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A Review of Methylglyoxal Content and Antioxidant Potential of *Apis cerana* and *Apis dorsata* Honey from Sumbawa for Functional Livestock Products and Veterinary Health

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ABSTRACT

Honey produced by *Apis cerana* and *Apis dorsata* in Sumbawa, Indonesia, is widely recognized for its medicinal value, primarily due to its rich content of *methylglyoxal* (MGO), *phenolic compounds*, and *flavonoids*. These bioactive components contribute to the honey's strong *antioxidant* and *antibacterial* properties, offering potential benefits for improving livestock health. This review explores the MGO concentration and antioxidant activity of both *A. cerana* and *A. dorsata* honey from Sumbawa, while assessing its potential as a functional livestock supplement within the One Health approach. Relevant literature from 2004 to 2025 was systematically reviewed using Scopus, PubMed, and Google Scholar databases. Honey from managed colonies (A. cerana) and wild nests (A. dorsata) was typically analyzed using *HPLC*, *SERS*, or *qNMR* for MGO quantification, while antioxidant potential was measured through *Folin-Ciocalteu*, *aluminum chloride*, *DPPH*, and *FRAP* assays. Findings indicate that *A. cerana* honey shows varying MGO levels influenced by floral sources and location, while studies on *A. dorsata* honey remain limited. Both types demonstrate significant antioxidant activity linked to their phenolic and flavonoid content. Evidence suggests their role in reducing oxidative stress, supporting immune function, and promoting livestock well-being. Overall, Sumbawa honey, especially from *A. cerana*, shows promise as a natural additive for livestock health management, aligning with sustainable agriculture and One Health principles. Further in vivo research is required to validate its therapeutic potential, particularly for *A. dorsata* honey.

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ABSTRAK

Madu yang dihasilkan oleh Apis cerana dan Apis dorsata di Sumbawa, Indonesia, dikenal memiliki khasiat terapeutik yang tinggi. Kandungan methylglyoxal (MGO), senyawa fenolik, dan flavonoid di dalamnya berperan penting dalam memberikan aktivitas antioksidan dan antibakteri yang kuat. Sifat bioaktif ini berpotensi dimanfaatkan untuk meningkatkan kesehatan ternak. Kajian ini bertujuan mengevaluasi kadar MGO dan potensi antioksidan madu A. cerana dan A. dorsata dari Sumbawa, serta menilai potensi penggunaannya sebagai produk fungsional peternakan dalam kerangka One Health. Tinjauan sistematis dilakukan terhadap literatur dari tahun 2004 hingga 2025 menggunakan basis data Scopus, PubMed, dan Google Scholar. Pengumpulan madu umumnya dilakukan dari koloni yang dikelola (A. cerana) atau sarang liar (A. dorsata). Penentuan kadar MGO dilaporkan menggunakan metode HPLC, SERS, atau qNMR, sedangkan aktivitas antioksidan diukur melalui uji Folin-Ciocalteu, aluminum chloride, DPPH, dan FRAP. Hasil menunjukkan bahwa madu A. cerana memiliki kadar MGO yang bervariasi tergantung pada sumber nektar dan kondisi geografis, sementara penelitian mengenai madu A. dorsata masih terbatas. Kedua jenis madu menunjukkan potensi antioksidan yang tinggi akibat kandungan fenolik dan flavonoidnya. Bukti ilmiah menunjukkan madu ini dapat membantu mengurangi stres oksidatif, memperkuat sistem imun, serta mendukung kesehatan ternak. Secara keseluruhan, madu Sumbawa, khususnya dari A. cerana, berpotensi menjadi bahan alami pendukung peternakan berkelanjutan yang sejalan dengan prinsip One Health. Diperlukan penelitian in vivo lebih lanjut untuk membuktikan efektivitas terapeutiknya, terutama pada madu A. dorsata.

