A Comparison of the Anti-\textit{Staphylococcus aureus} Activity of Extracts from Commonly Used Medicinal Plants

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Abstract

\textbf{Background:} Resurgences of \textit{Staphylococcus aureus} infection continue globally, with antibiotic resistance increasing dramatically, making these infections more difficult to treat. \textit{S. aureus} epidemics impose public health threats, and economic burdens on health care costs worldwide, presenting challenges modern medicine struggles to control.

\textbf{Objective:} In order to answer today’s call for effective treatments against \textit{S. aureus}, we evaluated and compared various botanical extracts that have historically been suggested as useful for their antimicrobial properties against \textit{S. aureus}.

\textbf{Design:} Briefly, \textit{S. aureus} cultures were treated with selected botanical extracts and the minimum inhibitory concentration (MIC) determined. In addition, to obtain more quantitative measures on bacterial growth, 24-hour growth studies were done to examine the temporal activity and stability of various botanicals on bacterial replication.

\textbf{Results:} The antimicrobial activity observed for the botanical extracts used in this comparative evaluation of efficacy included both bacteriostatic and bacteriocidal activity against \textit{S. aureus}. Highly effective botanicals including \textit{Salvia officinalis}, \textit{Eucalyptus globulus}, \textit{Coleus forskohlii}, \textit{Coptis chinensis}, \textit{Turnera diffusa}, and \textit{Larrea tridentata} exhibited MIC values ranging from 60 to 300 \(\mu\)g/mL and a 10\(^6\)-fold reduction in bacterial replication. \textit{Arctostaphylos uva-ursi} and \textit{Allium sativum} were slightly less effective, exhibiting MIC values ranging from 90 to 400 \(\mu\)g/mL and a 10\(^5\)-fold reduction, while \textit{Anemopsis californica} gave MIC value of 360 \(\mu\)g/mL and a 10\(^4\)-fold reduction in bacterial replication. Many botanicals, especially at lower doses, had an initial inhibitory effect followed by a recovery in bacterial replication. Such botanicals included \textit{E. globulus}, \textit{C. chinensis}, \textit{T. diffusa}, \textit{A. californica}, and \textit{Berberis vulgaris}.

\textbf{Conclusions:} Our data demonstrate that \textit{S. officinalis}, \textit{E. globulus}, \textit{C. forskohlii}, \textit{A. uva-ursi}, \textit{C. chinensis}, \textit{T. diffusa}, \textit{A. californica}, \textit{A. sativum}, and \textit{L. tridentata} all show promising direct antimicrobial activity against \textit{S. aureus}. For many of these botanicals, strong bacteriocidal activity was observed at higher concentrations, but even at lower concentrations, bacteriostatic activity was evident. Other botanicals including \textit{B. vulgaris}, \textit{Baptisia tinctoria}, and \textit{Glycyrrhiza glabra} showed moderate activity against \textit{S. aureus}, while \textit{Schisandra chinensis}, \textit{Echinacea angustifolia}, and \textit{Polygonum multiflorum} were shown to be ineffective.

Introduction

Prior to the 1940s, the United States saw an incidence of mortality associated with \textit{Staphylococcus aureus} infections > 80\%. With the introduction of antibiotics, that percentage dramatically decreased and remained reduced for many years. However, new challenges have evolved to deal with the repeated resurgences of antibiotic-resistant \textit{S. aureus} infections that continue to impose both public health threats and economic burdens on health care costs. Infections commonly caused by \textit{S. aureus} include skin and soft-tissue infections, toxic shock syndrome, endocarditis,
osteomyelitis, urinary tract infections, and gastrointestinal infections. As many S. aureus strains have become resistant to antibiotics over time, we now have essentially two categories of bacterial strains: (1) methicillin-resistant S. aureus (MRSA), which are resistant to all b-lactam antibiotics and (2) methicillin-sensitive S. aureus (MSSA), which are strains that have not been able to develop such resistance. Methicillin is a narrow-spectrum b-lactam antibiotic targeting cell wall synthesis and commonly used for Gram-positive organisms such as Staphylococcus. MRSA represents the ever-changing challenges that continue to call for new alternative therapies and ways of management. MRSA is a severe pathogen found to be most prevalent in hospitalized patients and is the second most prevalent pathogen found in health care settings outside of the hospital. In a study of children’s hospitals in the United States over the period of 1999–2008, the incidence of MRSA-infected children increased 10-fold. In addition, this trend is not limited to the United States, since we see a similar rise in incidence occurring globally.

