Original Research Article

Nigerian Journal of Biotechnology and Life Sciences
ISSN: 2814-0281
Vol. 3 No 1 (2026) p. 1 - 9
http://www.njbls.fud.edu.ng/

Antibacterial Activity of Garlic (*Allium Sativum*) and Honey (*Apis Mellifera*) On Respiratory Tract Pathogens

Bashir Salisu Unguwar Rimi[1], Surayya Lawan Idris[1*], Faiza Inuwa Hussain[1], Umar Labaran Bashir[1] Muhammad Abubakar Bello[1] Abubakar Ahmad Ahmad[2]

[1] Department of Biological Sciences, Northwest University, Kano
[2] Department of Biochemistry, Federal University Dutse

*Corresponding Author: idrissurayyalawan@gmail.com

Article into
Date received
09/05/2026
Date accepted
14/06/2026
Available online
15/06/2026

Keywords
Antibacterial activity, Antibiotic, Garlic, Honey, Respiratory tract infection, Respiratory tract Pathogens

Abstract

The exploration of natural products as potential antimicrobial agents is particularly important in the context of the global rise in antibiotic-resistant bacterial strains. The study aimed to determine the effects of garlic (*Allium Sativum*) and honey (*Apis mellifera*) on respiratory tract infection-causing bacteria. Respiratory tract isolates *Pseudomonas aeruginosa (P.aeruginosa), Klebsiella pneumoniae (K. pneumoniae), Streptococcus pneumoniae (S.pnuemoniae) Escherichia coli (E.coli)* and *Staphylococcus aureus (S.aureus)* were tested for susceptibility to Garlic and Honey extracts. The extracts activity against the isolates were compared with activity of commonly prescribed antibiotics against the bacteria. Minimum inhibitory concentration MIC and Minimum bactericidal concentration MBC of the extracts were also determined.The extracts were effective against the tested bacteria except *P.aeruginosa* which was resistant to honey extract. Commercial antibiotic Amikacin was effective against the tested pathogens except against *K. pneumoniae.* On the other hand all the tested pathogens were resistance to Erythromycin. The MIC of Honey against all the RT pathogens was 12.5%, MIC of Garlic against *P. aeruginosa, K. pnuemoniae* and *S. pneumoniae* was 6.25%; against *E.coli* and *S. aureus* was 12.5%. MIC of mixture of Garlic-Honey against all the pathogens was 6.25%.The MBC of Garlic on *P. aeruginosa, K. pnuemoniae* and *E.coli* was 12.5%, 25% for *S. aureus* and 6.25% for *S. pneumoniae.* MBC of Honey was 25% against all pathogens except *S.pneumoniae* which was 12.5%. The MBC for mixture of Garlic-Honey was 6.25% for *P. aeruginosa* and *S. pneumonia* and 12.5% for *E.coli, K. pnuemoniae* and *S. aureus.* Comparison of the MIC of the extracts show that there is significant difference between the MIC of Honey and mixture of Garlic-Honey, also there is significant difference between MIC of Honey and Garlic at $P \leq 0.05$ significance level. The findings demonstrated that both garlic and mixture of garlic-honey extracts exhibit significant antibacterial activity against the tested pathogens. The comparison with antibiotics revealed that the natural extracts could serve as effective alternatives. The MIC and MBC results also suggest that garlic and garlic-honey mixture could be used as natural treatments for respiratory tract infection. Further studies should investigate the specific mechanisms by which garlic and honey exert their antibacterial effects.

Introduction

The study of the interactions between natural products and bacterial growth has gained significant attention in the scientific community. Natural products, derived from various plant, animal, and microbial sources, have long been recognized for their potential to exhibit antimicrobial properties and influence the growth of diverse bacterial species (Cowan, 1999).

Many natural products, such as essential oils, plant extracts, and secondary metabolites, have been investigated for their ability to inhibit or modulate the growth of pathogenic bacteria (Arora & Kaur, 2007). These natural compounds may target various cellular processes, including cell wall synthesis, membrane integrity, enzymatic activities, and genetic regulation, leading to the disruption of bacterial growth and, in some cases, the induction of cell death (Burt, 2004).

The exploration of natural products as potential antimicrobial agents is particularly important in the context of the global rise in antibiotic-resistant bacterial strains. Natural compounds may offer novel mechanisms of action, potentially overcoming the resistance mechanisms developed by bacteria against conventional antibiotics (Cowan, 1999).

