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Author

Mpala, Lindiwe, Chikowe, Getmore, Cock, Ian Edwin

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The Inhibitory Activity of *Mischarytera lauteriana* (F.M.Bailey) Leaf Extracts against a Panel of Bacterial Pathogens

Lindiwe Mpala¹, Getmore Chikowe¹, Ian Edwin Cock^{1,2,*}¹School of Environment and Science, Griffith University, 170 Kessels Rd, Nathan, Brisbane, Queensland, AUSTRALIA.²Environmental Futures Research Institute, Griffith University, 170 Kessels Rd, Nathan, Brisbane, Queensland, AUSTRALIA.

ABSTRACT

Introduction: The development of multi-antibiotic resistant strains of bacteria has necessitated the search for new, effective antibacterial therapies. *M. lauteriana* was used by Australian Aborigines as a nutritious food. However, very little research has been published on this species and the antibacterial activity of *M. lauteriana* leaf extracts has not yet been reported. **Methods:** The ability of *M. lauteriana* leaf extracts to inhibit the growth of gram-negative and gram-positive bacterial species was investigated by disc diffusion and growth time course assays. The growth inhibitory activity was further quantified by MIC determination. Toxicity was determined using the *Artemia franciscana* nauplii bioassay. **Results:** The methanolic and aqueous *M. lauteriana* leaf extracts were good inhibitors of the growth of both gram-positive and gram-negative bacteria. The methanolic extract was a particularly good inhibitor of *K. pneumoniae* and *B. cereus* growth, with MIC values of 728 and 515 µg/mL respectively. The aqueous extract was also a good inhibitor of these bacteria (MICs of 953 and 860 µg/mL respectively). Whilst the *M. lauteriana* leaf extracts also inhibited the growth of *P. mirabilis*, *S. aureus* and *S. pyogenes*, the MIC values (in the range 1000-2000 µg/mL) were indicative of moderate inhibitory activity. The *M. lauteriana* leaf extracts were further investigated by growth time course assays against *K. pneumoniae* and *B. cereus*. Interestingly, both extracts

showed significant growth inhibition within 1h of exposure against both bacterial species. All extracts were determined to be nontoxic in the *Artemia franciscana* nauplii bioassay, indicating their safety for the treatment of gram-positive bacterial infections. **Conclusion:** The lack of toxicity of the *M. lauteriana* leaf extracts and their growth inhibitory bioactivity against multiple bacteria indicate their potential in the development of new anti-biotic chemotherapies.

Key words: Sapindaceae, Corduroy tamarind, Traditional Medicine, Antibacterial, Antibiotic resistant bacteria, Ankylosing spondylitis, *Klebsiella pneumoniae*, *Bacillus cereus*.

Correspondence:

Dr. Ian Edwin Cock

School of Environment and Science and Environmental Futures Research Institute Griffith University, 170 Kessels Rd, Nathan, Brisbane, Queensland, AUSTRALIA.

E-mail: I.Cock@griffith.edu.au

Phone no.: +61-7 37357637

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INTRODUCTION

Despite many significant advances in the treatment of disease, many bacterial pathogens remain difficult to treat effectively as many strains have become either extremely (XDR) or totally drug resistant (TDR) to common clinically used antibiotics.¹ There are now limited therapeutic options for the diseases caused by these pathogens and the problem is expected to worsen in the future as bacteria exchange resistance genes and more strains become multi-drug resistant (MDR). The development of alternative antibacterial treatment modalities has become crucial and is considered by the World Health Organisation (WHO) to be one of the most serious challenges facing medical science.² For a number of reasons reviewed elsewhere,¹ it is unlikely that the previous methods of antibiotic discovery/development will be as successful in the future and new treatment modalities are urgently required.