The concerns and problems associated with antibiotic resistance are certainly not limited to S. aureus. The development of bacterial antibiotic resistance in other microbes such as Enterobacteriaceae spp., Pseudomonas aeruginosa, and Neisseria gonorrhoea represent significant emerging public and global health threats that we face beyond MRSA. The development of antibiotic resistance involves genetic mutation and/or the acquisition of resistance genes. While pharmacological agents against MRSA and other bacteria have been and continue to be developed, they often have limited success and short shelf lives. Meanwhile, it is the very use of antibiotics, worldwide travel, and lack of precise therapeutic targets that promote a bacteria’s ability for resistance and global spread.

The emerging global health threats that S. aureus and MRSA pose call for the development of new and innovative avenues to control infection. In this study, we investigated the anti-Staphylococcus activity associated with botanicals historically used in the treatment of infections. The overall goal of these studies was to comparatively evaluate these historical remedies in order to answer today’s call for potential therapeutics against S. aureus infections. To this end, we investigated the efficacy of ethanol-based extracts of Salvia officinalis (sage), Eucalyptus globulus (eucalyptus), Coleus forskohlii (colesus), Arctostaphylos uva-ursi (uva-ursi), Capsella bursa-pastoris (Chinese goldthread), Larrea tridentata (chaparral), Turnera diffusa (damiana), Anemopsis californica (yerba mansa), Allium sativum (garlic), Baptisia tinctoria (wild indigo), Berberis vulgaris (barberry), Glyceria glabra (licorice), Schisandra chinensis (wu wei zi), Echinacea angustifolia (echinacea), and Polygonum multiflorum (Chinese knotweed) for in vitro activity against an MSSA strain of S. aureus. Our results demonstrate strong anti-Staphylococcus activity associated with certain botanicals, while others demonstrated limited or no direct anti-Staphylococcus effects.

Materials and Methods

Botanical extract preparation

Plant material was obtained from reputable sources with documentation of authenticity. All plant material was subsequently verified by qualified botanical specialists using herbal pharmacopoeia monographs and reference keys. A voucher specimen of all plant material was deposited in a repository. For extraction, the botanicals were ground to a fine powder, resuspended in extraction solution, and incubated for 14–21 days at room temperature. The described plant-to-liquid ratio in a mixture of 95% ethanol/distilled water/glycerol: fresh Salvia officinalis 1:3 (sage leaf 58/35/07), fresh Eucalyptus globulus 1:3 (eucalyptus leaf 53/42/05), dried Coleus forskohlii 1:1 (coleus root 47/53/0), fresh Arctostaphylos uva-ursi 1:3 (uva-ursi leaf and berry 42/48/10), dried Copitis chinensis 1:4 (Chinese goldthread root 58/37/05), fresh Larrea tridentata 1:3 (chaparral leaf and flower 79/15/06), dried Turnera diffusa 1:4 (damiana leaf 63/27/10), fresh Anemopsis californica 1:2 (yerba mansa rhizome and root 63/30/07), fresh Allium sativum 1:2 (garlic bulb 53/37/10), fresh Baptisia tinctoria 1:3 (wild indigo root 63/32/05), dried Berberis vulgaris 1:4 (barberry root 43/47/10), dried Glyceria glabra 1:1 (licorice root 26/64/10), dried Schisandra chinensis 1:3 (wu wei zhi berry 26/74/0), fresh Echinacea angustifolia 1:3 (echinacea root 47/48/05), and dried Polygonum multiflorum 1:3 (Chinese knotweed root 26/74/0). Following extraction, the liquid was pressed from the solid botanical material, filtered using unbleached paper filters, and pooled. Since the active antibacterial constituent(s) present in these extracts have not been identified, the extracts were normalized based on drying of the extracts and measurement of the remaining material. A sample of each extract was dried, and all extracts were found to contain similar concentrations of nonvolatile solutes (ranging between 19.6 and 37.5 mg/mL extract). The exact concentrations of nonvolatile solutes are noted in Table 1. This value is not meant to imply that the active constituent(s) include only nonvolatile solutes, but rather to provide a value of standardization, normalization, and comparison.

Antibiotic preparation

Antibiotics were obtained from Sigma-Aldrich (St. Louis, MO). The stock solution of tetracycline was prepared at 5 mg/mL in ethanol. A working solution was prepared by dilution in water to 50 μg/mL. Vancomycin was prepared and used as a working solution in water at 500 μg/mL.