INTRODUCTION

Honey is a natural product with significant health benefits for both humans and animals. It has been shown to enhance the biological activity of various body systems, including the cardiovascular, liver, and renal systems, shortly after intake (Ustinova & Ustinov, 2016). Honey's therapeutic properties include antibacterial, antifungal, antiparasitic, anti-inflammatory, immunomodulatory, antioxidant, and anti-osteoporosis effects (Safitri *et al*., 2024). It is also used in wound healing, stress relief, and the treatment of digestive and respiratory diseases (Wilczyńska & Żak, 2024). Honey from *Apis cerana* and *Apis dorsata*, particularly from Sumbawa, Indonesia, is noted for its bioactive potential. Apis cerana honey has demonstrated hepatoprotective activity, significantly alleviating liver injury in animal models (Zhao *et al*., 2018). Apis dorsata honey, on the other hand, is rich in bioactive compounds such as alkaloids, flavonoids, saponins, tannins, steroids, and triterpenoids, which contribute to its antioxidant and anticancer properties (Semuel *et al*., 2019). Additionally, honey hunting in Sumbawa is economically significant, supporting rural livelihoods (Al Hasan *et al*., 2025; Schouten *et al*., 2020).

Methylglyoxal (MGO) is a critical bioactive compound in honey, particularly known for its antibacterial properties. It is the dominant antibacterial component in Manuka honey, with concentrations above 150 mg/kg being directly responsible for its antibacterial activity (Atrott & Henle, 2009). MGO has been shown to inhibit the growth of various bacteria, including multidrug-resistant strains (Fidaleo *et al*., 2010; Hayashi *et al*., 2014). The presence of MGO in honey can be a marker for its unique bioactivity (Atrott & Henle, 2009; Sultanbawa

et al., 2015). Despite the known benefits of honey, there is limited research on the specific properties and bioactive compounds of Indonesian local honey, particularly from Sumbawa. This gap includes a lack of detailed studies on the chemical composition, bioactive potential, and therapeutic applications of these honeys (Al Hasan *et al*., 2025; Schouten *et al*., 2020). More research is needed to fully understand and utilize the medicinal properties of Sumbawa honey.

The primary objectives of this review are to critically synthesize existing evidence on the bioactive compounds and therapeutic properties of *Apis cerana* and *Apis dorsata* honey from Sumbawa, with particular emphasis on the contribution of methylglyoxal (MGO) to their antibacterial activity. Although numerous studies have documented the antioxidant and antimicrobial properties of honey from various geographical origins, comprehensive and integrative information regarding the chemical composition, MGO content, and bioactive profiles of Sumbawa honey especially from *Apis cerana* and *Apis dorsata* remains limited and fragmented in the literature. This review addresses this knowledge gap by compiling, comparing, and evaluating available findings to provide a coherent overview of the chemical and biofunctional characteristics of Sumbawa honey. The significance of this review lies in its potential to advance current understanding of the medicinal value of Sumbawa honey, inform its prospective application in therapeutic and veterinary contexts, and support sustainable honey production systems that may contribute to local economic development.

METHOD

This systematic review was conducted in accordance with the PRISMA 2020 guidelines. A comprehensive literature search was carried out using the Scopus, PubMed, and Google Scholar databases to identify relevant studies published between 2004 and 2025. The search strategy employed combinations of the keywords "*Apis cerana* honey," "*Apis dorsata* honey," "methylglyoxal," "antioxidant activity," and "livestock health." The study selection process followed the PRISMA framework, including identification, screening, eligibility, and inclusion stages, which are summarized in a PRISMA flow diagram.

Peer-reviewed original research articles were considered eligible if they reported quantitative or qualitative data on methylglyoxal (MGO) concentration, phenolic or flavonoid content, antioxidant activity, or functional applications of honey in veterinary or livestock-related contexts. Included studies were further classified based on study design, comprising *in vitro* assays (e.g., antioxidant and antimicrobial evaluations), *in vivo* experimental studies (laboratory or livestock-based), and applied or field-oriented studies related to animal health or production systems. Review articles, conference abstracts, and non-English publications were excluded.

Following title and abstract screening, full-text assessments were performed to ensure compliance with the inclusion criteria. A total of 49 studies were ultimately included in the final qualitative synthesis. Data extracted from the selected studies included honey origin, bee species, analytical methods, MGO levels,

bioactive compound profiles, antioxidant assays, and reported implications for veterinary or livestock applications. While the primary focus of this review was honey originating from Indonesia, particularly Sumbawa, studies from other geographical regions were also included for comparative purposes when they provided relevant biochemical or functional insights. All extracted data were synthesized and compared narratively to highlight patterns, consistencies, and remaining knowledge gaps.