The growing prevalence of antibiotic-resistant bacteria has become a pressing global concern, rendering many conventional antibiotics ineffective and necessitating the exploration of alternative antimicrobial strategies (WHO, 2021). Natural products, such as plant extracts, essential oils, and microbial secondary metabolites, have long been recognized for their potential antimicrobial properties (Cushnie et al., 2014). However, the systematic investigation of the effects of natural products on bacterial growth and their potential as novel antimicrobial agents requires further research and exploration.

The investigation of natural products as potential antimicrobial agents has gained significant attention in recent years, driven by the urgent need to address the growing global challenge of antibiotic resistance (WHO, 2021). This concerning trend has prompted the scientific community to search for alternative antimicrobial strategies, with natural products emerging as a promising avenue of investigation.

Natural products, such as plant extracts, essential oils, and secondary metabolites produced by microorganisms, have long been recognized for their diverse antimicrobial properties (Cowan, 1999). These compounds often exhibit complex chemical structures and multiple mechanisms of action, making it more challenging for bacteria to develop resistance (Cushnie et al., 2014). The aim of the study is to determine the effect of garlic (*Allium Sativum*) and honey (*Apis mellifera*) on respiratory tract infection causing bacteria.

Materials and methods

Study Area

This study was conducted at the Biology Laboratory, Department of Biological sciences, Northwest University Kano, Nigeria. Northwest University Kano is located along Muhammad Buhari way, Kano State.

Collection and Extraction of Honey

Raw wild honey samples was collected from the nests using a sterile container, sample of honey was first filtered with a sterile mesh to remove debris and the filtered extract was stored in bottle. This was considered as pure (100%) honey. The filtered extract was then diluted with sterile distilled water with the following concentration: 50%, 25%, 12.5% and 6.25% (v/v) (Andualem 2013).

Collection and preparation of Garlic extract

Matured fresh garlic (*Allium sativum*) bulbs were peeled and ground using pestle and mortar. Sterile cheesecloth was used to filter the garlic extract, this was considered as (100%) concentration. The filtrated extract was then diluted with distilled water to the following concentrations: 50%, 25%, 12.5% and 6.25% (v/v) (Ramalivhana et al., 2014).

Collection of Bacterial Isolates

Five bacterial species isolated from respiratory tract infection RTI patients including*: E.coli, K.pneumoniae, P. aeruginosa, S. aureus and S. pneumoniae* were collected from Microbiology Unit of Aminu Kano Teaching Hospital AKTH, Kano state, Nigeria. Identity of the isolates were confirmed by subculturing on appropriate growth media and biochemical tests.

Determination of antibacterial activity of Honey and Garlic extracts

Antibacterial susceptibility test was carried out using Muller hinton agar MH. The media was prepared according to manufacturer's instruction. Using a sterile cork borer (6 mm diameter, 4 mm deep and about 2 cm apart) were made and filled up with honey, extract from garlic and mixture of honey and extract of garlic samples in equal proportions one well from each plates was filled water as a negative control and another one was filled with chloramphenicol (32 micro gram per mile) positive control. Mc farland standard (0.5) of the clinical isolates (*E.coli, K. pneumoniae, P. aeruginosa, S. aureus and S. pneumonia)* were prepared according to the method described by Andrews (2006). The standard inoculum were inoculated and spread over on the MH agar for 24 hours. The plates were incubated at temperature of 37 degree Celsius for 24 hours.

Antibiotic susceptibility test AST

The test microorganisms were also tested against commonly prescribed antibiotics (Erythromycin ER30 Amikacim AK and Co-trimoxole CoT25) using similar methods for the determination of antimicrobial activity of honey and garlic extracts (Patel et al., 2011).

Determination of Minimum Inhibitory Concentration MIC

The MIC is defined as the lowest concentration of garlic extract that completely inhibits the growth of the organism. The MIC of the extracts were determined according to methods described by (Shahidi 2004) and Akinyemi et al. (2005). Extracts were diluted to concentrations ranging from 6.25% to 25% for garlic, honey and a mixture of garlic with honey (1:1, v/v). To each dilution of honey, garlic extract and a mixture of both, in nutrient broth tubes were seeded 100 µL of the standard and clinical bacterial inoculum. Negative control tubes with no bacterial inoculation were simultaneously maintained. Tubes were incubated aerobically at 37 °C for 24 h.

Determination of Minimum Bactericidal Concentration MBC

Dilutions showing no visible growth for the MIC were subcultured onto a fresh MH agar plate and incubated at 37 °C for 24 h. The lowest concentration of the extracts yielding no growth on the MH plate was recorded as MBC (Patel et al., 2011).

