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Exploring the Antioxidant Potential of Medicinal Plant Species: A Comprehensive Investigative Review

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ABSTRACT

Medicinal plants are esteemed for their therapeutic attributes, including their emerging role as potent antioxidants. This review consolidates contemporary research on the antioxidant capacities inherent in various medicinal plant species. Through meticulous scrutiny of scientific literature, the review elucidates the mechanisms that underpin the antioxidant activities of these plants and investigates their potential applications in healthcare and disease prevention. Key revelations encompass the diverse antioxidant compounds present in medicinal plants, their modes of action, and their ramifications for human health. Moreover, the review identifies gaps in current understanding and recommends future research directions to advance the field of botanical medicine. In the realm of natural remedies, medicinal plants have garnered attention not only for their therapeutic properties but also for their antioxidant potential. This review offers a comprehensive synthesis of contemporary research on the antioxidant capacities exhibited by various medicinal plant species. Through an exhaustive analysis of scientific literature, it delves into the mechanisms underpinning the antioxidant activities of these plants while exploring their prospective applications in healthcare and disease prevention. Key insights highlight the diverse antioxidant compounds found within medicinal plants, their intricate modes of action, and their implications for human health. Furthermore, the review underscores existing knowledge gaps and proposes avenues for future research to propel advancements in botanical medicine.

Keywords: *Antioxidants, Medicinal Plants, Phytochemicals, Free Radicals, Health Benefits.*

Introduction

Medicinal plants have been utilized for centuries in traditional medicine systems worldwide due to their diverse therapeutic properties. Among these properties, the antioxidant potential of medicinal plants has garnered significant attention in recent years [1]. Antioxidants play a crucial role in neutralizing harmful free radicals and oxidative stress, which are implicated in various chronic diseases, including cardiovascular diseases, cancer, and neurodegenerative disorders. As interest in natural remedies and preventive healthcare grows, understanding the antioxidant capacities of medicinal plants becomes increasingly important. This comprehensive investigative review aims to examine the current state of knowledge regarding the antioxidant potential of medicinal plant species [2]. By synthesizing and critically analyzing existing research, this review seeks to provide insights into the mechanisms underlying the antioxidant activities of these plants and their potential health benefits. Medicinal plants have played a pivotal role in traditional medicine systems for centuries, offering remedies for various ailments and health conditions [3]. Their significance transcends cultural and geographical boundaries, with diverse plant species harboring bioactive compounds that contribute to their therapeutic properties. Among these compounds, antioxidants have emerged as particularly noteworthy due to their potential to counteract oxidative stress and its associated health implications.

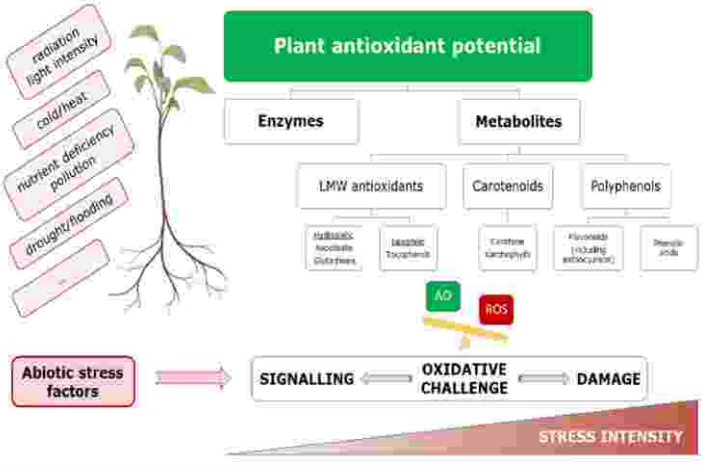

Figure 1 illustrates the importance of plant antioxidant potential in maintaining the cellular redox balance to counteract abiotic stress factors. Antioxidants (AO) scavenge reactive oxygen species (ROS), preserving cellular integrity and enhancing plant resilience to environmental challenges. Understanding the dynamics of antioxidant-ROS interactions is critical for elucidating plant stress responses and developing strategies to enhance plant adaptation and survival in changing environments. AO = Antioxidants; ROS = Reactive Oxygen Species adbopted from [1] and copyright permission from MDPI

Oxidative stress, resulting from an imbalance between reactive oxygen species (ROS) production and the body's antioxidant defense mechanisms, is implicated in the pathogenesis of numerous chronic diseases, including cardiovascular disorders, cancer, diabetes, and neurodegenerative conditions [4].