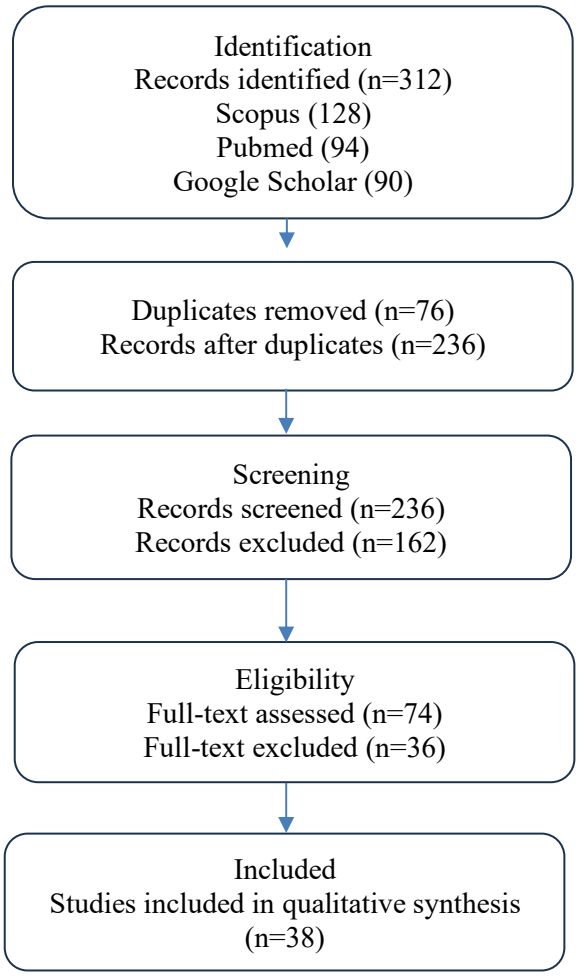


Figure 1. PRISMA 2020 flow diagram depicting the study selection process, from identification and screening to eligibility assessment and final inclusion, resulting in 38 studies included in the qualitative synthesis

RESULTS AND DISCUSSION

Methylglyoxal Content in *Apis cerana* and *Apis dorsata* Honey

Apis cerana, methylglyoxal (MGO) content in *Apis cerana* honey varies significantly based on geographical origin (Table 1) (Figure 1). The highest MGO concentration was found in honey from BHBC, followed by Membatu Laut, Kudat, and Ulu Kiulu, Tuaran (Hasbullah *et al.*, 2024). Apis dorsata: There is no specific data on MGO content in *Apis dorsata* honey from the provided abstracts.

Total Phenolic and Flavonoid Content

Apis cerana total phenolic content (TPC) and total flavonoid content (TFC) in Apis

cerana honey from Qiongzhong region were 45.46 mg GAE/100 g and 10.02 mg RE/100 g, respectively (Wu *et al*., 2022). Another study indicated that the phenolic content ranged from 4.46 to 15.04 mg GAE/100 g (Socha *et al*., 2011). *Apis dorsata* TPC and TFC in Apis dorsata honey from China were higher compared to common Apis cerana and Apis mellifera honey, with significant differences among samples (Cao *et al*., 2021). The phenolic content in Apis dorsata honey was also noted to be higher than in Apis cerana honey (Wu *et al*., 2020) (Table 1) (Figure 1).

Antioxidant Activity Profiles

Apis *cerana* antioxidant activity of Apis cerana honey is significantly correlated with its phenolic and flavonoid content (Table 1) (Figure 2). The antiradical activity (DPPH IC50) was 2.63 mg/mL, indicating strong antioxidant properties (Wu *et al*., 2022). Another study showed a significant correlation between antioxidant activity and polyphenol content (Hasbullah *et al*., 2024). *Apis dorsata* honey exhibited high antioxidant activity, which is closely related to its high phenolic content. The antioxidant activity varied significantly among samples, with a strong correlation to phenolic and flavonoid contents (Cao *et al*., 2021).

