with potential applications in food and pharmaceutical industries.

METHODOLOGY

Collection of plant samples

Healthy plants of lime and four varieties of banana (*Ambul* Banana (*Musa acuminata*, AA), *Anamalu* Banana (*Musa acuminata*, AAA), *Kolikuttu* Banana (*Musa acuminata* × *Musa balbisiana*, AAB), *Seeni* Banana (*Musa acuminata* × *Musa balbisiana*, AABB)) were purchased from retail vendors, and brought into the laboratory under humid conditions.

Pre-treatment and surface sterilization of samples

Fruits were washed with tap water and then with distilled water. Fruit peels were removed and shade dried at room temperature (30-32°C) for three days. The dried peels were grounded and kept in an air tight polyethylene bag until extraction.

Crude extraction

Pulverized peel (25 g) of each sample was soaked separately in 500 ml of methanol (99%) and kept in a shaker for 3 days. Each preparation was filtered through a sterilized Whatman No.1 filter paper and the filtered extract was concentrated to 25ml solutions using a rotary evaporator (30 rpm, 40 °C). The extract was stored in the refrigerator (4 °C).

Determination of total phenolic content

The total phenolic content was determined according to the method described by Lordan et al. (2013). Briefly, 10 μ g standard or the extract was mixed with 50 μ l Folin-ciocalteu's reagent in 96 well

microplate and then it was incubated at room temperature for 5 min. Sodium carbonate (40 µl of 7.5%) was added to the reaction mixture and incubated in the dark for 2 h and the absorbance was measured using a microplate reader (Thermo Scientific Multiskan Go, Thermo Fisher Scientific, USA) at 750 nm. Gallic acid and ascorbic acid were used as the standards in the concentration range of 25 µg/ml – 450 µg/ml. Results were expressed as µg Gallic acid/ml and µg Ascorbic acid/ml of extract.

Determination of antioxidant activity

DPPH radical scavenging activity:

DPPH radical scavenging activity was determined according to the method described by Farasat and Khavari-nejad, 2014. Each extract (100 µl) of 25, 50 and 100% was separately mixed with 100 µl of 0.16 mM DPPH solution and vortexed for 1 min. After incubating at dark for 30 min the absorbance was measured at 517 nm using microplate reader. Gallic acid and ascorbic acid were used as the standards. Percentage inhibition was calculated according to the equation (1).

$$\text{Inhibition (\%)} = \left(1 - \frac{A_{\text{sample}} - A_{\text{blank}}}{A_{\text{control}}}\right) \times 100 \dots (1)$$

where, A control is DPPH without sample, A sample is sample + DPPH, and A blank is sample without DPPH.

ABTS·+ radical scavenging activity:

ABTS·+ radical scavenging activity was determined according to the method Rajurkar and Hande, 2011. ABTS·+ radical was generated by reacting 7 mM ABTS in water and 2.45 mM potassium persulfate (1:1), stored in the dark at room temperature for 12-16 h before use. ABTS·+ solution was then diluted with methanol to obtain an absorbance of 0.70 at 734 nm. After the addition of 5 µl of dilutions 25, 50 and 100% to 3.995 ml of diluted ABTS·+ solution, the absorbance was measured 30 min after the initial mixing, at 517 nm using a microplate reader. Gallic acid was used as the standard. Percentage inhibition was calculated according to the equation (2).

$$\text{Inhibition (\%)} = \left(1 - \frac{B_{\text{sample}} - B_{\text{blank}}}{B_{\text{control}}}\right) \times 100 \dots (2)$$

where, B control is ABTS·+ without sample, B sample is sample + ABTS·+, and B blank is sample without ABTS·+

TBARS (lipid peroxidation) assay:

TBARS was determined according to the method described by Chen *et al.*, 2017. Each sample (2 g) was weighted into a centrifuge tube and 5 ml of 10% (w/v) TCA was added. It was vortexed at high speed for 2 min and the aqueous solution of 2-tiobarbituric acid (0.02 M, 5 ml) was added and vortexed for 30 sec. Solution was centrifuged at 3000xg for 10 min and the supernatant was filtered through a Whatman No 03 filter paper. Filtrate was placed in a boiling water bath for 45 min and was cooled to room temperature on ice. The absorbance was measured at 532 nm, and the total TBARS content was calculated according to the following equation.