Data analysis

Statistical analysis was carried out using SPSS 16.020 version window. The data was statistically analyzed using one way ANOVA. Statistical significance was accepted at $P \leq 0.05$ (Alemseged et al., 2018*).*

Results and Discussions

The present study focused on the antibacterial properties of honey, garlic and mixture of garlic-honey extract against the pathogens causing RTI. The result of antibacterial activity of Garlic and Honey and Mixture of Garlic-Honey is represented in Table 1. The inhibition zone was higher in Garlic extract (25-40mm) and mixture of Garlic-Honey (25-31mm). These inhibition zones are higher compared to inhibition zone produced by Honey and the Standard antibiotic tested against the Respiratory isolates.

The mean difference between inhibition zones of Garlic and Honey, Garlic and standard antibiotic are significant. While the mean difference between Garlic and mixture of Garlic-Honey is not significant at $P \leq 0.05$ significance level. The mean difference between inhibition zones of Garlic and Honey, Garlic and Standard antibiotic are significant, while the mean difference of Garlic and mixture of Garlic-Honey is not significant. Details of the comparison is represented in table 2 below.

Scientists from parts of the world have demonstrated the antibacterial properties of honey and garlic extracts separately against different clinical isolates originated from wounds, enteric pathogens, urinary tract infections and nosocomial infections (Molan., 1992; Selcuk., 2002; Mulu et al., 2004 and Abdullah et al., 2012). Local communities believed mixture of garlic and honey have great capacity of treating different infection including respiratory tract infections than using honey alone or garlic alone to treat different infections. Their claim were also supported by research from Gondar, Ethiopia by Andualem (2013) but in the present study, the inhibition capacity of mixture of honey and garlic extract was almost the as the inhibition of garlic extract alone. This may be due to the low inhibition capacity of honey used in this study.

Different researchers reported that various garlic extracts such as crude, aqueous and alcoholic extracts showed great antimicrobial properties against various microorganisms (Durairaj, 2009; Alorainy, 2011). The antimicrobial nature of garlic is due to the present of allicin (Harris et al., 2001; Ruddock et al., 2005). It interferes the normal process of RNA production and lipid synthesis, which affects the synthesis of protein and cell wall of microorganisms (Felberg et al., 1988).

Mousa et al. (2012) reported that honey was active against all tested pathogenic organisms except *P.aeruginosa*, which was the only resistant pathogen. This is similar to this study findings, as honey was active on all the RT pathogens except *P.aeruginosa.* Hazrati et al. (2010) reported that Honey has excellent antibacterial efficacy against MRSA and a variety of *Pseudomonas*, which are often associated with wound and burn infections. This is contrary to this study findings, as honey was not active on *P.aeruginosa.* This might be due to the difference in source of the isolates. Visavadia et al. (2008) pointed out that Manuka (*L. scoparium*) honey (showed efficacy against many pathogenic microorganisms, including: *Enterobacter erogenes, S. aureus, Salmonella zyphimurium*, and last, but not least, *Escherichia coli* (*E. coli*). The antibacterial efficacy of honey may be attributed to its to its osmotic effect, high sugar content, and low moisture content, as well as to the presence of gluconic acid, which produces the antiseptic H_2O_2 (Molan 1992; O'Grady et al., 1999). This is not in consistence with our findings, as honey showed the least antibacterial efficacy. The emergence of bacterial resistance to honey is very low because of variations in its composition due to differences in nectar source, climatic conditions, duration of storage and preservation conditions (Sherlock et al., 2010).

Table 1: Inhibition zone (mm) of Garlic, Honey, mixture of Garlic and Honey and Chloramphenicol antibiotic

Bacteria	Garlic	Honey	Mixture	Standard antibiotic
P.aeruginosa	25	10	30	30
E.coli	25	18	25	9
K. Pneumoniae	40	20	25	20
S. aureus	25	18	28	12
S. Pneumoniae	30	25	31	20

Key: Standard antibiotic (Chloramphenicol)

Table 2: One way ANOVA multiple comparisons of extract inhibition Comparison of extract