In recent years, there has been a surge of interest in exploring natural sources of antioxidants, including medicinal plants, as potential preventive and therapeutic agents against oxidative damage. The exploration of the antioxidant potential of medicinal plants represents a burgeoning field of research, driven by both traditional knowledge and modern scientific inquiry. While traditional medicine has long recognized the healing properties of plants, contemporary scientific studies have sought to elucidate the biochemical mechanisms underlying their therapeutic effects, including antioxidant activities. This introduction sets the stage for a comprehensive investigation into the antioxidant potential of medicinal plant species [5]. By synthesizing existing knowledge and highlighting gaps in understanding, this review aims to contribute to the collective understanding of the therapeutic value of medicinal plants in combating oxidative stress and promoting human health.

Key objectives of this review include:

- Surveying current research on the antioxidant capacities of various medicinal plant species.
- Exploring the mechanisms underlying the antioxidant activities of medicinal plants at the molecular level.
- Assessing the potential applications of medicinal plant antioxidants in healthcare and disease prevention.
- Identifying areas for further research and development to enhance our understanding of the antioxidant potential of medicinal plants.

Through an interdisciplinary approach that integrates traditional wisdom with modern scientific methodologies, this review seeks to shed light on the multifaceted role of medicinal plants as sources of natural antioxidants. By doing so, it aims to contribute to the growing body of knowledge in botanical medicine and promote the exploration of sustainable and holistic approaches to health and wellness [6]. As we embark on this journey of exploration, it becomes evident that unlocking the antioxidant potential of medicinal plants holds promise for addressing contemporary health challenges and advancing the frontiers of integrative medicine [7].

Antioxidant Compounds in Medicinal Plants: Medicinal plants harbor a rich array of bioactive compounds, many of which exhibit antioxidant properties. Phenolic compounds, such as flavonoids, phenolic acids, and tannins, are among the most abundant antioxidants found in plants. These compounds scavenge free radicals, chelate metal ions, and inhibit oxidative enzymes, thereby mitigating oxidative damage to cells and tissues [8]. Medicinal plants are reservoirs of diverse bioactive compounds, many of which exhibit antioxidant properties. Among the most prominent antioxidant compounds found in medicinal plants are phenolic compounds, including flavonoids, phenolic acids, and tannins. These phenolic compounds are renowned for their ability to scavenge free radicals, chelate metal ions, and inhibit oxidative enzymes, thereby mitigating oxidative damage to cellular components [9]. Flavonoids, such as quercetin, kaempferol, and catechins, are ubiquitous in medicinal plants and are recognized for their potent antioxidant activities. These compounds possess multiple hydroxyl groups on their phenolic rings, enabling them to donate electrons and neutralize free radicals, thereby protecting cells from oxidative stress-induced damage. Phenolic acids, including ferulic acid, gallic acid, and caffeic acid, are also prevalent in medicinal plants and contribute to their antioxidant capacity [10]. These compounds exert antioxidant effects by scavenging reactive oxygen species (ROS), inhibiting lipid peroxidation, and modulating redox-sensitive signaling pathways implicated in cellular homeostasis.

Tannins, another class of phenolic compounds, are characterized by their ability to form complexes with proteins and other macromolecules, thereby exerting antioxidant and astringent properties [11]. Through their metal-chelating activities and free radical scavenging abilities, tannins contribute to the overall antioxidant defense system of medicinal plants. Apart from phenolic compounds, medicinal plants contain other antioxidant constituents, including carotenoids, tocopherols, and alkaloids. Carotenoids, such as β-carotene and lycopene, serve as lipid-soluble antioxidants that protect cell membranes and lipoproteins from oxidative damage. Tocopherols, particularly α-tocopherol, are potent scavengers of lipid peroxyl radicals, thereby preventing lipid oxidation and preserving membrane integrity [12].

Alkaloids, a diverse group of nitrogen-containing compounds, exhibit antioxidant properties by virtue of their radical-scavenging and metal-chelating activities. Examples of alkaloids with antioxidant potential include berberine, caffeine, and quinoline alkaloids, which contribute to the overall antioxidant profile of medicinal plants [13]. The synergistic interactions among these antioxidant compounds in medicinal plants amplify their collective antioxidant capacity, thereby conferring robust protection against oxidative stress-induced damage. Furthermore, the abundance and diversity of antioxidant compounds in medicinal plants underscore their potential as valuable sources of natural antioxidants for therapeutic and nutritional applications. Understanding the repertoire of antioxidant compounds present in medicinal plants is crucial for harnessing their full therapeutic potential and developing innovative strategies for combating oxidative stress-related disorders. By elucidating the chemical composition and biological activities of these compounds, researchers can identify novel antioxidant agents and formulate evidence-based interventions for promoting human health and well-being [14].