$$\text{Total TBARS} = \text{Absorption } 532 \text{ nm} \times 7$$

Agar well diffusion antimicrobial assay:

Pathogenic strains of *Staphylococcus aureus* (ATCC 25923) and *Escherichia coli* (ATCC 35217) were obtained from American Type Cell Culture Collection, UAS and a loopful of the test isolates were taken from a stored agar slant and swabbed uniformly on Muller hunter agar (MHA) petri dishes separately and incubated at 37°C for 24 h. A loopful of the active colonies obtained were taken with a sterile wire loop, transferred into a 5ml of sterile saline (0.85%). Turbidity of the inoculums were compared with 0.5 McFarland standard solution (containing approximately 1.5×10^8 CFU/ml) as explained by Stefanovic and Comic, 2012.

Antimicrobial screening was performed using the agar well diffusion method. The MHA media was punched with 7mm diameter wells and filled with each extract (50 µl) at different concentrations (25, 35, 50 and 100%). The plates were then incubated at 37°C for 24 h. After the incubation, the zone of microbial growth inhibition due to each extract was measured in cm (Obinna *et al.*, 2008). Same procedure was continued, and the wells were filled with absolute extracts with different volumes (50, 100, 200, 300 µl). The antibiotic, Ofloxacin was used as the positive control and methanol was used as the negative controller.

Statistical analysis

All statistical analyses were conducted using Minitab 16 software. The inhibition zones were calculated as mean±SD. The significance among different data was evaluated by analysis of variance (One Way ANOVA) using general linear model with 95% confident level.

RESULTS AND DISCUSSION

Total phenolic content

Total phenol compounds are reported as gallic acid and ascorbic acid equivalents by reference to standard curve ($y = 0.0023x + 0.2899$, $R^2 = 0.971$) and ($y = 0.0063x + 0.0557$, $R^2 = 0.99$) respectively.

There were statistically significant differences ($p < 0.05$) in TPC among different peel extracts suggesting that TPC is dependent on the type of peel extract (Table 1). The methanolic extract of lime peel exhibited a higher TPC ($178.30 \pm 2.46 \mu\text{g GAE/ml}$ and $120.27 \pm 0.89 \mu\text{g AAE/ml}$) compared to the banana peel extracts. Among the banana varieties, *Anamalu* banana peel had the highest total phenol content ($177.87 \pm 3.68 \mu\text{g GAE/ml}$ and $102.11 \pm 1.35 \mu\text{g AAE/ml}$) and *Seeni* banana peel had the lowest total phenol content ($-6.48 \pm 1.84 \mu\text{g GAE/ml}$, $34.80 \pm 0.67 \mu\text{g AAE/ml}$). Higher phenolic content in the methanolic extract is responsible for the bioactivity, thus, lime peel extract and *Anamalu* peel extract are expected to exhibit better antioxidant and antibacterial activities.

Table 1: Mean (\pm SD) total phenolic content of peel extracts

Sample	Total Phenolic Content	
	Gallic Acid ($\mu\text{g GAE/ml}$ extract)	Ascorbic Acid ($\mu\text{g AAE/ml}$ extract)
<i>Ambul</i>	113.52 ± 9.22	78.62 ± 3.37
<i>Anamalu</i>	177.87 ± 3.68	102.11 ± 1.35
<i>Kolikuttu</i>	52.00 ± 2.16	56.15 ± 0.78
<i>Seeni</i>	-6.48 ± 1.84	34.80 ± 0.67
Lime	178.30 ± 2.46	120.27 ± 0.89