Plants produce a wide variety of secondary compounds, which provide them characteristic pigment, odour and flavour characteristics and may also give them antimicrobial properties.³ Traditional plant derived medicines have been used in most parts of the world for a variety of therapeutic purposes, including fighting microbial disease. Indeed, the ability of plant extracts to block the growth of pathogenic bacteria has become the focus of much recent study.^{4,5} Much of the research into traditional medicinal plant use has focused on Asian,^{6,7} African⁸⁻¹² and South American^{13,14} plants. However, the therapeutic potential of the flora of Australia has also received recent attention. The first Australians had well-developed medicinal systems and understood the therapeutic properties of a wide variety of Australian plants and how to use them effectively.¹⁵ Whilst studies have reported antibacterial activity for some Australian plant species,¹⁶⁻¹⁹ the antibacterial activity of many Australian

native plants remains unexamined. *Mischarytera lauteriana* (F.M.Bailey) (Family Sapindaceae; synonyms *Nephelium lauteriana* (F.M.Bailey), *Arytera lauteriana* (F.M.Bailey); common name corduroy tamarind) is a species of rainforest tree that is endemic to the north eastern regions of Australia. It is a medium sized, sparsely branched understory tree which has wavy elongated leaves (Figure 1a). Small white-yellow flowers form as inflorescences (Figure 1b). These flowers develop into fruit capsules containing bright orange fruit (Figure 1c). *M. lauteriana* fruit were used as a nutritious food source by Australian Aborigines. Surprisingly, we were unable to find any studies examining either the therapeutic properties, nutritional value or the phytochemistry of this species. This study was undertaken to screen of *M. lauteriana* leaf extracts for the ability to inhibit the growth of a panel of gram-positive and gram-negative bacterial pathogens.

MATERIALS AND METHODS

Plant Collection and Extraction

Mischarytera lauteriana (F.M.Bailey) leaves were obtained from Philip Cameron, senior botanical officer, Mt Cootha Botanical Gardens, Brisbane, Australia. The leaf samples were dried in a Sunbeam food dehydrator and stored at -30°C. Prior to use, the dried leaves were freshly ground to a coarse powder and 1g quantities were weighed into separate tubes. A volume of 50mL of AR grade methanol (Ajax Fine Chemicals, Australia) or sterile deionised water was added to individual 1g masses of the plant material and extracted for 24 hrs at 4°C with gentle shaking. The extract was filtered through filter paper (Whatman No. 54) under vacuum, followed by lyophilisation. The resultant pellets were weighed

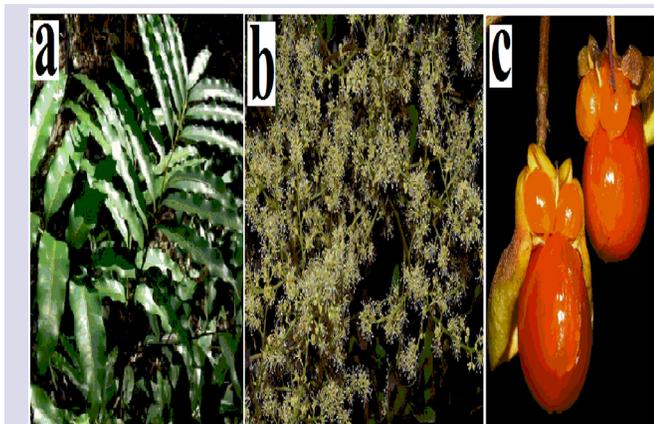


Figure 1: *M. lauteriana* (a) leaves, (b) flowers and (c) fruit.

to determine the extraction yield and subsequently dissolved in 10mL sterile deionised water (Containing 1% DMSO). The extracts were passed through 0.22µm filter (Sarstedt) and stored at 4°C until use.