Importance of MGO in Honey Bioactivity

MGO is the dominant bioactive compound in Manuka honey, responsible for its antibacterial properties (Atrott & Henle, 2009; Degen *et al*., 2013; Fidaleo *et al*., 2010; Hayashi *et al*., 2014; Stephens *et al*., 2015; Terio *et al*., 2021; Windsor *et al*., 2012). MGO levels in Manuka honey can range from 189 to 835 mg/kg, correlating directly with antibacterial activity (Atrott & Henle, 2009; Sultanbawa *et al*., 2015). MGO inhibits the growth of multidrug-resistant bacteria such as Pseudomonas aeruginosa (Hayashi *et al*., 2014) (Table 2).

Antioxidant and Antiaging Potential for Livestock Health

Honey, including varieties rich in MGO, exhibits strong antioxidant properties, which can help mitigate oxidative stress and inflammation (Ahmed *et al*., 2018; Hilary *et al*., 2017; Kishore *et al*., 2011; Miguel *et al*., 2017; Terzo *et al*., 2020). Antioxidants in honey can protect against age-related diseases and improve overall health by scavenging free radicals (Alzahrani *et al*., 2012; Wilczyńska & Żak, 2024). Honey's antioxidant activity is influenced by its botanical origin, with Manuka honey showing high phenolic content and strong antioxidant potential (Alzahrani *et al*., 2012) (Table 2).

Implications for Functional Livestock Products

Honey's bioactive properties, including its antibacterial and antioxidant effects, can be leveraged to develop functional livestock products that promote health and prevent diseases (Ahmed *et al*., 2018; Choi, 2021; Kuropatnicki *et al*., 2018). Honey can be used as a natural supplement to enhance livestock health, potentially reducing the need for synthetic antibiotics and promoting sustainable farming practices (Ahmed *et al*., 2018; Choi, 2021; Kuropatnicki *et al*., 2018) (Table 2).

One Health Perspective: Animal, Human, and Environmental Health

The One Health approach emphasizes the interconnectedness of human, animal, and environmental health, with honeybees playing a crucial role in this framework (Kniel *et al.*, 2018; López-Casas *et al.*, 2024; Mair *et al.*, 2023; Prata & Martins da Costa, 2024; López-Uribe *et al.*, 2020; Malhi *et al.*, 2020; Vithanage & Prasad, 2023; Wilfert *et al.*, 2021). Protecting bee health through sustainable practices can indirectly benefit human and environmental health, highlighting the importance of bees in the One Health model (López-Uribe *et al.*, 2020; Mair *et al.*, 2023; Prata & Martins da Costa, 2024; Wilfert *et al.*, 2021) (Table 2).

Table 1. Methylglyoxal (MGO) Content in *Apis cerana* and *Apis dorsata* Honey from Different Geographical Origins

Parameter	*Apis cerana*	*Apis dorsata*
MGO Content	Highest in BHBC, followed by Membatu Laut, Kudat, and Ulu Kiulu, Tuaran (Hasbullah *et al.*, 2024)	No specific data available
Total Phenolic Content	45.46 mg GAE/100 g; (Wu *et al.*, 2022) 4.46 to 15.04 mg GAE/100 g (Socha *et al.*, 2011)	Higher than *Apis cerana* and *Apis mellifera* honey (Cao *et al.*, 2021)
Total Flavonoid Content	10.02 mg RE/100 g (Wu *et al.*, 2022)	Higher than *Apis cerana* and *Apis mellifera* honey (Cao *et al.*, 2021)
Antioxidant Activity	Strong correlation with phenolic and flavonoid content; DPPH IC50 = 2.63 mg/mL (Wu *et al.*, 2022)	High antioxidant activity, correlated with phenolic and flavonoid contents (Cao *et al.*, 2021)