Mechanisms of Antioxidant Action

The antioxidant activities of medicinal plants are mediated through various mechanisms, including free radical scavenging, metal chelation, and modulation of antioxidant enzyme activities. By donating electrons or hydrogen atoms, antioxidant compounds neutralize reactive oxygen species (ROS) and prevent lipid peroxidation, protein oxidation, and DNA damage. Moreover, medicinal plant antioxidants exert protective effects against oxidative stress by enhancing endogenous antioxidant defense systems [16]. These include the upregulation of enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), which counteract ROS generation and maintain cellular redox homeostasis. The antioxidant actions of medicinal plants are mediated through a variety of mechanisms that help neutralize reactive oxygen species (ROS) and mitigate oxidative stress. Understanding these mechanisms is crucial for comprehending the therapeutic potential of medicinal plants in preventing and treating oxidative stress-related disorders. Some key mechanisms of antioxidant action include:

1. Free Radical Scavenging: Antioxidant compounds present in medicinal plants, such as phenolic compounds and carotenoids, act as electron donors, effectively neutralizing free

radicals and preventing oxidative damage to cellular components. By donating electrons to reactive oxygen species (ROS) and reactive nitrogen species (RNS), antioxidants stabilize these highly reactive molecules, thereby inhibiting chain reactions of lipid peroxidation, protein oxidation, and DNA damage [17].

2. Metal Chelation: Some antioxidants have the ability to chelate transition metal ions, such as iron and copper, which catalyze the generation of highly reactive hydroxyl radicals through Fenton and Haber-Weiss reactions. By sequestering these metal ions, antioxidants prevent the formation of hydroxyl radicals and mitigate oxidative stress-induced damage to biomolecules [18].

3. Enzyme Modulation: Antioxidants found in medicinal plants can modulate the activity of endogenous antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). These enzymes play critical roles in scavenging ROS and maintaining cellular redox balance. Antioxidants may upregulate the expression or activity of these enzymes, thereby enhancing the cellular defense mechanisms against oxidative stress [19].

4. Singlet Oxygen Quenching: Certain antioxidants possess the ability to quench singlet oxygen, a highly reactive form of oxygen generated during photosensitization reactions and oxidative stress. Antioxidants with singlet oxygen quenching properties, such as tocopherols and carotenoids, intercept singlet oxygen molecules and convert them into less harmful species, thereby protecting cells from oxidative damage [20].

5. Modulation of Signaling Pathways: Antioxidants derived from medicinal plants can modulate intracellular signaling pathways involved in oxidative stress response and inflammation. By inhibiting pro-inflammatory transcription factors, such as nuclear factor-kappa B (NF-κB), and activating antioxidant response elements (ARE), antioxidants exert anti-inflammatory and cytoprotective effects, thereby attenuating oxidative stress-mediated tissue injury [21].

6. Preservation of Membrane Integrity: Lipid-soluble antioxidants, including tocopherols and carotenoids, play a crucial role in preserving membrane integrity and fluidity by preventing lipid peroxidation. By scavenging lipid peroxyl radicals and stabilizing lipid bilayers, these antioxidants protect cellular membranes from oxidative damage and maintain cellular homeostasis. Overall, the diverse mechanisms of antioxidant action exhibited by medicinal plant compounds underscore their potential therapeutic utility in combating oxidative stress-related diseases and promoting overall health and well-being [22]. By elucidating these mechanisms, researchers can identify novel antioxidant agents from medicinal plants and develop targeted interventions for mitigating oxidative stress and its associated pathologies.

Health Implications and Potential Applications:
The antioxidant properties of medicinal plants have significant implications for human health and disease prevention. Epidemiological studies suggest that diets rich in plant-based antioxidants are associated with reduced risks of chronic diseases, including cardiovascular disorders, cancer, and age-related conditions emerging research highlights the potential the rapeutic applications of medicinal plant antioxidants in the management of oxidative stress-related disorders. Herbal extracts and phytochemical-rich formulations derived from medicinal plants show promise as adjunctive therapies for combating oxidative damage and mitigating disease progression [23].