(I) Plant extract & Antibiotic Antibiotic	(J) Plant extract & Antibiotic	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Garlic	Honey	-9.1333*	1.70489	.000	4.5635	13.7032
	Mixture	1.4000	1.70489	.844	-3.1698	5.9698
	Standard	-5.4667*	1.70489	.014	.8968	10.0365
Honey	Garlic	-9.1333*	1.70489	.000	-13.7032	-4.5635
	Mixture	-7.7333*	1.70489	.000	-12.3032	-3.1635
	Standard	3.6667	1.70489	.155	-8.2365	.9032
Mixture	Garlic	1.4000	1.70489	.844	-5.9698	3.1698
	Honey	-7.7333*	1.70489	.000	3.1635	12.3032
	Standard	-4.0667	1.70489	.096	-.5032	8.6365
Standard	Garlic	-5.4667*	1.70489	.014	-10.0365	-.8968
	honey	3.6667	1.70489	.155	-.9032	8.2365
	mixture	-4.0667	1.70489	.096	-8.6365	.5032

*. The mean difference is significant at the ≤0.05 level.

The MIC and MBC of Garlic, Honey and mixture of Garlic-Honey extracts according to this study are represented in Table 3. The MIC of Honey against all the RT pathogens was 12.5%, MIC of Garlic against *P. aeruginosa, K. pnuemoniae* and *S. pneumoniae* was 6.25%; against *E.coli* and *S. aureus* was 12.5%. MIC of mixture of Garlic-Honey against all the pathogens was 6.25%.

The MBC of Garlic on *P. aeruginosa, K. pnuemoniae* and *E.coli* was 12.5%, 25% for *S. aureus* and 6.25% for *S. pneumoniae.* MBC of Honey was 25% against all pathogens except *S.pneumoniae* which was 12.5%. The MBC for mixture of Garlic-Honey was 6.25% for *P. aeruginosa* and *S. pneumonia* and 12.5% for *E.coli, K. pnuemoniae* and *S. aureus.*

Comparison of the MIC of the extracts show that there is significant difference between the MIC of Honey and mixture of Garlic-Honey, also there is significant difference between MIC of Honey and Garlic at $P \leq 0.05$ significance level. While there is no significance difference between MIC of Garlic and mixture of Garlic-Honey (Table 4).

Table 3: MIC and MBC of different concentrations of Garlic extract, Honey and mixture of Garlic-Honey in percentage (%).

Organism	Honey		Garlic		Mixture	
	MIC	MBC	MIC	MBC	MIC	MBC
P.aeruginosa	12.5	25	6.25	12.5	6.25	6.25
E.coli	12.5	25	12.5	12.5	6.25	12.5
K. Pneumoniae	12.5	25	6.25	12.5	6.25	12.5
S. aureus	12.5	25	12.5	25	6.25	12.5
S. Pneumoniae	12.5	12.5	6.25	6.25	6.25	6.25

Key: MIC -Minimum Inhibitory Concentration

MBC -Minimum Bactericidal Concentration

Table 4: Comparisons of MIC of extracts with one way ANOVA multiple

Comparison of MIC	Mean Difference	Std Error	P-Value	95%ConfidenceInterval	
Honey -Mixture	10.75	2.574	0.001	5.14	16.36
Honey - Garlic	11.25	2.574	0.001	5.64	16.86
Mixture - Garlic	500	2.574	0.849	-5.11	6.11

Key: * The mean difference is significant at 0.05 significance level

For the antibiotics tested against the pathogens: Cotrimoxazole was active on *P.aeruginosa* and *S.pneumoniae* but not active on *S.aureus* and *K.pneumoniae.* All the pathogens were resistant to Erythromycin. Amikacin was active on all the pathogens except *S. pneumoniae*, which was resistant to the antibiotic (Table 5). This indicate that extracts of Garlic, Honey and mixture of Garlic-Honey have efficacy similar to antibiotics tested in this study. In case of Erythromycin; the antibiotic has less activity even compared to the least performing extract (honey), as it was not active on all the pathogens. This shows that, it might be possible to use garlic extract or mixture of garlic-honey as an alternative to antibiotic treatment in treatment RTI.

There is need for further studies on efficacy of application of honey with antimicrobial agents. Previous study have shown The application of tetracycline with Manuka honey yielded better antimicrobial potential against *S. aureus* and *P. aeruginosa* than was observed with either treatment alone.