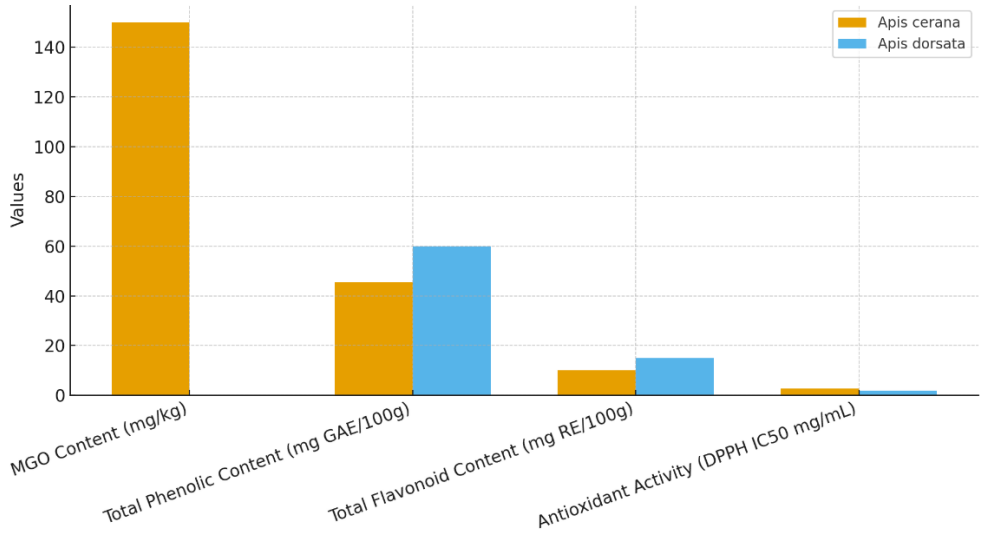


Figure 2. Comparison of MGO, phenolic, flavonoid content, and antioxidant activity in *Apis cerana* and *Apis dorsata* honey

Table 2. Overview of MGO, Antioxidant Potential, Functional Livestock Products, and One Health Perspectives from Honey Research

Aspect	Details
MGO in Honey	Dominant antibacterial compound in Manuka honey
Antioxidant Potential	Strong antioxidant properties, mitigates oxidative stress
Functional Livestock Products	Enhances health, reduces need for synthetic antibiotics
One Health Perspective	Interconnectedness of human, animal, and environmental health
Comparison with Previous Studies	Consistent findings on MGO and antioxidant properties

Comparative Insights: MGO, Phenolic, and Antioxidant Profiles

The data summarized in Table 1 reveal clear differences in the MGO, *phenolic*, and *antioxidant* profiles of *Apis cerana* and *Apis dorsata* honey. While measurable MGO levels are evident in *A. cerana* honey and vary across regions, equivalent data for A. dorsata honey is lacking, indicating a significant research gap. Conversely, *A. dorsata* honey consistently exhibits higher TPC and TFC, likely contributing to its superior antioxidant activity. These findings imply that A. cerana honey may be more valuable for its antibacterial activity related to MGO, while *A. dorsata* honey could be a richer source of antioxidant compounds. Figure 1 further illustrates the relative distribution of MGO, phenolic, and flavonoid content, as well as antioxidant activity, between the two honey types. This graphical comparison emphasizes the complementary strengths of *A. cerana* (antibacterial potential via MGO) and *A. dorsata* (antioxidant potential via phenolic and flavonoid compounds). Together, they may provide synergistic benefits when used in functional livestock formulations.

Integrative Perspective on Honey Applications

A broader synthesis of findings is presented in Table 2, which integrates MGO bioactivity, antioxidant potential, livestock applications, and One Health implications. This overview shows that honey is a nutritional product and a functional agent that can address livestock health issues. Its potential to act as a natural antibiotic substitute, coupled with its antioxidant properties, aligns with sustainable animal production strategies. From a One Health standpoint, sustainably using bee products like honey extends beyond animal health benefits. Protecting bee populations through sustainable apiculture directly supports pollination services, biodiversity, and human food security. Therefore, the use of *A. cerana* and *A. dorsata* honey in livestock production can be viewed as part of a holistic health strategy that unites environmental, animal, and human well-being.