Bacterial growth studies

Media and the bacterial culture Staphylococcus aureus ATCC 11632 were obtained from Hardy Diagnostics (Santa Monica, CA). For minimum inhibitory concentration (MIC) determination and growth studies, 18-hour cultures (ranging from 1 to 5×10⁸ colony-forming units (CFU)/mL) were diluted into media (1:1000 dilution; tryptic soy broth) followed by the addition of indicated concentrations of each botanical extract, antibiotic, or ethanol control. The cultures were incubated at 37°C with aeration (by continuous rotation) for 24 hours. For evaluation, the MIC value was determined as the dose of the botanical extract required to completely inhibit replication of the bacteria (as measured by a lack of turbidity absorbance). For growth studies, at the indicated times, samples were removed and the bacterial concentration was determined by serial dilutions on tryptic soy agar (CFU/mL media).
Table 1. Minimum Inhibitory Concentrations of Anti-Staphylococcus Botanical Extracts

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MIC (µL/mL)</th>
<th>Concentration (mg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancomycin</td>
<td>4.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>7.0</td>
<td>0.035</td>
</tr>
<tr>
<td>Salvia officinalis</td>
<td>5.8</td>
<td>0.15</td>
</tr>
<tr>
<td>Eucalyptus globulus</td>
<td>4.2</td>
<td>0.12</td>
</tr>
<tr>
<td>Coleus forskohlii</td>
<td>8.0</td>
<td>0.16</td>
</tr>
<tr>
<td>Arctostaphylos uva-ursi</td>
<td>2.9</td>
<td>0.09</td>
</tr>
<tr>
<td>Coptis chinensis</td>
<td>4.5</td>
<td>0.12</td>
</tr>
<tr>
<td>Larrea tridentata</td>
<td>1.7</td>
<td>0.06</td>
</tr>
<tr>
<td>Turnera diffusa</td>
<td>15.3</td>
<td>3.00</td>
</tr>
<tr>
<td>Anemopsis californica</td>
<td>18.0</td>
<td>3.60</td>
</tr>
<tr>
<td>Allium sativum</td>
<td>18.4</td>
<td>4.00</td>
</tr>
<tr>
<td>Baptisia tinctoria</td>
<td>47.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Berberis vulgaris</td>
<td>80.0</td>
<td>2400.0</td>
</tr>
<tr>
<td>Glycyrrhiza glabra</td>
<td>72.0</td>
<td>2700.0</td>
</tr>
<tr>
<td>Schisandra chinensis</td>
<td>&gt;100</td>
<td>Ineff.</td>
</tr>
<tr>
<td>Echinacea angustifolia</td>
<td>&gt;100</td>
<td>Ineff.</td>
</tr>
<tr>
<td>Polygonum multiflorum</td>
<td>&gt;100</td>
<td>Ineff.</td>
</tr>
</tbody>
</table>

Diluted (1000-fold) S. aureus cultures were treated with increasing concentrations of the indicated botanical extracts at 0 hours. The cultures were incubated at 37°C with continuous aeration (by rotation) and the MIC was determined at 24 hours. The MIC (noted as both microliters extract/milliliter diluent and micrograms nonvolatile constituents/milliliter diluent) was determined as the dose of the botanical extract required to completely inhibit replication of the bacteria as measured by a lack of turbidity absorbance. All botanical extracts had an average nonvolatile constituent concentration averaging 27.1 mg/mL (ranging from 19.6 to 37.5 mg/mL). Concentration (milligrams per milliliter) is based on the weight of nonvolatile constituents present in the extract per milliliter of aqueous media. MIC values expressed in micrograms per milliliter were based on drying of the botanical extracts and measurement of the dried weight. All botanical extracts were reasonably consistent with an average nonvolatile constituent concentration averaging 27.1 mg/mL (ranging from 19.6 to 37.5 mg/mL). These values are not meant to imply that the active constituent(s) present in the extracts are nonvolatile components, but rather are meant to serve solely as a reference standard for comparison and normalization between the different botanical extracts. Since the active constituent(s) for these botanicals have not been identified, these gross values provide a basis for comparison.