Qualitative Phytochemical Studies

Phytochemical analysis of the *M. lauteriana* leaf extracts for the presence of saponins, phenolic compounds, flavonoids, phytosteroids, triterpenoids, cardiac glycosides, anthraquinones, tannins and alkaloids was conducted by standard assays.^{16,17}

Antibacterial Screening

Test Microorganisms

All media was purchased from Oxoid Ltd., Australia. The reference strains of *E. coli* (ATCC157293), *Klebsiella pneumoniae* (ATCC31488), *Proteus mirabilis* (ATCC21721) and *Streptococcus pyogenes* (ATCC19615) were purchased from American Tissue Culture Collection (ATCC), USA. Clinical isolate microbial strains of *Bacillus cereus* and *Staphylococcus aureus* were obtained from Ms Michelle Mendell and Ms Jane Gifkins, Griffith University. All stock cultures were subcultured and maintained in nutrient broth at 4°C.

Evaluation of Antimicrobial Activity

Antimicrobial activity of the *M. lauteriana* leaf extracts was determined using a modified disc diffusion assay.²⁰⁻²³ Briefly, 100µL of the each bacterial suspension in log phase was spread onto individual nutrient agar plates and the extracts were tested for antibacterial activity using 6mm sterilised filter paper discs. The discs were each infused with 10µL of the individual plant extract, allowed to dry and placed onto the inoculated plates. The plates were allowed to stand at 4°C for 2 h before incubation at 37°C for 24 h. The diameters of the zones of inhibition (ZOIs) were measured to the closest whole millimetre. Each assay was performed three times in triplicate ($n=9$). Mean values (\pm SEM) are reported in this study. Standard discs of ampicillin (10µg) and chloramphenicol (10µg) were obtained from Oxoid, Australia and were used as positive controls to compare antibacterial activity. Filter discs infused with 10µL of distilled water were used as a negative control.

Minimum Inhibitory Concentration (MIC) Determination

The minimum inhibitory concentration (MIC) of each extract against susceptible bacteria was determined as previously described.^{24,25}

Briefly, the *M. lauteriana* leaf extracts were diluted in deionised water (1% DMSO) and tested across a range of concentrations. Discs were individually infused with 10µL of each extract, allowed to dry and placed onto the inoculated plates. The assay was completed as outlined above and graphs of the ZOI versus ln concentration were plotted for each extract. Linear regression was used to determine the MIC values of each extract.

Bacterial Growth Time Course Assay

Bacterial growth time course studies were performed as previously described.²⁶ Briefly, 3mL of the gram-positive bacterial species in nutrient broth were individually added to 27mL nutrient broth containing 3mL of 10mg/mL of the extract to give a final extract concentration of 1000µg/mL in the assay. The tubes were incubated at 37°C with gentle shaking. The optical density was measured hourly at 550nm for a 6h incubation period. Control tubes were incubated under the same conditions but without the extract. All assays were performed three times in triplicate ($n=9$).

Toxicity Screening

Artemia franciscana Nauplii Toxicity Screening

Toxicity was tested using an adapted *Artemia franciscana* nauplii lethality assay.²⁷⁻²⁹ Briefly, *A. franciscana* nauplii were incubated in the presence of the extracts, reference toxin (1mg/mL potassium dichromate) or artificial seawater (Negative control) at 25±1°C under artificial light. All treatments were performed three times in triplicate ($n=9$). The number of dead were counted in each well at 24h and 48h. At the completion of the 48h exposure period, the remaining live nauplii were sacrificed and the total number of nauplii in each well were counted and used to calculate the % mortality per well. LC₅₀ values were calculated for each treatment using probit analysis.

Statistical Analysis

Data are expressed as the mean \pm SEM of three independent experiments with internal triplicates ($n=9$). One-way ANOVA was used to calculate statistical significance between control and treated groups, with a P value <0.01 considered to be statistically significant.

RESULTS

Liquid Extraction Yields and Qualitative Phytochemical Screening

Extraction of 1g of dried and powdered *M. lauteriana* leaves with methanol and water yielded 256 and 184mg of extracted material respectively (Table 1). The extracts were resuspended in 10mL of deionised water (Containing 1% DMSO), resulting in an extract concentration shown in Table 1. Qualitative phytochemical studies showed that both extracts had similar phytochemical profiles. Both contained high levels of phenolic compounds as well as moderate levels of flavonoids, triterpenoids and saponins. Lower levels of tannins were also detected. Cardiac glycosides, phytosterols, alkaloids and anthraquinones were completely absent or below the detection thresholds for these assays.