CONCLUSION AND RECOMMENDATIONS

This review confirms that *Apis cerana* and *Apis dorsata* honey from Sumbawa possess distinct bioactive profiles relevant to livestock applications. *Apis dorsata* honey is more strongly associated with methylglyoxal (MGO)

content and antibacterial activity, whereas *Apis cerana* honey demonstrates higher phenolic and flavonoid contents, contributing to superior antioxidant capacity. In line with the purpose of this review, these findings emphasize the complementary roles of MGO and antioxidants in supporting livestock health. The underrepresentation of MGO-focused studies in Indonesian honeys, particularly *Apis dorsata*, highlights a clear research gap compared with Manuka honey. Practically, Sumbawa honey shows promise as a functional feed additive, an immune-support supplement, and a natural alternative to synthetic antibiotics within sustainable livestock systems. Future studies should prioritize standardized sampling and *in vivo* livestock trials to validate its efficacy within a One Health framework.

CONTRIBUTIONS STATEMENTS

RA: conceptualization (lead); data curation (lead). IK: formal analysis (lead); funding acquisition (lead). AM: investigation (lead); methodology (lead). ZA: project administration (lead); resources (lead); software (lead). IGNS: supervision (lead); validation (lead); visualization (lead). LKW: writing original draft preparation (lead). RA, IK, AM, ZA, IGNS, LKW: writing–review and editing (lead).

REFERENCES

Ahmed, S., Sulaiman, S. A., Baig, A. A., Ibrahim, M., Liaqat, S., Fatima, S., Jabeen, S., Shamim, N., & Othman, N. H. (2018). Honey as a potential natural antioxidant medicine: an insight into its molecular mechanisms of action. *Oxidative Medicine and Cellular Longevity*, *2018*(1), 8367846. https://doi.org/10.1155/2018/8367846

Al Hasan, R., Wahyono, E., Wicaksono, A., Agustine, R., Ishak, A., & Manan, A. (2025). Income contribution from forest honey: digital era opportunities for economic and environmental sustainability in Sumbawa. *IOP Conference Series: Earth and Environmental Science*, *1438*(1), 12033. https://doi.org/10.1088/1755-1315/1438/1/012033

Alzahrani, H. A., Boukraâ, L., Bellik, Y., Abdellah, F., Bakhotmah, B. A., Kolayli, S., & Sahin, H. (2012). Evaluation of the antioxidant activity of three varieties of honey from different botanical and geographical origins. *Global Journal of Health Science*, *4*(6), 191-196. https://doi.org/10.5539/gjhs.v4n6p191

Atrott, J., & Henle, T. (2009). Methylglyoxal in manuka honey–correlation with antibacterial properties. *Czech J. Food Sci.*, *27*(1), S163-S165. https://doi.org/10.17221/911-CJFS

Cao, L., He, C., & Sun, Y. (2021). Physicochemical and antioxidant properties of honeys produced by Apis dorsata and Apis laboriosa. *Food and Fermentation Industries*, 47(9), 262-267. https://www.cabidigitallibrary.org/doi/full/10.5555/20210265243

Choi, J.-S. (2021). Nutrition, safety, health functional effects, and availability of honeybee (Apis mellifera L.) Drone Pupae. *Insects*, *12*(9), 771, 1-15. https://doi.org/10.3390/insects12090771

Degen, J., Vogel, M., Richter, D., Hellwig, M., & Henle, T. (2013). Metabolic transit of dietary methylglyoxal. *Journal of Agricultural and Food Chemistry*, *61*(43), 10253–10260. https://doi.org/10.1021/jf304946p

Fidaleo, M., Zuorro, A., & Lavecchia, R. (2010). Methylglyoxal: a new weapon against staphylococcal wound infections? *Chemistry Letters*, *39*(4), 322–323. https://doi.org/10.1246/cl.2010.322

Hasbullah, M. I. J. J., Binjamin, B., Ador, K., Gobilik, J., Seung, C. C. F., Sam, L. M., Yaakub, N. M., Choon, J. L. N., & Benedick, S. (2024). Volatile organic compounds (vocs), dihydroxyacetone (DHA) and methylglyoxal (MGO) in tropical multifloral honey (apidae; apis cerana) from sites of different geographical origin in sabah, borneo. *Malaysian Journal of Biochemistry and Molecular Biology*, *27*(2), 1–15. https://doi.org/10.1016/j.ecolind.2026.114910