MIC values indicate the lowest concentration of an antimicrobial where no visible growth is detected. At the MIC value, minor bacterial growth may still be observed, but may not be visibly detected. In addition, MIC experiments do not allow temporal measurements of an antimicrobial that may affect the growth of a bacteria for a shorter period of time. Bacterial growth curves following treatment with an antimicrobial allow measurement of possible temporal effects as well as precise quantitative valuation of the levels of inhibition of an antimicrobial. Therefore, in order to further evaluate the activity of the botanical extracts against Staphylococcus, growth curves were performed where the replication of the bacteria was evaluated every 8 hours for a 24-hour period. As a control, Figure 1 demonstrates proof of concept in illustrating the activity of tetracycline and vancomycin. Tetracycline and vancomycin both began to show strong anti-Staphylococcus activity at concentrations of 6 µL/mL. For tetracycline, a slight recovery in replication was observed at 24 hours at the 6 µL/mL dose. For vancomycin at the 6 and 20 µL/mL dose and tetracycline at the 20 µL/mL dose, a 10−5−10−6-fold reduction was observed. Since the botanical extracts were prepared in ethanol, a control experiment was done to assess anti-Staphylococcus activity at increasing concentrations of ethanol. Ethanol demonstrated minor anti-Staphylococcus activity (~1 log reduction) at concentrations of 6%. The final ethanol concentrations found in the botanical treatments used in these studies (diluted in media) do not exceed 1%; therefore any antimicrobial activity observed could be attributed to botanical constituents.

The botanical extracts that demonstrated strong and moderate activity against S. aureus are shown in Figure 2 and the botanical extracts with weak or no anti-Staphylococcus activity are shown in Figures 3 and 4, respectively. As shown in Figures 2 and 3, bacterial retardation, bacteriostatic, and bactericidal activity was observed. Retardation activity is defined in these studies as a slower rate of growth in S. aureus colonies as compared to untreated samples. Bacteriostatic is defined as activity that resulted in very little or no bacterial growth related to the initial bacterial concentration (CFU/mL) of the samples. Bactericidal is defined as activity that resulted in a marked reduction in the bacterial concentration of the cultures compared to the initial bacterial concentration. As shown in Figure 2, Salvia, Eucalyptus, Coleus, Arcostaphylos, Coptis and Larrea exhibited 10–200 µL/mL dose and tetracycline at the 20 µL/mL dose, a 10−5−10−6-fold reduction was observed. For Salvia, Eucalyptus, Coleus, Arcostaphylos, Coptis, Turnera, and Larrea strong bactericidal activity was observed with a 10−2−10−3-fold reduction in bacterial concentration (CFU/mL) compared to the initial starting culture. Many botanicals, especially at lower doses, had initial inhibitory activity followed by growth recovery including Eucalyptus, Coptis, Turnera, Anemopsis, and Berberis. At these concentrations, the active constituent(s) present in the extracts may be limiting and are either being metabolized or have a short half-life.
Figure 3 represents botanicals with slight or moderate activity in our growth curve experiments including Berberis, Baptisia, and Glycyrrhiza. As shown, these botanicals reduced replication by 2–3 log units at the highest concentrations. For Berberis and Glycyrrhiza, even with this reduction, Staphylococcus was able to overcome this inhibitory effect by 24 hours. The botanicals Schisandra, Echinacea, and Polygonum appeared to be ineffective against S. aureus (Fig. 4). As shown, even at the highest concentration, no significant reduction in bacterial replication was observed at any time points in the growth curve.

Discussion

Botanical extracts have long been used as therapeutic agents for bacterial infections. In this study, botanical extracts with historical use in the treatment of S. aureus–associated infections were comparatively evaluated for their direct antibacterial activity. Several botanical extracts in this study demonstrated strong antimicrobial activity against Staphylococcus, exhibiting as much as a 6-log unit reduction in replication as compared to untreated cultures. These botanical extracts, which include Salvia, Eucalyptus, Coleus, Arctostaphylos, Coptis, Turnera, Anemopsis, Allium, and Larrea, show promising use against S. aureus, particularly for their bactericidal ability, but also for their inhibitory and bacteriostatic actions at lower doses. Berberis, Baptisia, and Glycyrrhiza also showed limited activity against S. aureus, but Schisandra, Echinacea, and Polygonum were shown to be ineffective. Recommendations regarding evaluatory criteria for botanical extracts suggest that extracts should demonstrate IC50 values <100 μg/mL for in vitro studies.8 For the most active botanicals in our study, MIC values corresponding to a complete lack of growth turbidity of S. aureus ranged from 60 to 300 μg/mL. In addition, in our growth studies, the doses of 6–20 μL/mL correspond to approximately 200–600 μg nonvolatile constituents/mL, respectively. Depending on the botanical, these doses resulted in typically 1000–1,000,000-fold reductions in Staphylococcus replication (Fig. 2). Therefore, these highly active botanicals in particular meet the recommended stringent endpoint criteria for therapeutic botanical use.

For Staphylococcus infections, many of these botanicals represent potentially effective therapeutics for topical, gastrointestinal, or urinary infections. For topical application, the highly active botanicals would likely have strong antimicrobial effects and therapeutic value for an infection. Traditionally, typical oral doses of such botanical tinctures to treat gastrointestinal, urinary, or septic infections range from 1 to 20 mL per day.9 In our assays, the effective dose for a single treatment ranges between 6 and 20 μL/mL. It is difficult to convert these in vitro doses to the same proportion of oral dosing; however, the average human contains approximately 5 L of blood. If our in vitro doses are converted to the average human blood volume, it would equate to 30–100 mL extract/5 L. This exceeds the traditional doses of these botanical extracts, but it must be pointed out that our studies were done with a single dose in an in vitro

![FIG. 1. Anti-Staphylococcus activity associated with control substances.](image-url)
FIG. 2. Highly and moderately active anti-*Staphylococcus* botanical extracts. Diluted (1000-fold) *S. aureus* cultures were left untreated (solid line), or treated with the indicated botanical extracts in the amount of 0.6, 2.0, 6.0, or 20.0 μL/mL at 0 hours (dashed lines). The cultures were incubated at 37°C with continuous aeration (by rotation) and colony-forming units per milliliter were determined every 8 hours over a period of 24 hours. Assays were repeated in triplicate. The milligrams nonvolatile constituents present in the extract per milliliter of aqueous liquid are noted for each botanical for standardization and comparison purposes.

FIG. 3. Weakly active anti-*Staphylococcus* botanical extracts. Diluted (1000-fold) *S. aureus* cultures were left untreated (solid line), or treated with the indicated botanical extracts in the amount of 0.6, 2.0, 6.0, or 20.0 μL/mL at 0 hours (dashed lines). The cultures were incubated at 37°C with continuous aeration (by rotation) and colony-forming units per milliliter were determined every 8 hours over a period of 24 hours. Assays were repeated in triplicate. The milligrams nonvolatile constituents present in the extract per milliliter of aqueous liquid are noted for each botanical for standardization and comparison purposes.
system. As a therapeutic, multiple doses at lower concentrations may have significant antimicrobial effects, even systemically. In addition, bacterial sepsis typically occurs with 1–100 CFU/mL blood, while in our assays, initial bacterial concentrations were approximately 1×10^5 CFU/mL media. Therefore, our assays represent a very high concentration of bacteria, and lower doses of these botanical extracts may have therapeutic value even in a systemically infected patient. However, it is also unclear what the bioavailability and absorption properties of the active constituent(s) present in these extracts are and if they could reach effective concentrations systemically. Therefore, further research is warranted to confirm the efficacy of the highly effective antimicrobial botanicals we have identified for use against _S. aureus_ gastrointestinal, urinary, and septic infections.

For most of the botanicals used in our experiments, safety profiles reflect low risk and few side-effects with use within recommended dosages. In our studies, _Salvia, Eucalyptus, Coleus, Arctostaphylos_, _Coptis, Turnera, Anemopsis_, _Allium_, and _Larrea_ demonstrated the strongest anti- _Staphylococcus_ activity. Historically, _Salvia officinalis_ (sage) has been used as an antiseptic for gingivitis and skin infections, including _S. aureus_ infections. It has antibacterial effects that appear to be due in part to the constituents carnosol, thujone, 1,8-cineole (an antimicrobial monoterpenic alcohol) and rosmarinic acid. Its anti-_S. aureus_ activity has been shown to be equivalent to commonly used anti- _Staphylococcus_ antibiotics. The active constituent carnosol also appears to act synergistically with other antibiotics, including gentamicin, erythromycin and tetracycline. It has been proposed that carnosol may inhibit drug efflux pumps, thereby allowing the action of _corilagin_. The antimicrobial properties of _Eucalyptus_ are well documented, and some research suggests particularly strong activity against MRSA. _C. forskohlii_ has increasingly been shown to be a broad-spectrum antibacterial. In limited studies, _Coleus_ extracts inhibited the replication of _Haemophilus influenza, S. pneumonia, S. pyogenes_ and _S. aureus_ in a similar way to standard antibiotics. The presumptive active constituent, forskolin, has been used to reduce urinary tract infections and enhance the antibacterial activity of antibiotics. _A. uva-ursi_ is traditionally a urinary antiseptic with action against _Escherichia coli, Proteus vulgaris, Enterobacter aerogenes, Streptococcus faecalis_, _Salmonella typhi_, and _S. aureus_. Uses have been primarily for urinary tract infections such as pyelonephritis and cystitis, the latter of which is commonly caused by _Staphylococcus_. _Arctostaphylos_ acts a urinary antimicrobial possibly due to constituents including arbutin (a glycosidic ether of hydroquinone), free hydroquinone, and/or aglycone p-hydroxyacetophenone. It has also been shown to reduce the MIC of β-lactam antibiotics against MRSA via the action of corilagin. _Coptis chinensis_ has traditionally been used for gastrointestinal, eye, and skin infections, including _Staphylococcus_-associated furuncles. Research has shown antimicrobial activity of _Coptis_ against several strains of MRSA as well as the potential for _Coptis_ to act synergistically when used in combination with β-lactam antibiotics. _Coptis_ extracts contain antibacterial constituents including protoberberine alkaloids such as palmatine and berberine. Berberine is also found in extracts from _Berberis vulgaris_, which in our studies was found to have only weak activity against _S. aureus_. This supports the fact that even though many presumptive active constituents have been identified in many botanical extracts, further research is necessary to confirm their specificity and/or possible synergism with other compounds. _Larrea tridentata_ has traditionally been used as a therapeutic for various bacterial infections including tuberculosis, subacute bronchitis, and subacute laryngitis. _Larrea_ expresses the antimicrobial constituent, nordihydroguaiaretic acid, which has been shown to have specific activity against MRSA. _Turnera diffusa_ is used as a urinary antiseptic with activity against both gram-positive and gram-negative pathogens.
bacteria. Research has also demonstrated resistance-modifying activity of Turnera extracts, where it can increase the potentiation of various antibiotics. Anemopsis californica has traditionally been used for the treatment of skin abscesses commonly associated with *S. aureus* infections and has been shown to have direct antibacterial activity. Anemopsis extracts contain antimicrobial constituents including thymol, 1,8 cineole, and lignans. Allium sativum has antimicrobial actions that are well documented, likely due in large part to the constituents allicin and ajoene. It has also been used for the treatment of bacterial vaginitis for which *Staphylococcus* is commonly associated. Much research exists on *Allium*’s antibacterial properties, and some research shows activity against multidrug-resistant bacteria, including MRSA.

The data from this study provide a comparative analysis of the direct antimicrobial activity of various botanicals against *S. aureus*. Further investigation into the role botanicals can have in *S. aureus* infections either as stand-alone therapies or as synergists and potentiators of antibiotics is warranted. As noted earlier, previous research suggests that many of these botanical extracts provide synergistic effects when combined with common antibiotics. Future research will focus on whether these synergistic effects may aid in preventing or slowing the development of antibiotic resistance.

Although no or limited direct antibacterial activity was found with some botanicals in this study (including *Berberis, Baptisia, Glycyrrhiza, Schisandra, Echinacea, and Polygonum*), these botanicals may still have indirect antibacterial effects. Such indirect effects may occur through alternative pathways such as immune modulation. For example, *Echinacea* is a well-known immune modulator commonly used for bacterial infections associated with carbuncles, boils, sepsis, gangrene, syphilis, diphtheria, cholera, and scarlet fever. Identification of the key active constituent(s) present in the effective anti-*Staphylococcus* extracts is of importance toward the development of a standardized pharmaceutical drug. Although presumptive active compounds have been identified for many of the botanicals described in this study, the actual compounds have yet to be confirmed and/or identified. Work is currently under way to fractionate and identify such active constituent(s). However, even though the active constituent(s) have not yet been identified from these extracts, the characterized anti-*Staphylococcus* activity of the total botanical extract is of significant importance since these unfractonated extracts are currently being used in the medical field by naturopathic physicians and by patients seeking alternative medicine therapeutics.

Botanicals offer a repertoire of additional therapeutics for treatment of microbial infections. This study provides a comparative evaluation of the direct antibacterial activity associated with several botanicals historically used for *S. aureus* infections. Future research needs to be done to investigate the ability of *S. aureus* to develop resistance to these botanical extracts, as well as the ability of the botanical extracts to act synergistically and possibly help prevent antibiotic resistance from developing. This global threat demands serious consideration for the complexity of nature’s defense mechanisms to be more deeply understood so that appropriate therapies can be developed and utilized accordingly.

**Disclosure Statement**

Yvan Rochon, PhD, is owner of Herbal Vitality, Inc.

**References**


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