Antimicrobial Activity

To determine the growth inhibitory activity of the *M. lauteriana* leaf extracts, aliquots (10µL) of each extract were screened in the disc diffusion assay. The *M. lauteriana* leaf extracts were effective at inhibiting the growth of 2 of the 3 gram-negative bacterial species tested (Figure 2). For both of these bacteria, the methanolic extract was a substantially more potent inhibitor of bacterial growth than the aqueous extract was.

Table 1: The Mass of Dried Extracted Material, the Concentration after Resuspension in Deionised Water and Qualitative Phytochemical Screenings of the *M. lauteriana* Leaf Extracts.

		Methanolic extract	Aqueous extract
Mass of extracted material (mg)		256	184
Concentration of resuspended extract (mg/mL)		25.6	18.4
Qualitative Phytochemical Tests	Phenols	Total phenols	+++
		Water soluble phenols	+++
		Insoluble phenols	++
	Saponins	Froth persistence	++
		Emulsion test	++
	Cardiac glycosides	Keller-Kiliani Test	-
	Triterpenoids	Salkowski Test	++
	Phytosterols	Acetic Anhydride Test	-
	Alkaloids	Meyer's Test	-
		Wagner's Test	-
		Draggendorff's Test	-
	Flavonoids	Kumar Test	++
	Tannins	Ferric Chloride Test	+
Lead Acetate Test		+	
Anthraquinones	Free	-	
	Combined	-	

+++ indicates a large response; ++ indicates a moderate response; + indicates a minor response; - indicates no response in the assay.

Only *E. coli* was completely resistant to the *M. lauteriana* leaf extracts. In contrast, *K. pneumoniae* was highly susceptible to the methanolic leaf extract, with a ZOI of 9.6mm measured. Both positive control antibiotics (ampicillin and chloramphenicol) were potent growth inhibitors, with ZOIs of up to 14.7mm (chloramphenicol against *E. coli*).

The gram-positive bacterial species appeared more susceptible to the extracts than the gram-negative species. Indeed, the growth of all gram-positive bacteria was inhibited by the *M. lauteriana* leaf extracts (Figure 3). As noted for the gram-negative bacteria, the methanolic extract was a substantially better inhibitor of gram-positive bacterial growth. *B. cereus* was most susceptible to the inhibitory effects of the extracts, with ZOIs of nearly 11mm measured (Figure 3). Indeed, the methanolic extract produced ZOIs that were only slightly smaller than the chloramphenicol control. This is noteworthy as the controls were tested at relatively high doses (10µg/disc). Furthermore, the control antibiotics are pure compounds, whereas the extracts are crude mixtures and the active compound(s) would be expected to be a minor % of the overall extracts mass. Therefore, these extracts may be particularly promising as targets for antibiotic drug discovery. The methanolic *M. lauteriana* leaf extract was also an effective inhibitor of *S. pyogenes* growth (Figure 3), albeit with a smaller ZOI (~8mm) noted. The ZOI measured against this bacterium was comparable to that of the chloramphenicol control, demonstrating its potential for the development of novel antibacterial chemotherapeutics. As *S. pyogenes* can cause a wide variety of diseases including pharyngitis, impetigo and rheumatic fever depending on the tissue that it infects, these extracts may be particularly useful as targets for antibiotic discovery. Only the methanolic *M. lauteriana* leaf extract inhibited the growth of *S. aureus*, whilst the aqueous extract was completely ineffective. Smaller ZOIs (7.3mm) were recorded against this bacterium, indicating only low to moderate activity.