Table 5: Antibacterial activity of commercial antibiotics against the isolates (mm)

Pathogen	Antibiotic	Zone of Inhibition (mm)
P.aeruginosa	COT 25	13
	ER 15	0
	AK 30	20
E.coli	COT 25	28
	ER 15	10
	AK 30	19
K. Pneumoniae	COT 25	10
	ER 15	6
	AK 30	20
S. aureus	COT 25	10
	ER 15	6
	AK 30	20
S. Pneumoniae	COT 25	15
	ER 15	15

Key: Susceptible S (▪), Intermediate I (◦), Resistant R (#)

COT- Co-trimoxazole (S ≥16mm, I 11-15mm, R ≤10mm), ER – Erythromycin (S ≥23mm, I 16-22mm, R ≤ 15mm) , AK Amikacin (S ≥ 17mm , I 15mm-16 ,R ≤14mm)

This finding suggests that such a combination is a possible treatment strategy especially for wound healing (Jenkins and Cooper 2012). Müller et al. (2013) reported that the combination of rifampicin with subinhibitory concentrations of Medihoney reversed rifampicin resistance in clinical isolates of *S. aureus*, including Methicillin resistant *Staphylococcus aureus* (MRSA). Also, MRSA became susceptible to oxacillin upon the application of subinhibitory concentrations of honey.

CONCLUSION

The findings of this study demonstrated that both Garlic and Honey extracts exhibit antibacterial activity against the tested Respiratory pathogens. Garlic was active on all the pathogens (*E.coli, K. pneumoniae, P. aeruginosa, S. aureus and S. pneumoniae)* while Honey was more active on *K. pneumonia* and *S. pneumonia* and not active on *P. aeruginosa.* The MIC and MBC of Garlic and mixture of Garlic-Honey suggest that they could be used as natural treatments for respiratory tract infection. The comparison with antibiotics revealed that the natural extracts could serve as effective alternatives to antibiotics.

Acknowledgement

The author's thank Almighty God for giving the health and ability to perform this research. They would also like to express their appreciation to the Department of Biological sciences, Northwest University Kano for the facilities provided and guidance by the department technologists and academic staff during this study and throughout my academic journey.

Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

Author Contribution

Bashir Salisu - Developing the research idea, conducting experiment and gathering data, preparing first version of the manuscript. Surayya Lawan Idris - Funding related resources, critical reviewing, overseeing the project & mentoring the research team. Faiza Inuwa Husssain - Revising and reviewing the manuscript. Umar Labaran Bashir - Improving the manuscript. Muhammad A. Bello - Creating tables. Abubakar Ahmad Data interpretation.

References

Abdullah, F. E., Aftab, K., Khanum, R., & Khan, S. S. (2012). Antibacterial activity of honey against bacteria isolated from respiratory tract infections. *J Dow Uni Health Sci*; 6, 95-99.

Akinyemi, K. O., Oladapo, O., Okwara, C. E., Ibe, C. C., & Fasure, K. A. (2005). Screening of crude extracts of six medicinal plants used in Southwest Nigerian orthodox medicine for anti-methicillin resistant Staphylococcus aureus activity. *BMC Complement Altern Med*; 5, 6.

Alemseged, M., Adugna, S., & Bayu, E. (2018). Antibacterial properties of mixture honey and garlic (Allium Sativum) extracts against respiratory tract infection causing bacteria. *J Pharmacovigilance* ;6(4).

Alorainy, M. S. (2011). Evaluation of antimicrobial activity of garlic (Allium sativum) against E. coli O157: H7. *J Agri Vet Sci*; 4, 149-157.

Andualem, B. (2013). Synergistic antimicrobial effect of Tenegn honey (*Trigona iridipennis*) and garlic against standard and clinical pathogenic bacterial isolates. *International Journal of Microbiology Research*; 4, 16-22.

Andrews, J. M. (2006). BSAC standard disc susceptibility testing method (version 5). *Journal of Antimicrobial Chemotherapy*; 58(3), 511-529.

Arora, D. S., & Kaur, J. (2007). Antimicrobial activity of spices. *International Journal of Antimicrobial Agents;* 12(3), 257-262.

Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods—*A review. International Journal of Food Microbiology*; 94(3), 223-253.

Cowan, M. M. (1999). Plant products as antimicrobial agents. *Clinical Microbiology Reviews*; 12(4), 564-582.

Cushnie, T. T., Cushnie, B., & Lamb, A. J. (2014). Alkaloids: An overview of their antibacterial, antibiotic-enhancing and antivirulence activities. *International Journal of Antimicrobial Agents*; 44(5), 377-386.

Durairaj, S., Srinivasan, S., & Lakshmanaperumalsamy, P. (2009). In vitro antibacterial activity and stability of garlic extract at different pH and temperature. *Electronic Journal of Biology*; 5, 5-10.

