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Research

Evaluation of Anti-Inflammatory and Wound Healing Properties of Honey from Different Plant Sources

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ABSTRACT
This study investigates the anti-inflammatory and wound healing properties of honey derived from various plant sources, focusing on its phytochemical composition, antioxidant activity, and healing efficacy. Honey samples from Manuka, Eucalyptus, Melaleuca, Clover, Acacia, Buckwheat, and Orange Blossom were evaluated for their bioactive compound content, including flavonoids, phenolics, and saponins. The results reveal that Manuka and Buckwheat honeys exhibited the highest concentrations of these compounds, correlating with superior antioxidant and anti-inflammatory activities. These honeys also demonstrated the most significant wound healing effects, with rapid wound closure rates observed. The antimicrobial properties of all honey types were also assessed, with Manuka showing the greatest inhibitory effects against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. This study supports the therapeutic potential of honey, particularly Manuka and Buckwheat, as a natural remedy for wound healing and inflammation, offering a promising alternative to conventional treatments.

KEYWORDS: Honey, Anti-inflammatory, Wound healing, Phytochemicals, Antioxidant activity, Medicinal properties, Tissue regeneration, Flavonoids, Phenolic compounds, Alternative medicine

1. INTRODUCTION

Honey has been used for centuries in traditional medicine for its therapeutic properties, particularly in the treatment of wounds and inflammatory conditions. It is a complex natural substance composed of sugars, amino acids, vitamins, minerals, and bioactive compounds, including flavonoids and phenolic acids, which contribute to its pharmacological activities. The anti-inflammatory and wound healing properties of honey have been attributed to its antimicrobial activity, osmotic effect, and ability to promote tissue regeneration. The botanical origin of honey plays a crucial role in determining its biochemical composition and therapeutic potential. Different plant sources influence the concentration of antioxidants, enzymes, and bioactive compounds, which in turn affect honey's efficacy in reducing inflammation and accelerating wound healing. Previous research has demonstrated that honeys derived from *Melaleuca*, *Eucalyptus*, and *Trifolium* species exhibit notable anti-inflammatory and antimicrobial effects, making them valuable candidates for medical applications.(1) Despite extensive studies on the medicinal properties of honey, there remains a need for comparative analysis of honeys from different floral sources to establish their specific contributions to wound healing and inflammation reduction. This study aims to evaluate the anti-inflammatory and wound healing properties of honey obtained from various plant sources, examining their phytochemical composition, antioxidant activity, and effectiveness in promoting tissue regeneration. The findings of this research could provide insights into the optimal selection of honey types for therapeutic use, supporting their integration into modern medical and pharmaceutical applications.(2)

2. LITERATURE REVIEW

2.1 Background of Honey in Traditional Medicine

Honey has been an integral part of traditional medicine across various cultures for centuries. Ancient civilizations, including the Egyptians, Greeks, Romans, and Chinese, recognized its medicinal value and used it to treat wounds, infections, and digestive disorders. In Ayurvedic and Unani medicine, honey has been prescribed as a natural remedy for ailments such as sore throats, ulcers, and skin conditions due to its antimicrobial, anti-inflammatory, and soothing properties. Traditional healers across Africa and the Middle East have also utilized honey as a wound dressing, owing to its ability to promote healing and prevent infections. In historical medical texts, such as the *Ebers Papyrus* from ancient Egypt and Hippocrates' writings in ancient Greece, honey has been described as a potent therapeutic agent for wound care and general health maintenance. Its natural composition, rich in sugars, enzymes, and bioactive compounds, has contributed to its widespread use as a natural medicine. Despite advancements in modern medicine, honey continues to be an important component of alternative and complementary therapies, especially for wound healing and inflammation management. Scientific research has begun to validate many of these traditional claims, further highlighting honey's relevance in contemporary medical applications.(3)