Health Implications and Potential Applications:
The antioxidant properties of medicinal plants have profound implications for human health and offer a wide array of potential applications in preventive healthcare and disease management. Understanding the health implications of medicinal plant antioxidants is instrumental in harnessing their therapeutic potential and promoting their integration into holistic approaches to wellness. Some key health implications and potential applications include:

1. Disease Prevention: Oxidative stress is implicated in the pathogenesis of various chronic diseases, including cardiovascular disorders, cancer, diabetes, neurodegenerative diseases, and inflammatory conditions. The antioxidant compounds present in medicinal plants offer protective effects against oxidative damage to cells, tissues, and organs, thereby reducing the risk of developing these debilitating diseases.

2. Anti-Aging Effects: Oxidative stress is a major contributor to the aging process, leading to cellular damage, tissue degeneration, and functional decline. Medicinal plant antioxidants help counteract the effects of oxidative stress by scavenging free radicals, preserving cellular integrity, and promoting cellular repair mechanisms. By mitigating oxidative damage, medicinal plant antioxidants may contribute to healthy aging and longevity.

3. Immune Enhancement: Oxidative stress compromises immune function and increases susceptibility to infections and diseases. The antioxidant compounds present in medicinal plants possess immunomodulatory properties, bolstering the body's immune defenses against pathogens and enhancing immune surveillance mechanisms. By promoting immune resilience, medicinal plant antioxidants may help prevent and mitigate infectious diseases and support overall immune health.

4. Skin Health and Beauty: Oxidative stress contributes to skin aging, wrinkles, and other dermatological concerns by inducing collagen degradation, elastin breakdown, and DNA damage. The antioxidant constituents of medicinal plants, such as polyphenols, carotenoids, and flavonoids, exhibit photoprotective, anti-inflammatory, and anti-aging effects on the skin. Incorporating medicinal plant extracts or formulations rich in antioxidants into skincare products may help maintain skin health, enhance complexion, and protect against UV-induced damage.

5. Neuroprotection: Oxidative stress is implicated in the pathogenesis of neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease, and multiple sclerosis. The antioxidant compounds found in medicinal plants possess neuroprotective properties, scavenging free radicals, reducing neuroinflammation, and preserving neuronal function. By mitigating oxidative damage to the brain and nervous system, medicinal plant antioxidants may offer therapeutic benefits in preventing or slowing the progression of neurodegenerative disorders.

6. Metabolic Health: Oxidative stress is closely linked to metabolic disorders, such as obesity, insulin resistance, and metabolic syndrome. The antioxidant compounds present in medicinal plants exhibit anti-inflammatory, insulin-sensitizing, and lipid-lowering effects, which may help mitigate metabolic dysfunction and improve metabolic health outcomes. Integrating medicinal plant antioxidants into dietary interventions and lifestyle modifications may support metabolic homeostasis and reduce the risk of metabolic diseases [24].

The antioxidant potential of medicinal plants holds significant promise for promoting human health, preventing disease, and enhancing overall well-being. By leveraging the diverse health implications and potential applications of medicinal plant antioxidants, researchers, healthcare practitioners, and consumers can harness the therapeutic benefits of nature's pharmacy and embrace holistic approaches to health maintenance and disease management. Further research and clinical studies are warranted to elucidate the efficacy, safety, and optimal dosing of medicinal plant antioxidants in diverse populations and clinical settings, the antioxidant potential of medicinal plant species offers a promising avenue for preventive and therapeutic interventions in healthcare [25]. However, several challenges and opportunities exist in this field, including standardization of extraction methods, identification of bioactive compounds, and elucidation of their mechanisms of action. Future research endeavors should focus on elucidating the synergistic interactions among antioxidant compounds in medicinal plants and their bioavailability and pharmacokinetics in humans. Additionally, clinical trials are warranted to evaluate the efficacy and safety of medicinal plant antioxidants in diverse patient populations. By advancing our understanding of the antioxidant capacities of medicinal plants, we can harness their therapeutic potential to promote human health and well-being in the era of integrative medicine.

Conclusion and Future Directions

The exploration of the antioxidant potential of medicinal plants represents a dynamic and promising field of research with far-reaching implications for human health and well-being. The comprehensive review of antioxidant compounds, mechanisms of action, health implications, and potential applications underscores the multifaceted therapeutic value of medicinal plants in combating oxidative stress and its associated pathologies. Through the synthesis of current scientific evidence, it is evident that medicinal plants harbor a rich repertoire of antioxidant compounds, including phenolic compounds, carotenoids, tocopherols, and alkaloids, which contribute to their antioxidant capacity. These bioactive constituents exert antioxidant effects through diverse mechanisms, including free radical scavenging, metal chelation, enzyme modulation, and preservation of cellular integrity. The health implications of medicinal plant antioxidants extend across various domains, including disease prevention, anti-aging effects, immune enhancement, skin health, neuroprotection, and metabolic health. By targeting oxidative stress-mediated mechanisms underlying chronic diseases, medicinal plant antioxidants offer promising avenues for preventive healthcare and integrative medicine approaches.

1. Standardization and Quality Control: Standardization of extraction methods, characterization of bioactive compounds, and quality control measures are essential for ensuring the reproducibility and efficacy of medicinal plant-based antioxidant formulations.

2. Bioavailability and Pharmacokinetics: Understanding the bioavailability and pharmacokinetic profiles of medicinal plant antioxidants is crucial for optimizing dosage regimens, enhancing therapeutic efficacy, and elucidating their mechanisms of action in vivo.

3. Clinical Trials and Translational Research: Well-designed clinical trials are needed to evaluate the safety, efficacy, and long-term effects of medicinal plant antioxidants in diverse patient populations and disease conditions. Translational research efforts are also needed to bridge the gap between preclinical studies and clinical practice.

4**. Mechanistic Insights and Molecular Targets:** Further elucidation of the molecular mechanisms underlying the antioxidant activities of medicinal plant compounds will enhance our understanding of their therapeutic potential and identify novel molecular targets for drug discovery and development.

5. Sustainable Harvesting and Conservation: Sustainable harvesting practices and conservation efforts are essential for preserving biodiversity, protecting endangered plant species, and ensuring the long-term availability of medicinal plants for future generations.

In conclusion, the exploration of medicinal plant antioxidants holds promise for addressing contemporary health challenges and advancing the frontiers of integrative medicine. By embracing a multidisciplinary approach that integrates traditional knowledge with modern scientific methodologies, we can unlock the full therapeutic potential of medicinal plants and promote holistic approaches to health and wellness in the pursuit of human flourishing.

References

1. Llauradó Maury, G.; Méndez Rodríguez, D.; Hendrix, S.; Escalona Arranz, J.C.; Fung Boix, Y.; Pacheco, A.O.; García Díaz, J.; Morris-Quevedo, H.J.; Ferrer Dubois, A.; Aleman, E.I.; et al. Antioxidants in Plants: A Valorization Potential Emphasizing the Need for the Conservation of Plant Biodiversity in Cuba. *Antioxidants* 2020, *9*, 1048. https://doi.org/10.3390/antiox9111048

2. Farzaneh, V., & Carvalho, I. S. (2015). A review of the health benefit potentials of herbal plant infusions and their mechanism of actions. *Industrial Crops and Products*, *65*, 247-258.

3. Pandey, A. K., & Singh, P. (2017). The genus Artemisia: A 2012–2017 literature review on chemical composition, antimicrobial, insecticidal and antioxidant activities of essential oils. *Medicines*, *4*(3), 68.

4. Andrew, M., & Jayaraman, G. (2020). Structural features of microbial exopolysaccharides in relation to their antioxidant activity. *Carbohydrate research*, *487*, 107881.

5. Mothana, R. A., Lindequist, U., Gruenert, R., & Bednarski, P. J. (2009). Studies of the in vitro anticancer, antimicrobial and antioxidant potentials of selected Yemeni medicinal plants from the island Soqotra. *BMC complementary and alternative medicine*, *9*, 1-11.

6. Cui, J. L., Guo, T. T., Ren, Z. X., Zhang, N. S., & Wang, M. L. (2015). Diversity and antioxidant activity of culturable endophytic fungi from alpine plants of Rhodiola crenulata, R. angusta, and R. sachalinensis. *PloS one*, *10*(3), e0118204.

7. Miguel, M. G. (2010). Antioxidant activity of medicinal and aromatic plants. A review. *Flavour and Fragrance Journal*, *25*(5), 291-312.

8. Akhtar, N., & Mirza, B. (2018). Phytochemical analysis and comprehensive evaluation of antimicrobial and antioxidant properties of 61 medicinal plant species. *Arabian journal of chemistry*, *11*(8), 1223-1235.

9. Jahanban-Esfahlan, A., Ostadrahimi, A., Tabibiazar, M., & Amarowicz, R. (2019). A comparative review on the extraction, antioxidant content and antioxidant potential of different parts of walnut (Juglans regia L.) fruit and tree. *Molecules*, *24*(11), 2133.

10. Roginsky, V., & Lissi, E. A. (2005). Review of methods to determine chain-breaking antioxidant activity in food. *Food chemistry*, *92*(2), 235-254.

11. Chand, K., Hiremathad, A., Singh, M., Santos, M. A., & Keri, R. S. (2017). A review on antioxidant potential of bioactive heterocycle benzofuran: Natural and synthetic derivatives. *Pharmacological Reports*, *69*(2), 281-295.

12. Kiokias, S., Proestos, C., & Oreopoulou, V. (2020). Phenolic acids of plant origin—A review on their antioxidant activity in vitro (o/w emulsion systems) along with their in vivo health biochemical properties. *Foods*, *9*(4), 534.

13. Bhadoriya, S. S., Ganeshpurkar, A., Narwaria, J., Rai, G., & Jain, A. P. (2011). Tamarindus indica: Extent of explored potential. *Pharmacognosy reviews*, *5*(9), 73.

14. Borges Bubols, G., da Rocha Vianna, D., Medina-Remon, A., von Poser, G., Maria Lamuela-Raventos, R., Lucia Eifler-Lima, V., & Cristina Garcia, S. (2013). The antioxidant activity of coumarins and flavonoids. *Mini reviews in medicinal chemistry*, *13*(3), 318-334.

15. Xu, D. P., Li, Y., Meng, X., Zhou, T., Zhou, Y., Zheng, J., & Li, H. B. (2017). Natural antioxidants in foods and medicinal plants: Extraction, assessment and resources. *International journal of molecular sciences*, *18*(1), 96.

16. Ali, S. S., Kasoju, N., Luthra, A., Singh, A., Sharanabasava, H., Sahu, A., & Bora, U. (2008). Indian medicinal herbs as sources of antioxidants. *Food research international*, *41*(1), 1-15.

17. Xie, Jian-Hua, Ming-Liang Jin, Gordon A. Morris, Xue-Qiang Zha, Han-Qing Chen, Yang Yi, Jing-En Li et al. "Advances on bioactive polysaccharides from medicinal plants." *Critical reviews in food science and nutrition* 56, no. sup1 (2016): S60-S84.

18. Nagarani, G., Abirami, A., & Siddhuraju, P. (2014). A comparative study on antioxidant potentials, inhibitory activities against key enzymes related to metabolic syndrome, and anti-inflammatory activity of leaf extract from different Momordica species. *Food Science and Human Wellness*, *3*(1), 36-46.

19. Fernando, I. S., Kim, M., Son, K. T., Jeong, Y., & Jeon, Y. J. (2016). Antioxidant activity of marine algal polyphenolic compounds: a mechanistic approach. *Journal of medicinal food*, *19*(7), 615-628.

20. Iqbal, S., Younas, U., Sirajuddin, Chan, K. W., Sarfraz, R. A., & Uddin, K. (2012). Proximate composition and antioxidant potential of leaves from three varieties of Mulberry (Morus sp.): a comparative study. *International journal of molecular sciences*, *13*(6), 6651-6664.

21. Muddathir, A. M., Yamauchi, K., Batubara, I., Mohieldin, E. A. M., & Mitsunaga, T. (2017). Anti-tyrosinase, total phenolic content and antioxidant activity of selected Sudanese medicinal plants. *South African Journal of Botany*, *109*, 9-15.

22. Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food chemistry*, *99*(1), 191-203.

23. Battin, E. E., & Brumaghim, J. L. (2009). Antioxidant activity of sulfur and selenium: a review of reactive oxygen species scavenging, glutathione peroxidase, and metal-binding antioxidant mechanisms. *Cell biochemistry and biophysics*, *55*(1), 1-23.

24. Silva, CG da, R. S. Herdeiro, C. J. Mathias, A. D. Panek, C. S. Silveira, V. P. Rodrigues, M. N. Rennó et al. "Evaluation of antioxidant activity of Brazilian plants." *Pharmacological research* 52, no. 3 (2005): 229-233.

25. Nadeem, M., Muhammad Anjum, F., Issa Khan, M., Tehseen, S., El-Ghorab, A., & Iqbal Sultan, J. (2013). Nutritional and medicinal aspects of coriander (Coriandrum sativum L.) A review. *British Food Journal*, *115*(5), 743-755.