The antimicrobial efficacy was further quantified by determining the MIC value. The methanolic and aqueous extracts were particularly good inhibitors of *K. pneumoniae* (MICs of 728 and 953µg/mL for the methanolic and aqueous extracts respectively) and *B. cereus* growth (MICs of 515 and 860µg/mL for the methanolic and aqueous extracts respectively). Both extracts were also moderate inhibitors of *P. mirabilis* growth (MIC values of 1126 and 2030µg/mL respectively), whilst the methanolic extract was also a moderate inhibitor of *S. aureus* growth (MIC = 1388 µg/mL). *E. coli* was completely resistant to the methanolic and aqueous *M. lauteriana* leaf extracts at all concentrations tested.

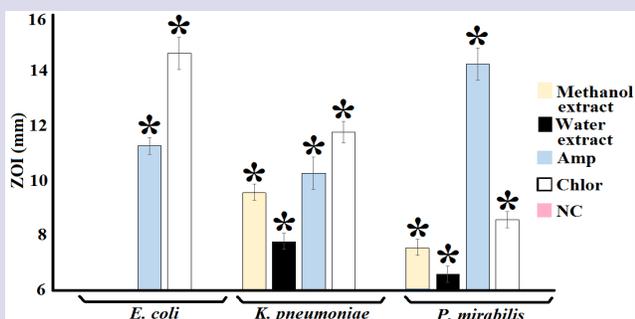


Figure 2: Growth Inhibitory activity of the *M. lauteriana* leaf extracts and reference antibiotics against gram-negative bacterial species measured as ZOIs (mm) ± SEM. Ampicillin (Amp) and chloramphenicol (Chlor) standard discs (10µg) were used as positive controls. All assays were completed three times, each with internal triplicates ($n=9$) and the results are expressed as mean zones of inhibition (mm) ± SEM. * indicates results that are significantly different to the untreated control ($P<0.01$).

Bacterial Growth Time Course Assay

The antibacterial activity of the *M. lauteriana* leaf methanolic and aqueous extracts was further investigated against *K. pneumoniae* and *B. cereus* by bacterial growth time course assays in the presence and absence of the extracts (Figure 4). The starting concentration of the extract used in these assays was 1000µg/mL. The *M. lauteriana* leaf methanolic and aqueous leaf extracts both significantly inhibited *K. pneumoniae* within 1h of exposure, indicating a rapid antimicrobial action (Figure 4a). The absorbance of the *K. pneumoniae* culture remained substantially lower than the untreated control for the first 4 hrs of exposure. After that time, the absorbance increased to approximately the same level as the control, indicating that the methanolic and aqueous extracts are bacteriostatic rather than bacteriocidal at the concentrations tested.

A different trend was noted for the *M. lauteriana* leaf methanolic extracts against when tested against *B. cereus* growth (Figure 4b). The absorbance of the *B. cereus* culture (and thus the bacterial growth) remained substantially lower than the untreated control for the entire 6 h incubation period, indicating that the methanolic extract may be bacteriocidal at the concentrations tested (Figure 4b). The aqueous extract was also rapid in its inhibition of *B. cereus* growth, with a significant decrease in bac-

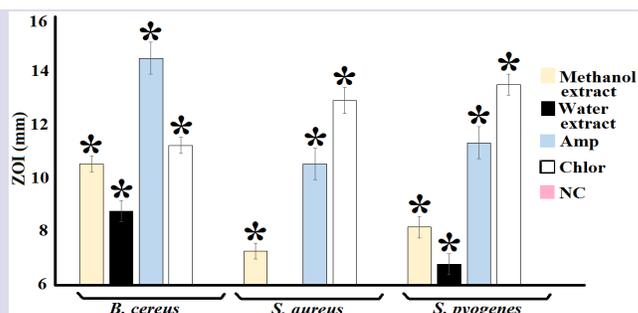


Figure 3: Growth inhibitory activity of the *M. lauteriana* leaf extracts and reference antibiotics against gram-positive bacterial species measured as ZOIs (mm) ± SEM. Ampicillin (Amp) and chloramphenicol (Chl) standard discs (10µg) were used as positive controls. NC = negative control. All assays were completed three times, each with internal triplicates ($n=9$) and the results are expressed as mean zones of inhibition (mm) ± SEM. * indicates results that are significantly different to the untreated control ($P<0.01$).

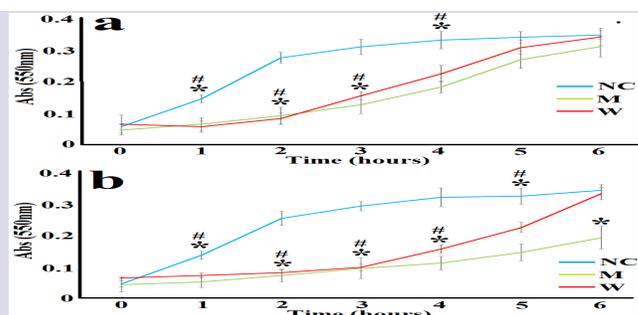


Figure 4: Bacterial growth curves the *M. lauteriana* leaf extracts against (a) *K. pneumoniae* and (b) *B. cereus*. All bioassays were performed three times in triplicate ($n=9$) and are expressed as mean ± SEM. * = methanolic extract results that are significantly different between the treated and the untreated control growth; # = aqueous extract results that are significantly different between the treated and the untreated control growth ($P<0.01$).

terial growth also noted within the first hour of incubation. However, in contrast to the inhibition of *B. cereus* growth by the methanolic extract, *B. cereus* growth had returned to similar levels to that of the untreated control by the end of the 6h incubation period (as judged by turbidity). This may indicate that the aqueous *M. lauteriana* leaf extracts had bacteriostatic effects at the tested concentration, rather than bactericidal effects.

Quantification of Toxicity

The toxicity of the *M. lauteriana* leaf extracts was initially tested at 2mg/mL in the *A. franciscana* nauplii bioassay (Figure 5). The mortality in the presence of both extracts was not significantly different to that of the untreated control at 24h and thus they were deemed to be non-toxic. Extracts with 24h LC₅₀ values >1000µg/mL have previously been defined as non-toxic.^{28,29} In contrast, the potassium dichromate positive control induced substantial mortality within 4h (Results not shown), with 100% mortality induction seen by 24h. The mortality induction remained low for the *M. lauteriana* leaf extracts at 48h. Indeed, the % mortality induction was substantially <50% for all extracts at all times tested and therefore it was not possible to determine LC₅₀ values for any of the *M. lauteriana* leaf extracts (Table 2).

DISCUSSION

Despite the initial potency of many antibiotic chemotherapies, recent increases in bacterial resistance to many antibiotics has made the development of new antibiotic therapies a high priority.¹ A parallel decrease in the introduction of new antibiotic therapies in recent years has further compounded this problem. As a result, interest in re-evaluating medicinal plants for new antibiotic chemotherapies has escalated substantially.³⁰ Interestingly, we were unable to find records of the medicinal usage of *M. lauteriana* by Australian Aborigines. Furthermore, no scientific evaluations have yet evaluated any therapeutic properties of this species. To the best of our knowledge, this is the first study to report bacterial growth inhibitory activity for this species.

The ability of the *M. lauteriana* leaf extracts to inhibit the growth of both gram-positive and gram-negative bacteria is in agreement with previous reports of the antibacterial activity of other Australian plant species.^{31,32} However, a slightly greater susceptibility of the gram-positive bacteria was noted compared to the gram-negative species. The greater

susceptibility of gram-positive bacteria to the *M. lauteriana* leaf extracts noted in this study is in agreement with previously reported results for South American,^{13,33} African^{34,35} and Australian³⁶ plant extracts. Results within our laboratory have also confirmed the greater susceptibility of gram-positive bacteria towards other Australian plant extracts.^{37,38} The gram-negative bacterial cell wall outer membrane is thought to act as a barrier to many substances including antibiotics.³⁹ The uptake of the *M. lauteriana* leaf extract antibiotic compounds by gram-negative bacteria is presumably affected by the cell wall outer membrane. In contrast, other studies have demonstrated that gram-negative bacteria are often more susceptible to plant extracts from different Australian plant species.⁴⁰⁻⁴²