Hayashi, K., Fukushima, A., Hayashi-Nishino, M., & Nishino, K. (2014). Effect of methylglyoxal on multidrug-resistant Pseudomonas aeruginosa. *Frontiers in Microbiology*, *5*, 180, 1-16. https://doi.org/10.3389/fmicb.2014.00180

Hilary, S., Habib, H., Souka, U., Ibrahim, W., & Platat, C. (2017). Bioactivity of arid region honey: an in vitro study. *BMC Complementary and Alternative Medicine*, *17*(1), 177, 1-10. https://doi.org/10.1186/s12906-017-1664-9

Kishore, R. K., Halim, A. S., Syazana, M. S. N., & Sirajudeen, K. N. S. (2011). Tualang honey has higher phenolic content and greater radical scavenging activity compared with other honey sources. *Nutrition Research*, *31*(4), 322–325. https://doi.org/10.1016/j.nutres.2011.03.001

Kniel, K. E., Kumar, D., & Thakur, S. (2018). Understanding the complexities of food safety using a “One Health” approach. *Preharvest Food Safety*, 401–411. https://doi.org/10.1128/9781555819644.ch22

Kuropatnicki, A. K., Kłósek, M., & Kucharzewski, M. (2018). Honey as medicine: historical perspectives. *Journal of Apicultural Research*, *57*(1), 113–118. https://doi.org/10.1080/00218839.2017.1411182

López-Casas, S., Ávila-Vargas, L., Jiménez, N., & González, J. (2024). Prioritizing the health of aquatic ecosystems to ensure human and biodiversity health. *Acta Biol Colomb,* 29(3), 22-25. https://doi.org/10.15446/abc.v29n3.117023

López-Uribe, M. M., Ricigliano, V. A., & Simone-Finstrom, M. (2020). Defining pollinator health: a holistic approach based on ecological, genetic, and physiological factors. *Annual Review of Animal Biosciences*, *8*(1), 269–294. https://doi.org/10.1146/annurev-animal-020518-115045

Mair, K. S., Irrgeher, J., & Haluza, D. (2023). Elucidating the role of honey bees as biomonitors in environmental health research. *Insects*, *14*(11), 874, 1-17. https://doi.org/10.3390/insects14110874

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: threats, opportunities and solutions. In *Philosophical transactions of the Royal Society B*., 375(1794), 20190104). The Royal Society. https://doi.org/10.1098/rstb.2019.0104

Miguel, M. G., Antunes, M. D., & Faleiro, M. L. (2017). Honey as a complementary medicine. *Integrative Medicine Insights*, *12*, 1178633717702869. https://doi.org/10.1177/1178633717702869

Prata, J. C., & Martins da Costa, P. (2024). Honeybees and the one health approach. *Environments*, *11*(8), 161, 1-16. https://doi.org/10.3390/environments11080161

Safitri, E., Purnobasuki, H., Al-Anshori, A. A., Lestari, T. D., Utama, S., & Yimer, N. (2024). Honey-derived phytochemicals: Implications for stem cell activation and health benefits. *Journal of Functional Foods*, *114*, 106058. https://doi.org/10.1016/j.jff.2024.106058

Schouten, C., Lloyd, D., Ansharyani, I., Salminah, M., Somerville, D., & Stimpson, K. (2020). The role of honey

hunting in supporting subsistence livelihoods in Sumbawa, Indonesia. *Geographical Research*, *58*(1), 64–76. https://doi.org/10.1111/1745-5871.12380

Semuel, M. Y., Kaunang, E. S. N., & Manopo, J. S. (2019). The bioactive contents and antioxidant activity of honey bee nest extract of Apis dorsata Binghami from the North Sulawesi. *Molekul*, *14*(2), 92–102. http://dx.doi.org/10.20884/1.jm.2019.14.2.502

Socha, R., Juszczak, L., Pietrzyk, S., Gałkowska, D., Fortuna, T., & Witczak, T. (2011). Phenolic profile and antioxidant properties of Polish honeys. *International Journal of Food Science and Technology*, *46*(3), 528–534. https://doi.org/10.1111/j.1365-2621.2010.02517.x