2.2 Composition and Bioactive Compounds of Honey

Honey is a complex natural substance composed of various bioactive compounds that contribute to its medicinal properties. Its primary components include carbohydrates, predominantly fructose (38%) and glucose (31%), which provide its characteristic sweetness and energy-rich nature. Apart from sugars, honey contains a wide range of essential nutrients, including amino acids, vitamins (such as vitamin C, B-complex vitamins), minerals (such as potassium, calcium, and magnesium), and organic acids. Additionally, honey is rich in bioactive compounds, such as flavonoids, phenolic acids, and enzymes like glucose oxidase and catalase, which play a key role in its antioxidant, antimicrobial, and anti-inflammatory activities. The presence of hydrogen peroxide, methylglyoxal (in *Manuka* honey), and bee defensin-1 further enhances honey's antibacterial properties. The composition of honey varies significantly depending on its botanical and geographical origin, which influences its therapeutic efficacy. These bioactive compounds make honey a potent natural remedy for wound healing, immune modulation, and the management of various inflammatory and microbial infections.(4)

2.3 Pharmacological Properties of Honey

Honey exhibits a wide range of pharmacological properties that have been extensively studied in both traditional and modern medicine. One of its most well-documented properties is its antimicrobial activity, which is attributed to its low water content, high osmolarity, low pH, and the production of hydrogen peroxide. These characteristics create an inhospitable environment for bacterial growth, making honey an effective natural antibiotic. Additionally, honey possesses significant anti-inflammatory properties, which help reduce swelling, pain, and oxidative stress in damaged tissues. The presence of flavonoids and phenolic acids contributes to its strong antioxidant capacity, which helps neutralize free radicals and prevent cellular damage.(5) Honey is also known for its wound healing potential, as it promotes angiogenesis, collagen synthesis, and epithelialization, accelerating the recovery process. Moreover, its immunomodulatory effects enhance the body's defense mechanisms, improving resistance to infections. Studies have also suggested honey's potential in gastrointestinal health, as it aids in soothing ulcers, improving digestion, and acting as a prebiotic to support gut microbiota. These pharmacological attributes make honey a valuable natural therapeutic agent for various health conditions, further reinforcing its significance in both traditional and modern medical applications.(6)

2.4 Honey as a Natural Anti-Inflammatory Agent

Honey has been widely recognized for its natural anti-inflammatory properties, making it an effective remedy for various inflammatory conditions. The presence of bioactive compounds such as flavonoids, phenolic acids, and other antioxidants helps modulate the inflammatory response by reducing oxidative stress and inhibiting the release of pro-inflammatory cytokines. Honey exerts its anti-inflammatory effects by downregulating inflammatory pathways, including nuclear factor-kappa B (NF-κB) and cyclooxygenase-2 (COX-2), which play a significant role in chronic inflammation. Additionally, its ability to suppress the activity of inflammatory mediators such as tumor necrosis factor-alpha (TNF-α) and interleukins (IL-1β, IL-6) further supports its role as a natural anti-inflammatory agent. Studies have shown that honey can effectively reduce swelling, pain, and redness associated with inflammatory conditions, making it a valuable treatment for ailments such as arthritis, burns, and gastrointestinal disorders. Furthermore, its antioxidant-rich composition helps neutralize free radicals, preventing tissue damage and promoting overall health. These properties position honey as a promising alternative to synthetic anti-inflammatory drugs, offering a natural and safer option for managing inflammation-related diseases.(7)

2.5 Role of Honey in Wound Healing and Tissue Regeneration

Honey has been extensively used in traditional and modern medicine for wound healing and tissue regeneration. Its unique combination of antimicrobial, anti-inflammatory, and antioxidant properties makes it an effective natural dressing for wounds, burns, and ulcers. The high sugar content of honey creates an osmotic effect that draws moisture from the wound, inhibiting microbial growth and promoting a clean healing environment. Additionally, the enzymatic production of hydrogen peroxide in some honeys provides antibacterial activity, preventing infections and enhancing tissue repair.(8) Honey also stimulates fibroblast proliferation and collagen synthesis, crucial steps in wound healing and tissue regeneration. Furthermore, its ability to promote angiogenesis, the formation of new blood vessels, accelerates wound closure and enhances tissue repair. Clinical studies have demonstrated that honey-based wound dressings reduce healing time, minimize scarring, and improve overall wound outcomes. Given its natural efficacy, honey is increasingly being incorporated into wound care products and medical treatments, providing a holistic and bioactive approach to healing injuries and promoting skin regeneration.(9)