Whilst an investigation of the phytochemistry of the *M. lauteriana* leaf extracts was beyond the scope of our study, moderate to high levels of polyphenolics, flavonoids, triterpenoids and saponins were noted in the extracts in the qualitative phytochemical screening study. Lower levels of tannins were also detected. Flavonoids have well established bacterial growth inhibitory activities.⁴³ The flavonoids kaempferol and myricetin have been reported to be potent growth inhibitors of a panel of bacterial pathogens.⁴⁴ Similarly, quercetin, rutin and their corresponding glycosides inhibit the growth of *Pseudomonas maltophilia* and *Enterobacter cloacae*.⁴⁵ The antimicrobial activity of terpenoids has also been extensively documented. Monoterpenoids including α-pinene, β-pinene, sabinene, myrcene, terpinene, limonene, piperitone and β-phellandrene inhibit the growth of a panel of bacteria, including several antibiotic resistant strains of Enterobacteriaceae.⁴³ The antibacterial activities for several sesquiterpenoids including α-cubebene, copaene and caryophyllene have been reported.⁴³ Similarly, many tannin compounds have bacterial growth inhibitory activity. Gallotannins inhibit the growth of a broad spectrum of bacterial species⁴⁶ through a variety of mechanisms including binding cell surface molecules including lipoteichoic acid and proline-rich cell

Table 2: Minimum Inhibitory Concentrations (µg/mL) of the *M. lauteriana* leaf Extracts Against each Bacterial Strain and LC₅₀ values (µg/mL) against *Artemia* nauplii.

Organism	Exposure time (h)	MIC or LC ₅₀ (µg/mL)	
		Methanolic extract	Aqueous extract
<i>E. coli</i>	24	-	-
<i>K. pneumoniae</i>	24	728	953
<i>P. mirabilis</i>	24	1126	2030
<i>B. cereus</i>	24	515	860
<i>S. aureus</i>	24	1388	-
<i>S. pyogenes</i>	24	1050	1692
<i>Artemia</i> nauplii	24	CND	CND
	48	CND	CND

Numbers indicate the mean MIC or LC₅₀ values of three independent experiments in triplicate (n=9). - indicates that an the extract did not inhibit bacterial growth at any concentration tested; CND indicates that an LC₅₀ could not be determined as the mortality did not exceed 50% at any concentration tested.

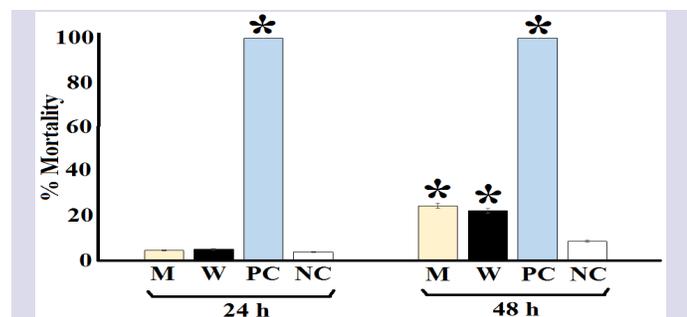


Figure 5: The lethality of the *M. lauteriana* leaf extracts (2000µg/mL), potassium dichromate control (1000µg/mL) and seawater (negative control). All bioassays were performed three times in triplicate (n=9) and are expressed as mean ± SEM. * indicates results that are significantly different to the untreated (seawater) control at the equivalent exposure time (P<0.01)."

surface proteins,^{47,48} and by inhibiting glucosyltransferase enzymes.⁴⁹ Ellagitannins are also highly potent inhibitors of bacterial growth, with MIC values as low as 62.5 µg/mL.^{46,48} Ellagitannins have also been reported to function via several antibiotic mechanisms including interaction with cytoplasmic oxidoreductases and by disrupting bacterial cell walls.^{46,48} Thus, it is likely that multiple compounds within the *M. lauteriana* leaf extracts are contributing to the antibacterial activity reported here.

The findings reported here also indicate that the extracts examined were non-toxic (LC₅₀ >1000 µg/mL) in the *Artemia nauplii* bioassay. Whilst toxicity was assessed in this study with the test organism *A. franciscana*, toxicity towards *A. franciscana* has previously been shown to correlate well with toxicity towards human cells for many toxins.^{28,29} However, further studies are required to determine whether this is also true for the *M. lauteriana* leaf extracts examined in these studies. The results of this study indicate that the *M. lauteriana* leaf extracts may be good candidates for antimicrobial drug discovery and further examination is warranted. Whilst the extracts examined in this report have potential as bacterial growth inhibitors, caution is needed before these compounds can be applied to medicinal purposes. Purification and identification of the bioactive components is needed to examine the mechanisms of action of these agents.

CONCLUSION

The growth inhibitory activity of the *M. lauteriana* leaf extracts against gram-positive and gram-negative bacteria and their lack of toxicity indicate their potential for the development of novel chemotherapies to treat a variety of diseases caused by bacterial pathogens. Further studies aimed at the purification of the bioactive components are needed to examine the mechanisms of action of these agents.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ABBREVIATIONS

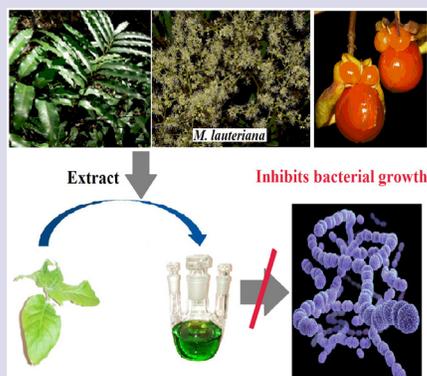
DMSO: Dimethyl sulfoxide; **LC₅₀:** The concentration required to achieve 50 % mortality; **MIC:** Minimum inhibitory concentration; **ZOI:** Zone of inhibition.

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PICTORIAL ABSTRACT



SUMMARY

- Methanolic and aqueous *M. lauteriana* leaf extracts were screened for the ability to block the growth of a panel of bacteria.
- The growth inhibition of both gram-positive and gram-negative bacteria was tested.
- The antibacterial activity was quantified by determining the MIC values of each extract.
- Growth time course studies were undertaken against the gram-positive bacterial species.
- Toxicity of the *M. lauteriana* leaf extracts was determined using the *Artemia nauplii* toxicity bioassay.

ABOUT AUTHORS



Ms Getmore Chikowe completed BSc at Griffith University in life sciences. Following graduation, she undertook a research project in Dr Ian Cock's laboratory in the School of Natural Sciences at Griffith University. The project examined the growth inhibitory properties of a variety of Australian native plants against an extensive panel of bacterial pathogens.



Dr Ian Cock leads a research team in the Environmental Futures Research Institute and the School of Natural Sciences at Griffith University, Australia. His research involves bioactivity and phytochemical studies into a variety of plant species of both Australian and international origin, including Aloe vera, South Asian and South American tropical fruits, as well as Australia plants including *Scaevola spinescens*, *Pittosporum phylliraeoides*, *Terminalia ferdinandiana* (Kakadu plum), *Australian Acacias*, *Syzygiums*, *Petalostigmas* and *Xanthorrhoea johnsonii* (grass trees). This range of projects has resulted in nearly 200 publications in a variety of peer reviewed journals.

Ms Lindiwe Mpala completed at BSc Griffith University in life sciences. Following graduation, she undertook a research project in Dr Ian Cock's laboratory in the School of Natural Sciences at Griffith University. The project examined the growth inhibitory properties of a variety of Australian native plants against an extensive panel of bacterial pathogens.