Stephens, J. M., Greenwood, D. R., Fearnley, L., Bong, J., Schlothauer, R. C., & Loomes, K. M. (2015). Honey production and compositional parameters. In *Processing and impact on active components in food* (pp. 675–680). Elsevier. https://doi.org/10.1016/B978-0-12-404699-3.00081-0

Sultanbawa, Y., Cozzolino, D., Fuller, S., Cusack, A., Currie, M., & Smyth, H. (2015). Infrared spectroscopy as a rapid tool to detect methylglyoxal and antibacterial activity in Australian honeys. *Food Chemistry*, *172*, 207–212. https://doi.org/10.1016/j.foodchem.2014.09.067

Terio, V., Bozzo, G., Ceci, E., Savarino, A. E., Barrasso, R., Di Pinto, A., Mottola, A., Marchetti, P., Tantillo, G., & Bonerba, E. (2021). Methylglyoxal (MGO) in Italian Honey. *Applied Sciences*, *11*(2), 831, 1-15. https://doi.org/10.3390/app11020831

Terzo, S., Mulè, F., & Amato, A. (2020). Honey and obesity-related dysfunctions: A summary on health benefits. *The Journal of Nutritional Biochemistry*, *82*, 108401. https://doi.org/10.1016/j.jnutbio.2020.108401

Ustinova, O. I., & Ustinov, Y. V. (2016). Biological activity of honey as natural health product. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, *7*(1), 1032–1038. https://www.researchgate.net/publication/292464534_Biological_activity_of_honey_as_natural_health_product

Vithanage, M., & Prasad, M. N. V. (2023). *One Health: Human, Animal, and Environment Triad*. John Wiley & Sons. pp. *87-93. https://books.google.co.id/books?hl=id&lr=&id=-WfFEAAAQBAJ&oi=fnd&pg=PA22&dq=Vithanage,+M.,+%26+Prasad,+M.+N.+V.+(2023).+One+Health:+Human,+Animal,+and+Environment+Triad.+John+Wiley+%26+Sons.+pp.+87-93.&ots=O7OxVd85KV&sig=P-NTgv2-ToEQ0UYIksK2V-1PHPs&redir_esc=y#v=onepage&q&f=false*

Wilczyńska, A., & Żak, N. (2024). Polyphenols as the main compounds influencing the antioxidant effect of honey—A review. *International Journal of Molecular Sciences*, *25*(19), 10606. https://doi.org/10.3390/ijms251910606

Wilfert, L., Brown, M. J. F., & Doublet, V. (2021). OneHealth implications of infectious diseases of wild and managed bees. *Journal of Invertebrate Pathology*, *186*, 107506. https://doi.org/10.1016/j.jip.2020.107506

Windsor, S., Pappalardo, M., Brooks, P. R., Williams, S., & Manley-Harris, M. (2012). A convenient new analysis of dihydroxyacetone and methylglyoxal applied to Australian Leptospermum honeys. *Journal of Pharmacognosy and Phytotherapy*, *4*(1), 6–11. https://doi.org/10.5897/JPP11.025

Wu, J., Duan, Y., Gao, Z., Yang, X., Zhao, D., Gao, J., Han, W., Li, G., & Wang, S. (2020). Quality comparison of multifloral honeys produced by Apis

cerana cerana, Apis dorsata and Lepidotrigona flavibasis. *Lwt*, *134*, 110225. https://doi.org/10.1016/j.lwt.2020.110225

Wu, J., Zhao, S., Chen, X., Jiu, Y., Liu, J., Gao, J., & Wang, S. (2022). Physicochemical parameters, multi-elemental composition and antiradical activity of multifloral honeys from Apis cerana cerana in Hainan province, China. *Food Science and Technology*, *42*, e22522. https://doi.org/10.1590/fst.22522

Zhao, H., Cheng, N., He, L., Peng, G., Liu, Q., Ma, T., & Cao, W. (2018). Hepatoprotective effects of the honey of apis cerana fabricius on bromobenzene-induced liver damage in mice. *Journal of Food Science*, *83*(2), 509–516. https://doi.org/10.1111/1750-3841.14021