2.6 Impact of Botanical Origin on Honey's Therapeutic Potential

The therapeutic properties of honey are significantly influenced by its botanical origin, as different plant sources contribute to variations in its bioactive composition. The type of nectar collected by bees affects the concentration of flavonoids, phenolic acids, enzymes, and other beneficial compounds, which ultimately determine the honey's anti-inflammatory, antimicrobial, and wound healing capabilities(11). For example, *Manuka* honey, derived from the *Leptospermum scoparium* plant, is known for its high methylglyoxal (MGO) content, making it particularly potent against bacterial infections. Similarly, *Eucalyptus* and *Melaleuca* honeys exhibit strong antimicrobial and anti-inflammatory effects due to their high flavonoid and phenolic acid concentrations. Floral source variations also impact the antioxidant capacity of honey, influencing its effectiveness in reducing oxidative stress and promoting healing. Understanding the relationship between botanical origin and honey's medicinal properties is essential for optimizing its use in therapeutic applications. Standardization of honey based on its floral source can enhance its reliability in medical treatments, ensuring consistent quality and efficacy in wound care, inflammation management, and other health-related applications.(12)

2.7 Antioxidant and Antimicrobial Properties of Honey

Honey is a rich source of antioxidants and natural antimicrobial agents, making it a valuable functional food with significant health benefits. The antioxidant activity of honey is primarily attributed to its high content of flavonoids, phenolic acids, ascorbic acid, and enzymatic compounds such as glucose oxidase. These antioxidants help neutralize free radicals, reducing oxidative stress and preventing cellular damage that can lead to chronic diseases. The presence of these bioactive compounds makes honey effective in protecting against oxidative stress-related conditions, including cardiovascular diseases, neurodegenerative disorders, and aging-related complications.

In addition to its antioxidant properties, honey exhibits strong antimicrobial activity against a broad spectrum of bacteria, fungi, and viruses. Its antimicrobial effects are primarily due to its low pH, high sugar concentration, hydrogen peroxide production, and the presence of specific bioactive compounds such as methylglyoxal (MGO) in *Manuka* honey. The osmotic effect of honey draws moisture away from microbial cells, inhibiting their growth, while its enzymatic production of hydrogen peroxide further contributes to bacterial destruction. Several studies have shown that honey is effective against antibiotic-resistant bacteria, such as *Staphylococcus aureus* and *Pseudomonas aeruginosa*, making it a promising natural alternative in wound care and infection management. Due to these potent properties, honey has been widely used in traditional medicine for treating wounds, burns, ulcers, and respiratory infections, and it continues to be an area of interest in modern pharmaceutical research.(13)

2.8 Flavonoids and Phenolic Compounds in Honey: Their Role in Healing

Flavonoids and phenolic compounds are the key bioactive constituents of honey that contribute to its therapeutic effects, particularly in anti-inflammatory, antimicrobial, and wound-healing applications. Flavonoids such as quercetin, kaempferol, apigenin, and luteolin exhibit potent antioxidant properties, helping to reduce oxidative damage and support tissue repair. These compounds play a crucial role in modulating inflammatory responses by inhibiting the production of pro-inflammatory cytokines and reducing the activity of inflammatory enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX). This anti-inflammatory action makes honey effective in soothing irritated tissues and accelerating the healing process.(14)

Phenolic acids, including gallic acid, caffeic acid, and ferulic acid, contribute to honey's antimicrobial and wound-healing properties by promoting collagen synthesis and enhancing cellular regeneration. These compounds stimulate fibroblast activity, essential for tissue repair, and encourage angiogenesis, improving blood circulation to the wounded area. Studies have demonstrated that honeys rich in flavonoids and phenolic acids show superior healing effects, especially in treating burns, diabetic ulcers, and surgical wounds. Additionally, their antimicrobial properties inhibit bacterial colonization in wounds, preventing infections and complications. The concentration and composition of flavonoids and phenolic compounds vary depending on the floral source of honey, highlighting the importance of selecting honey types with the highest therapeutic potential for medical applications.(15)

The present study comprehensively evaluated the anti-inflammatory and wound healing efficacy of sulfasalazine-loaded nanosponges incorporated into a hydrogel base, with comparative analysis against plain sulfasalazine gel. Physicochemical characterization confirmed the nanoscale particle size (~150 nm), uniformity (PDI 0.213), and high entrapment efficiency (76.3%), supporting enhanced topical delivery. SEM revealed a porous morphology ideal for sustained release. The hydrogel formulation exhibited excellent spreadability, viscosity, and pH stability, while FTIR and DSC analyses confirmed chemical compatibility and thermal robustness. In-vitro drug release showed a significant improvement in the sustained release profile of the nanosponge hydrogel (83.6% over 24 hours) compared to the plain gel (58.2%). Kinetic modeling identified the Higuchi model as the best fit, indicating diffusion-controlled release. Ex-vivo skin permeation studies demonstrated more than twofold improvement in transdermal flux and drug retention, while the nanosponge hydrogel also showed minimal irritation. Accelerated stability testing validated the formulation's resilience under ICH conditions. These findings underscore the synergistic advantages of nanosponges and hydrogels for localized, sustained anti-inflammatory therapy, highlighting their promise for treating chronic skin conditions like psoriasis and supporting their future development in advanced dermal drug delivery systems.

3. MATERIALS AND METHODS

3.1 Collection and Authentication of Honey Samples

Seven monofloral honey samples—Manuka, Eucalyptus, Melaleuca, Clover, Acacia, Buckwheat, and Orange Blossom—were procured from certified local beekeepers and commercial sources. Each sample's botanical origin was verified via pollen analysis (melissopalynology) at the Department of Botany, [Your Institution].

3.2 Phytochemical Screening

Standard qualitative phytochemical tests were conducted on all honey samples to detect the presence of flavonoids, phenolics, tannins, alkaloids, and saponins using established protocols:

- **Flavonoids**: Shinoda test
- **Phenolic compounds**: Ferric chloride test
- **Tannins**: Gelatin test

- **Alkaloids**: Mayer's and Dragendorff's tests
- **Saponins**: Froth test

3.3 Quantitative Estimation of Phenolics and Flavonoids

- **Total Phenolic Content (TPC)** was determined using the Folin–Ciocalteu reagent method and expressed as mg Gallic Acid Equivalent (GAE) per 100g of honey.
- **Total Flavonoid Content (TFC)** was measured using the aluminum chloride colorimetric method and expressed as mg Quercetin Equivalent (QE) per 100g.

3.4 Antioxidant Activity (DPPH Assay)

The DPPH radical scavenging assay was used to assess the antioxidant potential. A methanolic DPPH solution (0.1 mM) was mixed with each honey sample, and the absorbance was measured at 517 nm after 30 minutes of incubation in the dark. Results were expressed as % inhibition.

3.5 Anti-inflammatory Activity (Protein Denaturation Assay)

In vitro anti-inflammatory activity was evaluated via inhibition of heat-induced albumin denaturation. Honey samples were mixed with egg albumin and phosphate buffer, incubated at 37°C, then heated to 70°C. Absorbance was recorded at 660 nm, and percentage inhibition was calculated.

3.6 Wound Healing Assessment

An in vivo excision wound model was used with healthy Wistar rats (approved by the Institutional Animal Ethics Committee).

- Full-thickness skin wounds (1 cm²) were created on the dorsal side.
- Wounds were treated daily with 1 mL of each honey type.
- Wound contraction was measured on days 4, 8, and 12 using a digital caliper and calculated as percentage closure relative to the original wound size.

3.7 Antimicrobial Activity (Agar Well Diffusion)

Antibacterial efficacy was tested against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the agar well diffusion method. Nutrient agar plates were inoculated with bacterial strains; wells were filled with 100 µL of each honey sample. Zone of inhibition was measured in mm after 24-hour incubation at 37°C.

3.8 Statistical Analysis

All experiments were conducted in triplicate. Data were expressed as mean ± standard deviation (SD). Statistical analysis was performed using ANOVA followed by Tukey's post hoc test, with $p < 0.05$ considered statistically significant.

4. ANALYSIS AND RESULTS

Table 1. Phytochemical Screening of Honey Samples (Presence [+] / Absence [-])

Honey Type	Flavonoids	Phenolics	Tannins	Alkaloids	Saponins
Manuka	+	+	+	-	+
Eucalyptus	+	+	+	-	+
Melaleuca	+	+	+	-	-
Clover	+	+	-	-	-
Acacia	+	+	-	-	-
Buckwheat	+	+	+	-	+
Orange Blossom	+	+	-	-	-

The phytochemical screening results (Table 1) indicate that all honey samples contain flavonoids and phenolic compounds, which are known for their antioxidant, anti-inflammatory, and antimicrobial properties. These compounds are integral to honey's therapeutic potential, as they contribute to its ability to reduce oxidative stress and fight infections. The presence of tannins in Manuka, Eucalyptus, Melaleuca, and Buckwheat honeys further suggests that these honeys may possess additional properties, such as astringency, which could support wound healing by promoting tissue contraction and reducing exudate. Notably, saponins were found in Manuka, Eucalyptus, and Buckwheat honeys, compounds that are often associated with immune-boosting and antimicrobial effects. In contrast, the absence of alkaloids across all honey types suggests that the therapeutic properties of these honeys are not related to alkaloid-based mechanisms.

Table 2. Total Phenolic and Flavonoid Content of Honey Samples

Honey Type	Total Phenolic Content (mg GAE/100g)	Total Flavonoid Content (mg QE/100g)
Manuka	92.5 ± 2.3	41.7 ± 1.8

Eucalyptus	87.6 ± 1.9	39.2 ± 2.1
Melaleuca	89.1 ± 2.2	40.5 ± 1.9
Clover	74.3 ± 1.7	30.8 ± 1.5
Acacia	69.2 ± 2.0	27.6 ± 1.2
Buckwheat	91.4 ± 2.5	42.3 ± 2.0
Orange Blossom	76.9 ± 1.8	33.1 ± 1.6

In the quantitative assessment of total phenolic and flavonoid content (Table 2), it is evident that Manuka honey has the highest concentrations of both phenolic compounds (92.5 mg GAE/100g) and flavonoids (41.7 mg QE/100g), followed closely by Buckwheat honey, which contains 91.4 mg of phenolics and 42.3 mg of flavonoids per 100g. These high concentrations are likely contributors to the superior antioxidant and anti-inflammatory activities observed in these honeys, which are critical for both reducing oxidative stress and supporting the healing process. On the other hand, Acacia honey exhibited the lowest concentrations of both phenolics and flavonoids, which might explain its comparatively lower bioactivity in the subsequent assays.

Table 3. Antioxidant Activity (DPPH Assay)

Honey Type	% DPPH Inhibition
Manuka	88.2 ± 1.5
Eucalyptus	82.7 ± 2.0
Melaleuca	85.9 ± 1.8
Clover	73.5 ± 2.3
Acacia	70.1 ± 2.4
Buckwheat	80.3 ± 1.7
Orange Blossom	76.4 ± 2.2

The antioxidant activity, as measured by the DPPH assay (Table 3), shows that all honey types possess significant antioxidant capacity, with Manuka honey again demonstrating the highest inhibition at 88.2%. This suggests that Manuka honey may offer the most robust protection against oxidative stress, a key factor in the prevention of chronic diseases and tissue damage. The Eucalyptus and Melaleuca honeys also exhibited strong antioxidant properties, with inhibition values of 82.7% and 85.9%, respectively. In contrast, Acacia honey showed the lowest antioxidant activity, which aligns with its lower content of phenolic and flavonoid compounds. These findings suggest that honey's antioxidant capacity is closely linked to its phytochemical composition, especially phenolics and flavonoids.

Table 4. Anti-inflammatory Activity (Protein Denaturation Inhibition)

Honey Type	% Inhibition
Manuka	84.3 ± 2.1
Eucalyptus	80.5 ± 1.8
Melaleuca	82.1 ± 1.5
Clover	70.8 ± 2.0
Acacia	68.2 ± 2.1
Buckwheat	75.9 ± 1.9
Orange Blossom	71.5 ± 2.3

The anti-inflammatory activity measured by protein denaturation inhibition (Table 4) indicates that honey's ability to reduce inflammation is largely driven by its phytochemical content. Manuka honey again leads with the highest inhibition (84.3%), suggesting that its unique bioactive compounds, such as methylglyoxal, may be particularly effective in modulating inflammatory pathways. Eucalyptus and Melaleuca honeys also demonstrated strong anti-inflammatory effects, with inhibition percentages of 80.5% and 82.1%, respectively. These results support the hypothesis that honey derived from certain plants, such as Manuka and Melaleuca, may offer more potent anti-inflammatory benefits, making them particularly useful for managing conditions like arthritis, burns, or gastrointestinal disorders. In contrast, honeys with lower phenolic and flavonoid content, like Acacia honey, showed less pronounced anti-inflammatory effects.

Table 5. Wound Healing Activity: % Wound Closure Over Time

Honey Type	Day 4 (%)	Day 8 (%)	Day 12 (%)
Manuka	41.2 ± 2.4	71.6 ± 3.1	91.4 ± 2.7
Eucalyptus	38.5 ± 2.1	68.9 ± 2.9	88.2 ± 2.4
Melaleuca	40.7 ± 2.2	69.8 ± 3.2	89.9 ± 3.1
Clover	32.8 ± 2.0	58.6 ± 2.4	77.6 ± 2.5
Acacia	30.5 ± 2.3	54.2 ± 2.8	75.4 ± 2.8
Buckwheat	43.3 ± 2.5	73.5 ± 3.0	92.1 ± 2.3
Orange Blossom	35.1 ± 2.1	60.4 ± 2.5	79.2 ± 2.9

The wound healing activity (Table 5) results highlight significant differences in the healing potential of the different honey types. Manuka and Buckwheat honeys demonstrated the highest wound closure rates, with Manuka honey achieving 91.4% closure by day 12 and Buckwheat honey following closely with 92.1%. These results suggest that honey types with higher concentrations of phenolics and flavonoids may more effectively promote tissue regeneration and repair. In comparison, honeys such as Acacia and Clover showed slower healing rates, with less than 80% closure by day 12. This data indicates that the biochemical composition of honey—particularly its antioxidant and anti-inflammatory components—plays a crucial role in accelerating wound healing. The high wound healing efficacy of Manuka and Buckwheat honeys further underscores the importance of selecting honey with a robust bioactive profile for therapeutic applications in wound care.

Table 6. Antimicrobial Activity (Zone of Inhibition in mm)

Honey Type	*S. aureus*	*P. aeruginosa*
Manuka	21.4 ± 1.3	19.2 ± 1.1
Eucalyptus	20.6 ± 1.5	18.5 ± 1.3
Melaleuca	21.0 ± 1.4	18.9 ± 1.2
Clover	16.7 ± 1.2	14.2 ± 1.1
Acacia	15.3 ± 1.0	13.5 ± 1.0
Buckwheat	19.8 ± 1.1	17.6 ± 1.2
Orange Blossom	17.2 ± 1.3	15.1 ± 1.0

Lastly, the antimicrobial activity (Table 6) reveals that all honey types exhibit varying degrees of antibacterial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Manuka honey once again outperformed the others, with zones of inhibition of 21.4 mm against *S. aureus* and 19.2 mm against *P. aeruginosa*, likely due to its high methylglyoxal content. Eucalyptus and Melaleuca honeys also demonstrated significant antimicrobial activity, further supporting their use in treating infections. In contrast, honeys like Acacia and Clover showed less potent antimicrobial effects, which may correlate with their lower content of bioactive compounds known to target microbial pathogens.

These findings collectively suggest that honey's phytochemical composition—specifically its concentrations of phenolic compounds, flavonoids, and saponins—directly influences its antioxidant, anti-inflammatory, wound healing, and antimicrobial properties. Honeys such as Manuka and Buckwheat, which contain higher levels of these bioactive compounds, exhibit superior therapeutic activities, making them particularly valuable in both wound care and as natural anti-inflammatory agents.

5. CONCLUSION

This study evaluated the anti-inflammatory and wound healing properties of honey derived from various plant sources, with a focus on its phytochemical composition, antioxidant activity, and effectiveness in promoting tissue regeneration. The results demonstrate that honey from sources such as Manuka and Buckwheat exhibits the most potent therapeutic properties, including high antioxidant and anti-inflammatory activities, along with superior wound healing capabilities. These honeys also showed significant antimicrobial properties, likely due to their elevated concentrations of phenolic compounds, flavonoids, and saponins. Conversely, Acacia and Clover honeys, which contained lower levels of these bioactive compounds, showed less pronounced therapeutic effects. These findings underline the importance of botanical origin in determining honey's medicinal potential, suggesting that honeys from certain plants should be prioritized for use in medical applications. The integration of honey into modern medical treatments for wound care and inflammation management is well-supported by these results, highlighting its potential as a natural, effective alternative to synthetic therapies.

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