note GAE= gallic acid equivalents, AAE=ascorbic acid equivalents

Similar to current findings previous researches have also revealed a higher tpc of banana and lime peel extracts (gonzalez-montelongo *et al.*, 2010; singanusong *et al.*, 2015; aboul-enein *et al.*, 2016; fatemeh *et al.*, 2012). Specifically, singanusong *et al.*, 2015 revealed tpc of lime peel as $987.51 \text{ mg gae}/100 \text{ g}$. Aboul-enein *et al.*, 2016 showed that tpc in methanolic extract of banana peels as 17.89 mg/g dw . Further, fatemeh *et al.*, 2012 reported the tpc in two varieties of banana peel (cavendish and dream) as 585.29 and $685.57 \text{ mg gae}/100 \text{ g dry matter}$ and 91.90 and $160.77 \text{ mg gae}/100 \text{ g dry matter}$ at two stages of ripeness (ripe and green). Different extract concentrations and different procedures adopted for tpc analysis, even when using gallic acid as reference are likely to give different results. Therefore, we were unable to

conduct direct comparison of these findings with current study results due to differences in assessment methods and fruit varieties used.

DPPH radical scavenging activity

Concentration (%) of the antioxidants present in a (peel extract) required for the inhibition of DPPH radical up to 50%, was calculated as IC₅₀, by linear regression analysis using a graph constructed by plotting the percentage of scavenging against the respective concentration of standard antioxidants (*Ambul*; $y = 91.659x + 0.7159$, $R^2 = 0.9997$, *Anamalu*; $y = 97.695x - 0.66$, $R^2 = 0.9997$, *Kolikuttu*; $y = 91.371x + 0.4075$, $R^2 = 0.9998$, *Seeni*; $y = 91.564x - 0.0501$, $R^2 = 0.9998$ and lime; $y = 98.343x - 0.658$, $R^2 = 0.9999$).

Both, banana and lime extracts, of the present work showed free radical (DPPH) scavenging or antioxidant activity in a concentration-dependent manner. The lime peel extract had higher value ($51.51\% \pm 0.76$) compared to that of all banana types (Table 2). The banana variety *Seeni* showed the lowest antioxidant activity ($54.65\% \pm 0.11$).

Table 2: Mean (\pm SD) DPPH radical scavenging activity of peel extracts

Sample	DPPH Radical Scavenging Activity% (IC ₅₀)
<i>Ambul</i>	53.77 ± 1.53
<i>Anamalu</i>	51.85 ± 0.63
<i>Kolikuttu</i>	54.26 ± 0.86
<i>Seeni</i>	54.65 ± 0.11
Lime	51.51 ± 0.76
Gallic Acid	14.87 ± 1.31
Ascorbic acid	15.45 ± 0.59

According to Loizzo *et al.*, 2012 the methanolic extract of lime peels extracted from 3 different areas in of high Jonio coast in Cosenza province, Italy, showed DPPH IC₅₀ values between 78.3 and 93.8 gmL^{-1} . Aboul-Eneinet *et al.*, (2016) have reported that DPPH IC₅₀ values of banana peel depends on the type of extract used. According to them banana peel extract with 80% methanol was $56.22 \mu\text{gmL}^{-1}$, 80% ethanol was $75.34 \mu\text{gmL}^{-1}$, aqueous extract was $120.03 \mu\text{gmL}^{-1}$, and 80% acetone was $55.45 \mu\text{gmL}^{-1}$.

ABTS+radical scavenging activity

The concentration (%) of these compounds required to inhibit 50% of the radical-scavenging effect (IC₅₀) was determined by linear regression analysis using a graph constructed by plotting the percentage of scavenging against the respective concentration of standard antioxidants (*Ambul*; $y =$

$80.654x + 3.7119$, $R^2 = 1$, *Anamalu*; $y = 83.317x + 1.0702$, $R^2 = 1$, *Kolikuttu*; $y = 82.83 + 1.8833$, $R^2 = 0.9996$, *Seeni*; $y = 76.503x - 1.3467$, $R^2 = 0.9986$ and lime; $y = 98.848x - 0.9795$, $R^2 = 0.9996$). The radical scavenging activity of banana peel and lime peel extracts were compared with those of gallic acid and ascorbic acid at the same concentrations. The lower IC_{50} value reflects greater antioxidant activity of the sample. The results of $ABTS^+$ -scavenging activity of banana peel extracts and lime peel extracts are summarized in Table 3 (IC_{50} values)

Table 3: Mean (\pm SD) $ABTS^+$ radical scavenging activity of peel extracts

Sample	$ABTS^+$ Radical Scavenging Activity% (IC_{50})
<i>Ambul</i>	7.39 \pm 0.80
<i>Anamalu</i>	58.72 \pm 0.84
<i>Kolikuttu</i>	58.08 \pm 0.47
<i>Seeni</i>	67.14 \pm 1.38
Lime	51.56 \pm 0.35
Gallic acid	13.04 \pm 0.15

The results from the antioxidant assay showed that tested peel extracts have a potential scavenge free radicals to a certain extent. The highest $ABTS^+$ radical scavenging activity was reported in lime peel (51.56% \pm 0.35) and it could be due to the presence of higher phenolic content. The tested banana peel extracts showed antioxidant activity in the order of *Ambul* (57.39% \pm 0.80), *Kolikuttu* (58.08% \pm 0.47), *Anamalu* (58.72% \pm 0.84) and *Seeni* (67.14% \pm 1.38) from highest to the lowest.

Loizzo et al., 2012 have reported that the TEAC values for $ABTS$ assay with methanolic extracts of lime peels from 3 different areas of high Jonio coast in Cosenza province, Italy were between 18.7 and 41.4 μ M/g and depend on the area of growth. According to GomesRebello et al., 2014 the $ABTS$ assay TEAC value of banana peel was 242 μ M/g. However, current results could not be compared with these findings due to the differences in the methods used for assessing the $ABTS^+$ scavenging activity.

Table 5: Mean inhibition zone values of peel extracts (50 μ l) against *S. aureus*

Concentration	Mean inhibition zone diameter (cm) \pm SD						
	<i>Ambul</i>	<i>Anamalu</i>	<i>Kolikuttu</i>	<i>Seeni</i>	Lime	Antibiotic	Methanol
25%	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	1.1 \pm 0.0	<i>nzi</i>
35%	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	1.1 \pm 0.0	<i>nzi</i>
50%	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	1.3 \pm 0.0	<i>nzi</i>
100%	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	<i>nzi</i>	1.5 \pm 0.1	<i>nzi</i>

Note: *nzi*= no zone of inhibition

TBARS lipid peroxidation activity

TBARS assay detects the level of malondialdehyde (MDA), the major lipid oxidation product, and also some minor related compounds.

The results illustrate that the total TBARS content is low, and antioxidant activity is high in lime peel extract, followed by *Ambul* banana, when compared with the standards gallic acid and ascorbic acid. Further it was observed that, though the total TBARS content is high in *Seeni* banana peel extract its, antioxidant activity is low.

Table 4: Mean (\pm SD) total TBARS content

Sample	Total TBARS (μ M/g)
<i>Ambul</i>	1.84
<i>Anamalu</i>	4.74
<i>Kolikuttu</i>	3.06
<i>Seeni</i>	5.83
Lime	2.20
Gallic	1.58
Ascorbic Acid	1.86

Antimicrobial Activity

The peel extracts of five plant species were investigated to evaluate their antibacterial activity against *S.aureus* and *E.coli* using well diffusion method. Antibacterial activity of the tested peel extracts- (50 μ l) against *S. aureus* and *E.coli* were initially evaluated with different concentrations (25, 35, 50, and 100%) as shown in Table 5 and Table 6. The results revealed that banana peel extracts and lime peel extract have no potential antimicrobial activity when compared with the antibiotic, the positive controller used for both bacteria. The antibacterial activity of concentrated peel extracts of lime and banana varieties were evaluated against *S. aureus* and *E. coli* with different volumes. The results are summarized in the Tables 7 and 8, and Figures 1 and 2).

Table 6: Mean inhibition zone values of peel extracts (50 μ l) against *E.coli*

Concentration	Mean inhibition zone diameter (cm) \pm SD						
	<i>Ambul</i>	<i>Anamalu</i>	<i>Kolikuttu</i>	<i>Seeni</i>	Lime	Antibiotic	Methanol
25%	nzi	nzi	nzi	nzi	nzi	1.7 \pm 0.0	nzi
35%	nzi	nzi	nzi	nzi	nzi	1.9 \pm 0.0	nzi
50%	nzi	nzi	nzi	nzi	nzi	2.3 \pm 0.0	nzi
100%	nzi	nzi	nzi	nzi	nzi	2.6 \pm 0.1	nzi

Note: nzi= no zone of inhibition

Table 7: Mean inhibition zone values of peel extracts (100%) at different volumes against *S. aureus*

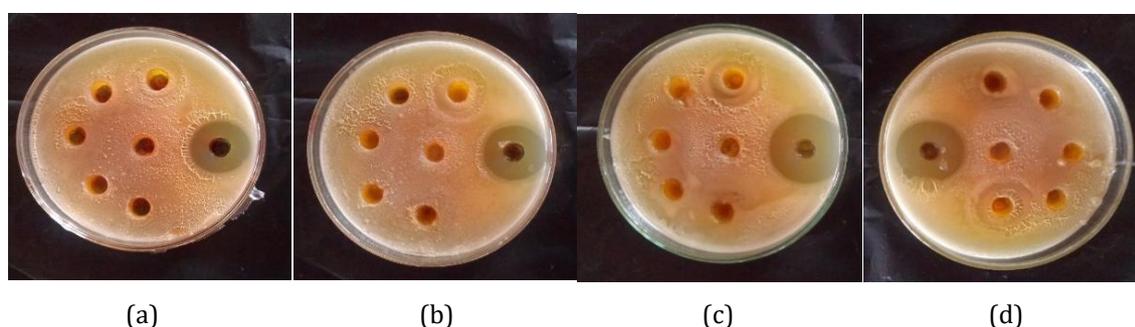
Volume (μ l)	Mean inhibition zone diameter (cm) \pm SD						
	<i>Ambul</i>	<i>Anamalu</i>	<i>Kolikuttu</i>	<i>Seeni</i>	Lime	Antibiotic	Methanol
300	nzi	nzi	nzi	nzi	1.8 \pm 0.1	2.6 \pm 0.0	nzi
200	nzi	nzi	nzi	nzi	1.7 \pm 0.0	2.5 \pm 0.0	nzi
150	nzi	nzi	nzi	nzi	1.6 \pm 0.0	2.1 \pm 0.0	nzi
100	nzi	nzi	nzi	nzi	1.5 \pm 0.0	2.1 \pm 0.0	nzi
50	nzi	nzi	nzi	nzi	nzi	1.5 \pm 0.1	nzi

Note: nzi= no zone of inhibition

Table.8: Mean inhibition zone values of peel extracts (100%) against *E.coli*

Volume (ml)	Mean inhibition zone diameter (cm) \pm SD						
	<i>Ambul</i>	<i>Anamalu</i>	<i>Kolikuttu</i>	<i>Seeni</i>	Lime	Antibiotic	Methanol
300	nzi	nzi	nzi	nzi	1.9 \pm 0.0	3.3 \pm 0.2	nzi
200	nzi	nzi	nzi	nzi	1.1 \pm 0.0	3.1 \pm 0.0	nzi
150	nzi	nzi	nzi	nzi	1.1 \pm 0.0	3.0 \pm 0.0	nzi
100	nzi	nzi	nzi	nzi	nzi	3.0 \pm 0.0	nzi
50	nzi	nzi	nzi	nzi	nzi	2.7 \pm 0.1	nzi

Note: nzi=no zones of inhibition

**Figure 1: Mean inhibition zone diameter lime peel extracts (100%) at different volumes against *S. aureus* (a) 100 ml (b) 150 ml (c) 200 ml (d) 300 ml**

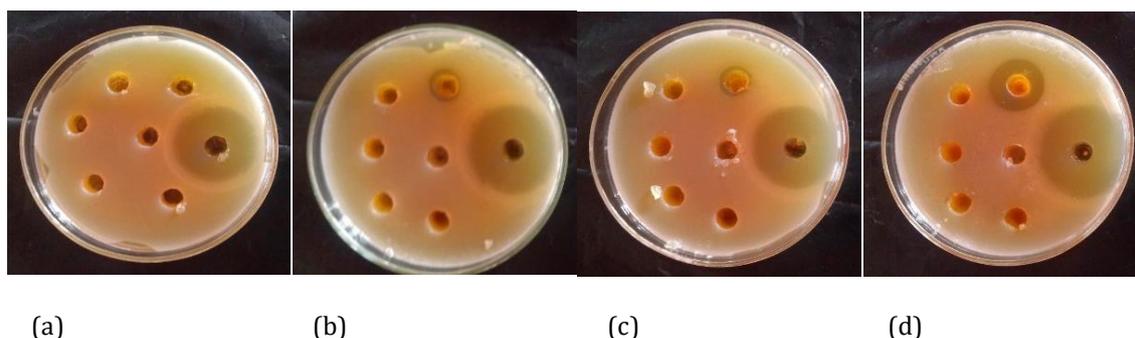


Figure 2: Mean inhibition zone diameter lime peel extracts (100%) at different volumes against *E. coli* (a) 100ml (b) 150ml (c) 200ml (d) 300ml

All the four banana varieties showed negative antimicrobial affect against the selected bacteria. But when compared with the positive control, the lime peel extract noted a significant antimicrobial activity against *S. aureus* and *E. coli* at volumes below 100 μ l and 150 μ l respectively. At volume 300 μ l lime peel showed the highest antimicrobial activity against the bacteria *E. coli*.

The results from previous studies of Sekar *et al.*, 2013, agreed with the current study indicating that the methanol extract of citrus varieties showed lower to moderate antibacterial activity towards *S. aureus* and *E. coli* at 20 mg/ml. However, other citrus varieties had better inhibition compared to lime. Acheampong *et al.*, 2015, indicated a high antimicrobial capacity of fresh peels of lime compared to the dried peels.

In contrast to the current study findings, have demonstrated a good inhibitory effect of aqueous banana peel extract (0.1 ml) against *S. aureus* with inhibition zone 30 mm. According to Bankar *et al.*, 2010 and Chabuck *et al.*, 2013. *E. coli* showed no susceptibility to banana peel extract and is in line with the current study findings. Sumathy. 2011, studied the antifungal and antimicrobial properties of yellow banana fruit peel and found that it is effective against different gram positive and negative bacteria. Additionally, Aboul-Enein *et al.*, 2016, showed that 80% ethanol extract inhibited bacterial species at 400 μ g/ml against bacteria *S. aureus* (10.53 mm) and *E. coli* (9.67 mm). The differences in current results in comparison to previous findings could be due to the differences in the banana varieties and methodologies used.

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CONCLUSION

In the current study, the antioxidant and antimicrobial potency of methanolic peel extract of lime and four commonly consumed banana varieties in Sri Lanka were evaluated. The results showed that phenolic content is highest in lime peel extract (178.30 ± 2.46 μ g GAE/ml and 120.27 ± 0.89 μ g AAE/ml) followed by *Anamalu* banana variety (177.87 ± 3.68 μ g GAE/ml, and 102.11 ± 1.35 μ g AAE/ml). While, *Seeni* banana showed the lowest phenolic content (-6.48 ± 1.84 μ g GAE/ml, 34.80 ± 0.67 μ g AAE/ml). The banana and lime peel extracts possess a good ability to scavenge the free radicals DPPH and ABTS+. Moreover, Lime and *Anamalu* banana had the highest DPPH scavenging activity (IC₅₀: $51.51\% \pm 0.76$; $51.85\% \pm 0.63$) whereas *Seeni* banana showed the lowest (IC₅₀: $54.65\% \pm 0.11$). The highest ABTS+ radical scavenging activity was reported in lime peel (IC₅₀: $51.56\% \pm 0.35$) and the lowest was observed in *Seeni* variety (IC₅₀: $67.14\% \pm 1.38$). The total TBARS content was low in lime peel extract the antioxidant activity was high (2.205 μ M/g). However, in contract to the expectation, banana peel extracts (100%) revealed no antimicrobial activity against *S. aureus* and *E. coli*. However, a considerable antimicrobial effect was observed only by the lime peel extracts. The absolute lime peel extracts (300 μ l) showed an inhibitory zone of 1.9 ± 0.0 cm against *E. coli* and 1.8 ± 0.1 cm against *S. aureus*. The results of this study will aid in utilizing the peel extracts of banana and lime in developing food products with antioxidant and antimicrobial properties

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