Feldberg, R., Chang, S., & Kotik, A. (1988). In vitro mechanism of inhibition of bacterial cell growth by allicin. *Antimicrobial Agents and Chemotherapy*; 32, 1763-1768.

Harris, J. C., Cottrell, S. L., Plummer, S., & Lloyd, D. (2001). Antimicrobial properties of *Allium sativum* (Garlic). *Applied Microbiology and Biotechnology;* 57, 282-286.

Hazrati M., Mehrabani D., Japoni A., Montasery H., Azarpira N., Hamidian-shirazi A.R., Tanideh N. (2010). Effect of Honey on Healing of Pseudomonas aeruginosa Infected Burn Wounds in Rat. *Journal of Applied Animal Research*; 37(2):161–165.

Jenkins R.E., Cooper R. Synergy between oxacillin and manuka honey sensitizes methicillin-resistant *Staphylococcus aureus* to oxacillin (2012). *Journal of Antimicrobial Chemotherapy*; 67(6):1405–1407. doi: 10.1093/jac/dks071.

Molan, P. C. (1992). The antibacterial activity of honey: 2. Variation in the potency of the antibacterial activity. *Bee World*; 73, 59-76.

Mousa, A., Noureddine, D., Mohamed, H., Abdelmelak, M., & Aissat, S. (2012). Antibacterial activity of various honey types of Algeria against Staphylococcus aureus and Streptococcus pyogenes. *Asian Pacific Journal of Tropical Medicine*; 7, 773-776.

Müller P., Alber D.G., Turnbull L., Schlothauer R.C., Carter D.A., Whitchurch C.B., Harry E.J.(2013).Synergism between Medihoney and rifampicin against methicillin-resistant Staphylococcus aureus (MRSA) *PLoS One* ;8(2) doi: 10.1371/journal.pone.0057679.

Mulu, A., Tessema, B., & Derbie, F. (2004). In vitro assessment of the antimicrobial potential of honey on common human pathogens. *Ethiopian Journal of Health Development*; 18, 107-111.

O'Grady N.P., Tropea M., Preas H.L., 2nd, Reda D., Vandivier R.W., Banks S.M., Suffredini A.F. (1999). Detection of macrophage inflammatory protein (MIP)-1alpha and MIP-1beta during experimental endotoxemia and human sepsis. J Infect Dis.; 179(1):136–141. doi: 10.1086/314559.

Patel, R. V., Thaker, V. T., & Patel, V. K. (2011). Antimicrobial activity of ginger and honey on isolates of extracted carious teeth during orthodontic treatment. *Asian Pacific Journal of Tropical Biomedicine;* 1, S58-S61.

Ramalivhana, J. N., Obi, C. L., Samie, A., Iweriebor, B. C., Uaboi-Egbenni, P., & Eloff, J. N. (2014). Antibacterial activity of honey and medicinal plant extracts against Gram negative microorganisms. *African Journal of Biotechnology*; 13, 616-625.

Ruddock, P. S., Liao, M., Foster, B. C., Lawson, L., Arnason, J. T., & Mahady, G. B. (2005). Garlic natural health products exhibit variable constituent levels and antimicrobial activity against Neisseria gonorrhoeae, Staphylococcus aureus and Enterococcus faecalis. *Phytotherapy Research*; 19, 327-334.

Selçuk, H., & Nevin, K. (2002). Investigation of antimicrobial effect of honey collected from various regions of Turkey. *Pakistan Journal of Biological Sciences*; 5, 325-328.

Shahidi, G. A. (2004). Evaluation of antimicrobial properties of Iranian medicinal plants against Micrococcus luteus, Serratia marcescens, Klebsiella pneumonia, and

Bordetella bronchiseptica. *Asian Journal of Plant Sciences*; 3(1), 82-86.

Sherlock O., Dolan A., Athman R., Power A., Gethin G., Cowman S., Humphreys H.(2010). Comparison of the antimicrobial activity of Ulmo honey from Chile and Manuka honey against methicillin-resistant *Staphylococcus aureus*, *Escherichia coli and Pseudomonas aeruginosa*. *BMC Complement Altern Med*.; 10:47. doi: 10.1186/1472-6882-10-47.

Visavadia Bhavin G, Honeysett Jan, Danford Martin. Manuka honey dressing: An effective treatment for chronic wound infections (2008). *British Journal of Oral and Maxillofacial Surgery*; 46 (8):696–697. doi: 10.1016/j.bjoms.2007.12.014.

World Health Organization. (2021). Antimicrobial resistance. Retrieved from https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance.