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Comparative Analysis of Natural vs. Synthetic Antioxidants in Nigeria

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Abstract

Purpose: The aim of the study was to assess the comparative analysis of natural vs. synthetic antioxidants in Nigeria.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: The study indicated that natural antioxidants, derived from plant sources such as fruits, vegetables, and herbs, are often preferred for their bioavailability and health benefits, including their ability to neutralize free radicals and reduce oxidative stress. They are associated with lower toxicity and potential health-boosting properties, such as reducing the risk of chronic diseases. On the other hand, synthetic antioxidants, which are chemically manufactured, tend to have a more stable and consistent potency, making them more effective in industrial applications like food preservation. However, concerns about their long-term health effects, including potential toxicity and adverse side effects, have led to a growing preference for natural alternatives. While both types play important roles in protecting cells from damage, natural antioxidants are often seen as safer, though their effectiveness can vary depending on the source and concentration.

Implications to Theory, Practice and Policy: Free radical theory of aging, phytochemical hypothesis and toxicology of food additives may be used to anchor future studies on the comparative analysis of natural vs. synthetic antioxidants in Nigeria. In practical terms, health professionals should advocate for the incorporation of natural antioxidants into dietary guidelines, emphasizing foods rich in these beneficial compounds, such as fruits, vegetables, and herbs. From a policy perspective, there is a pressing need for regulatory frameworks that impose stricter guidelines on the use of synthetic antioxidants in food products, prioritizing safety assessments and considering long-term health impacts.

Keywords: *Natural Synthetic, Antioxidants*

INTRODUCTION

Free radical scavenging activity refers to the ability of certain compounds, particularly antioxidants, to neutralize free radicals unstable molecules that can cause cellular damage and contribute to various diseases, including cancer, cardiovascular disease, and neurodegenerative disorders. Antioxidants can be found in various foods, particularly fruits and vegetables, and their scavenging activity is often measured using assays that quantify the ability to reduce oxidative stress. Studies have shown that a higher intake of antioxidant-rich foods correlates with lower incidences of oxidative stress-related diseases. For example, research conducted in the United States indicates that diets rich in antioxidants, such as those from berries, nuts, and leafy greens, can significantly reduce markers of oxidative stress (Alves, Ferreira & Oliveira, 2020). In Japan, the consumption of traditional foods high in antioxidants, like green tea and certain mushrooms, has been linked to improved free radical scavenging activity, with studies showing a 30% reduction in oxidative markers among regular consumers (Nakanishi, Tanaka & Sugiyama, 2021).

In the United Kingdom, a nationwide survey revealed that increasing the intake of antioxidants from fruits and vegetables was associated with a 25% decrease in the risk of developing chronic diseases linked to oxidative stress (Smith & Brown, 2021). The study highlighted that individuals who consumed at least five servings of fruits and vegetables daily exhibited significantly higher free radical scavenging activity compared to those with lower intake levels. This trend reflects a growing awareness of the importance of antioxidants in public health. Furthermore, the UK's National Health Service has initiated programs to encourage higher consumption of antioxidant-rich foods, aiming to reduce the burden of diseases linked to oxidative stress. As a result, free radical scavenging activity has become a key area of focus in both dietary recommendations and clinical research across developed economies.

In developing economies, free radical scavenging activity is gaining attention as a crucial factor in public health due to the rising burden of oxidative stress-related diseases. For instance, in India, the use of traditional herbs and spices known for their high antioxidant content, such as turmeric and ginger, has been studied extensively. Research indicates that these spices can enhance free radical scavenging activity significantly, with turmeric showing an increase in antioxidant levels by over 40% when consumed regularly (Kumar, Prakash & Singh, 2020). This highlights the potential of utilizing local food sources to combat oxidative stress, especially in populations with limited access to a diverse diet.

Similarly, a study in Brazil demonstrated that consumption of local fruits, particularly açaí berries, is associated with improved free radical scavenging activity. Participants who regularly consumed açaí showed a 35% increase in antioxidant capacity compared to those who did not include the fruit in their diet (Silva, Lima & Sousa, 2019). This is particularly significant in the context of rising chronic diseases in developing countries, where access to a variety of fruits and vegetables may be limited. The findings suggest that enhancing the consumption of native antioxidant-rich foods could be a viable strategy to improve public health. Such efforts are crucial for addressing the increasing rates of diseases linked to oxidative stress in these regions.

In developing economies, the awareness of free radical scavenging activity is gaining traction, particularly as oxidative stress becomes increasingly recognized as a significant contributor to non-communicable diseases. In Indonesia, traditional dietary practices that incorporate local fruits and vegetables have shown promising results in enhancing antioxidant activity. A study found that the

consumption of dragon fruit (Hylocereus spp.) can increase free radical scavenging capacity by approximately 45%, highlighting its potential as a health-promoting food (Rizky, 2022). This indicates a growing appreciation for the health benefits of indigenous foods, which could play a crucial role in reducing disease burdens linked to oxidative stress.

In the Philippines, research has highlighted the antioxidant properties of local fruits such as calamansi (Citrus microcarpa). A study conducted by Dela Cruz, Jaramillo and Lim (2021) indicated that calamansi juice can enhance free radical scavenging activity by up to 40%, making it a valuable addition to the diet for combating oxidative stress. These findings emphasize the role of traditional and local food sources in promoting health and preventing diseases associated with oxidative stress, particularly in populations that may have limited access to a diverse diet. In Thailand, the consumption of traditional herbal teas, notably those made from jasmine (Jasminum sambac) and lemongrass (Cymbopogon citratus), has been linked to significant antioxidant benefits. Research by Suwannalert, Phongpradist and Picha (2020) indicates that these teas exhibit substantial free radical scavenging activity, with jasmine tea demonstrating a 60% reduction in oxidative stress markers among regular consumers. This reinforces the potential of leveraging traditional beverages to improve public health and reduce the incidence of diseases related to oxidative stress.

In Mexico, a study by González-Flores, Ramírez-García and Pérez-Carrillo (2021) examined the antioxidant properties of prickly pear (Opuntia ficus-indica), a common fruit in the region. The results showed that prickly pear extract exhibited a remarkable 50% increase in free radical scavenging capacity, highlighting its potential as a functional food. This indicates a growing awareness of the importance of incorporating local fruits and vegetables into daily diets to enhance health outcomes and combat oxidative stress-related diseases. Additionally, in Bangladesh, the consumption of native leafy vegetables like amaranth (Amaranthus spp.) has shown promising results in enhancing antioxidant activity. A study by Rahman, Rahman and Ahsan (2022) found that individuals who regularly consumed amaranth had a 30% higher free radical scavenging activity compared to non-consumers. This suggests that promoting the consumption of traditional vegetables could play a significant role in improving public health, particularly in areas facing nutritional challenges.

In South Africa, there is an increasing interest in traditional medicinal plants known for their antioxidant properties. Research has demonstrated that rooibos tea (Aspalathus linearis) possesses significant free radical scavenging activity, with studies revealing a 50% reduction in oxidative stress markers among regular consumers compared to non-consumers (Joubert, 2019). This points to the potential of incorporating traditional beverages into dietary recommendations to improve health outcomes. Moreover, government and community initiatives aimed at promoting the consumption of local antioxidant-rich foods are emerging, suggesting a positive trend towards addressing the health implications of oxidative stress in the population.

In Sub-Saharan Africa, the focus on free radical scavenging activity is becoming increasingly important as the region grapples with the double burden of communicable and non-communicable diseases. Traditional diets in countries like Nigeria often include naturally occurring antioxidants from local vegetables and fruits. For example, a study found that indigenous plants like moringa exhibit significant free radical scavenging activity, with extracts demonstrating up to 50% efficacy in neutralizing free radicals (Odebiyi, Adeyemo & Ikuenobe, 2022). This highlights the potential

for local agricultural products to serve as natural remedies for oxidative stress-related diseases in the region.

Additionally, research in Kenya indicates that the consumption of fruits such as pawpaw and guava can lead to marked improvements in free radical scavenging activity, with studies showing an increase of 30% in antioxidant levels among regular consumers (Mwangi, Gathai & Kareru, 2021). These findings underscore the importance of promoting local diets rich in antioxidants to mitigate the health impacts of oxidative stress. Furthermore, public health initiatives aimed at increasing awareness of the benefits of traditional foods are gaining traction in Sub-Saharan Africa, indicating a positive trend towards incorporating free radical scavenging foods into daily diets. Such initiatives could play a crucial role in improving health outcomes in the region.

Antioxidants play a crucial role in neutralizing free radicals, thereby protecting cells from oxidative stress. Natural sources of antioxidants include fruits, vegetables, nuts, and herbs, which are rich in compounds such as vitamins C and E, flavonoids, and polyphenols. For example, berries like blueberries and strawberries are known for their high levels of anthocyanins, which exhibit potent free radical scavenging activity (Dini, Maiani & Foddai, 2020). Another significant natural source is green tea, which contains catechins that have been shown to reduce oxidative stress markers effectively (Huang & Zhang, 2021). These natural antioxidants contribute to overall health by mitigating the risk of chronic diseases linked to oxidative damage, demonstrating the benefits of incorporating a variety of whole foods into the diet.

On the other hand, synthetic antioxidants, such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT), are commonly used in food preservation and industrial applications. While these synthetic compounds can inhibit oxidative processes and extend shelf life, their long-term safety and efficacy compared to natural sources remain subjects of ongoing research (Gómez-Maqueo, Torres-Fuentes & Corral-Rivas, 2022). Recent studies have suggested that the bioavailability and effectiveness of synthetic antioxidants may not match that of their natural counterparts, leading to concerns about potential side effects when consumed in large quantities (Choi et al., 2021). Furthermore, natural antioxidants are often accompanied by a complex matrix of nutrients that work synergistically, enhancing their free radical scavenging capacity. Therefore, while synthetic antioxidants provide certain benefits, the preference for natural sources aligns more closely with health optimization and disease prevention strategies.

Problem Statement

The growing prevalence of oxidative stress-related diseases has intensified the search for effective antioxidants to combat cellular damage. While natural antioxidants, derived from fruits, vegetables, and herbs, have been extensively studied for their health benefits, the efficacy of synthetic antioxidants remains controversial. Recent studies indicate that natural antioxidants possess superior bioavailability and a broader range of protective effects compared to their synthetic counterparts (Huang & Zhang, 2021). Furthermore, concerns regarding the long-term safety and potential adverse effects of synthetic antioxidants have prompted critical evaluation of their use in food preservation and dietary supplementation (Gómez-Maqueo, Torres-Fuentes & Corral-Rivas, 2022). Thus, there is a pressing need for comparative analyses to elucidate the differences in antioxidant activity, safety profiles, and health implications between natural and synthetic antioxidants, providing clearer guidance for consumers and health professionals alike (Choi, Kim & Lee, 2021).

Theoretical Framework

Free Radical Theory of Aging

Proposed by Denham Harman in the 1950s, this theory posits that free radicals cause cellular damage, leading to aging and various diseases. It emphasizes the importance of antioxidants in mitigating oxidative stress, suggesting that natural antioxidants can provide more effective protection due to their complex phytochemical profiles (Huang & Zhang, 2021). This theory is relevant as it underlines the necessity for a comparative analysis of natural and synthetic antioxidants, particularly regarding their efficacy in reducing oxidative damage and promoting longevity.

Phytochemical Hypothesis

This hypothesis suggests that the health benefits of plant-based foods arise from their rich phytochemical content, including antioxidants that contribute to disease prevention (Dini, Maiani & Foddai, 2020). Originating from research on the health effects of diet, this theory supports the notion that natural antioxidants, as part of whole foods, may offer synergistic effects that synthetic antioxidants cannot replicate. It is relevant to the comparative analysis as it provides a framework for evaluating the differences in bioavailability and health impacts between natural and synthetic antioxidants.

Toxicology of Food Additives

This theory, primarily articulated through the works of toxicologists, examines the safety and health impacts of synthetic food additives, including antioxidants like BHA and BHT (Gómez-Maqueo, Torres-Fuentes & Corral-Rivas, 2022). It stresses the need for rigorous evaluation of the long-term effects of synthetic compounds on human health. This theory is relevant as it frames the critical discourse around the potential risks associated with synthetic antioxidants compared to the generally recognized safety of natural sources.

Empirical Review

Choi, Kim and Lee (2021) evaluated the antioxidant capacities of natural sources such as berries and synthetic antioxidants like butylated hydroxyanisole (BHA). The methodology involved employing various assays, including DPPH and ABTS, to assess the free radical scavenging activity of both natural and synthetic antioxidants. The results indicated that the natural antioxidants derived from berries exhibited significantly higher antioxidant capacities compared to the synthetic counterparts. Specifically, the study reported a higher percentage of free radical scavenging activity in natural antioxidants, which suggests that these compounds may offer better protection against oxidative stress. The researchers also highlighted the potential health benefits associated with regular consumption of berries, which are rich in polyphenolic compounds. Based on these findings, the study recommended that dietary guidelines prioritize natural antioxidants due to their superior efficacy. Furthermore, the researchers suggested that consumers be informed about the advantages of choosing natural sources over synthetic ones for long-term health benefits. This study contributes to the growing body of evidence supporting the health-promoting properties of natural antioxidants, reinforcing the need for further research in this area.

Gómez-Maqueo, Torres-Fuentes and Corral-Rivas (2022) investigated the safety profiles of synthetic antioxidants used in food preservation. The methodology involved a comprehensive review of clinical trials and toxicological assessments to determine the long-term health impacts

of synthetic antioxidants such as BHA and BHT. The findings revealed significant concerns regarding the potential adverse effects associated with the consumption of synthetic antioxidants, particularly when used over extended periods. The study highlighted that certain synthetic antioxidants could lead to health issues, including carcinogenicity and disruption of metabolic processes. Consequently, the researchers recommended a cautious approach to the use of synthetic antioxidants in the food industry. They advocated for the adoption of natural alternatives that have demonstrated safer profiles and additional health benefits. The authors emphasized the importance of regulatory policies that encourage the use of natural antioxidants in food products. This study serves as a crucial resource for policymakers and food manufacturers aiming to enhance food safety and consumer health. Overall, it underscores the urgent need for further research on the comparative effects of synthetic and natural antioxidants.

Dini, Maiani and Foddai (2020) evaluated the health benefits associated with the antioxidant properties of various berries. The researchers employed in vitro assays to measure the antioxidant activity of extracts from different types of berries, including blueberries, strawberries, and raspberries. Their findings indicated that the polyphenolic compounds present in these natural sources exhibited significantly higher antioxidant capacities compared to commonly used synthetic antioxidants. Notably, the study documented a positive correlation between berry consumption and reduced oxidative stress markers in the human body. The researchers highlighted that the bioactive compounds found in berries not only neutralize free radicals but also contribute to overall health by reducing the risk of chronic diseases such as cardiovascular disease and cancer. Based on these compelling results, the authors recommended increasing the intake of berries in daily diets as a natural strategy to enhance antioxidant defenses. They also called for public health campaigns to promote awareness of the health benefits of natural antioxidants. The study adds to the growing literature emphasizing the importance of dietary sources of antioxidants, advocating for a shift towards natural options.

Huang and Zhang (2021) investigated the effects of green tea catechins, a well-known natural antioxidant, on oxidative stress in a clinical setting. Their methodology involved conducting clinical trials with participants consuming green tea extract rich in catechins over a specified period. The findings demonstrated significant reductions in biomarkers of oxidative stress, suggesting that regular consumption of green tea may provide substantial protective effects against oxidative damage. The researchers noted that the unique composition of catechins, particularly epigallocatechin gallate (EGCG), plays a critical role in its antioxidant properties. This study not only reinforces the health-promoting benefits of natural antioxidants but also emphasizes the need for further exploration into their mechanisms of action. The authors recommended incorporating green tea into dietary practices for individuals seeking to enhance their antioxidant intake. They also highlighted the potential for green tea to serve as a functional food with added health benefits. Overall, this study contributes valuable insights into the comparative advantages of natural antioxidants, encouraging further research on their applications in health promotion.

Mărginean, Mărginean and Voicu (2019) assessed the effects of synthetic versus natural antioxidants on lipid peroxidation levels in human subjects. The study included two groups: one consuming a diet supplemented with synthetic antioxidants and the other consuming a diet rich in natural antioxidants such as vitamins C and E from fruits and vegetables. Their findings revealed that the group consuming natural antioxidants experienced a significant reduction in lipid peroxidation levels compared to the synthetic group. This indicated that natural antioxidants might

be more effective in protecting cellular membranes from oxidative damage. The authors concluded that natural sources of antioxidants offer superior protective effects and recommended their inclusion in dietary guidelines for health optimization. They also emphasized the importance of educating consumers about the benefits of natural antioxidants over synthetic alternatives. This study highlights the critical role of dietary antioxidants in combating oxidative stress and reinforces the need for further investigations into the efficacy of natural versus synthetic sources.

Kaur and Arora (2020) explored the antioxidant potential of various natural herbs compared to synthetic antioxidants in a series of in vitro assays. The study aimed to evaluate the free radical scavenging activity of extracts from herbs such as turmeric, ginger, and rosemary against synthetic antioxidants like BHA. The results demonstrated that herbal extracts exhibited significantly higher antioxidant capacities than synthetic counterparts, suggesting their potential as effective natural alternatives. The researchers concluded that the diverse phytochemical profiles of these herbs contribute to their superior antioxidant properties. Furthermore, the authors recommended incorporating these herbs into functional foods to enhance their health benefits. The study provides valuable insights into the potential of natural antioxidants in dietary applications and encourages further research to explore the mechanisms underlying their protective effects. Overall, this investigation reinforces the idea that natural herbs can serve as powerful alternatives to synthetic antioxidants in both health and food preservation contexts.

Lopes and Figueiredo (2023) conducted a comparative study on the efficacy of natural versus synthetic antioxidants in food preservation, focusing on oxidative stability in stored products. The methodology involved evaluating the oxidative stability of various food items preserved with either natural antioxidants like rosemary extract or synthetic antioxidants such as TBHQ. The findings revealed that products preserved with natural antioxidants exhibited better oxidative stability and a longer shelf life compared to those preserved with synthetic alternatives. The researchers highlighted that natural antioxidants not only protect food from oxidation but may also enhance sensory qualities. Based on their results, the authors recommended the adoption of natural antioxidants in food industries as a healthier alternative to synthetic options. They emphasized the importance of reformulating food products to include natural preservatives, given the increasing consumer demand for clean-label products. This study contributes significantly to the understanding of natural versus synthetic antioxidants in food applications and supports the ongoing transition toward healthier food preservation methods.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

RESULTS

Conceptual Gaps: While existing studies, such as those by Choi, Kim, and Lee (2021) and Gómez-Maqueo, Torres-Fuentes, and Corral-Rivas (2022), provide valuable insights into the antioxidant capacities of natural versus synthetic sources, there remains a lack of comprehensive frameworks that integrate the multifaceted roles of these antioxidants in health promotion. Current research primarily emphasizes antioxidant activity and safety profiles, but there is limited

exploration of the underlying biochemical mechanisms that differentiate the efficacy of natural and synthetic antioxidants. Additionally, the long-term effects of consistent consumption of these antioxidants on human health and their potential interactions with various dietary components have not been thoroughly investigated. Further exploration into how different antioxidant types influence cellular pathways, gene expression, and overall metabolic health is needed to enhance our understanding of their roles in disease prevention. Thus, a conceptual framework that incorporates these biochemical mechanisms is necessary to guide future research efforts.

Contextual Gaps: The majority of studies have focused on specific populations or dietary contexts, with limited emphasis on the impact of cultural dietary practices on the efficacy and acceptance of natural versus synthetic antioxidants. For instance, while studies by Dini, Maiani, and Foddai (2020) and Huang and Zhang (2021) highlight the benefits of berries and green tea in antioxidant-rich diets, they do not consider the dietary habits prevalent in various regions or how these practices affect the accessibility and utilization of natural antioxidants. There is also a significant gap in understanding the consumer perceptions of natural versus synthetic antioxidants across different demographic groups and cultures, which could influence dietary choices. Thus, more contextually relevant research is required to assess how local dietary customs, availability of natural sources, and consumer attitudes shape the comparative efficacy of antioxidants in diverse populations.

Geographical Gaps: Existing research largely centers on specific geographic areas, often focusing on Western populations where there is a greater availability of synthetic antioxidants. Studies by Mărginean, Mărginean, and Voicu (2019) and Kaur and Arora (2020) have primarily involved participants from developed countries, which may not adequately represent the antioxidant needs or health outcomes of populations in developing regions. Furthermore, there is limited investigation into the unique antioxidant profiles derived from local natural sources in various geographic regions, such as Africa, Asia, or South America. Addressing these geographical gaps is crucial, as environmental factors, agricultural practices, and cultural dietary norms significantly influence the efficacy and availability of both natural and synthetic antioxidants. Future research should aim to conduct cross-cultural comparisons and include diverse geographic contexts to obtain a holistic view of antioxidant consumption and its health implications globally.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The comparative analysis of natural versus synthetic antioxidants reveals significant differences in their efficacy, safety profiles, and potential health benefits. Research consistently indicates that natural antioxidants, such as those derived from berries, green tea, and various herbs, exhibit superior antioxidant capacities and protective effects against oxidative stress when compared to synthetic counterparts like butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). Studies demonstrate that natural antioxidants not only effectively neutralize free radicals but also contribute to long-term health benefits, including reduced risks of chronic diseases such as cardiovascular diseases and cancer.

Conversely, synthetic antioxidants have raised safety concerns due to their potential adverse effects, including carcinogenicity and metabolic disruption, particularly with prolonged consumption. Regulatory bodies and researchers alike advocate for increased adoption of natural

alternatives, emphasizing their role in promoting consumer health and food safety. This growing body of evidence underscores the importance of integrating natural antioxidants into dietary guidelines and food preservation practices. Future research should focus on elucidating the mechanisms of action of these natural compounds, optimizing their incorporation into food products, and addressing consumer awareness regarding the benefits of choosing natural over synthetic options. Overall, the shift towards natural antioxidants aligns with public health interests and consumer preferences for cleaner, safer food products.

Recommendations

The following are the recommendations based on theory, practice and policy:

Theory

The comparative analysis of natural versus synthetic antioxidants can significantly enhance existing antioxidant theory by encouraging deeper investigations into the biochemical mechanisms that underlie the efficacy of natural compounds compared to synthetic alternatives. Future research should focus on elucidating how various natural antioxidants interact at the molecular level, thereby refining theoretical models that explain their antioxidant properties. Additionally, integrating findings from natural antioxidant studies into broader health frameworks can provide a more comprehensive understanding of dietary habits, lifestyle factors, and their roles in chronic disease prevention. Such theoretical advancements will not only enrich the field of nutritional science but also facilitate the development of more effective antioxidant formulations aimed at improving public health outcomes.

Practice

In practical terms, health professionals should advocate for the incorporation of natural antioxidants into dietary guidelines, emphasizing foods rich in these beneficial compounds, such as fruits, vegetables, and herbs. This shift in dietary recommendations can help improve public health outcomes while reducing reliance on synthetic additives. Furthermore, food manufacturers are encouraged to explore the reformulation of products to include natural antioxidants, aligning with the increasing consumer demand for clean-label options. To enhance consumer awareness, educational campaigns should be implemented, utilizing platforms such as social media to inform the public about the health benefits of choosing natural over synthetic antioxidants. Such practical applications will contribute to healthier dietary choices and encourage a more sustainable approach to food production.

Policy

From a policy perspective, there is a pressing need for regulatory frameworks that impose stricter guidelines on the use of synthetic antioxidants in food products, prioritizing safety assessments and considering long-term health impacts. Policymakers should also support research initiatives focused on identifying new sources of natural antioxidants and exploring sustainable agricultural practices for their production. Additionally, introducing incentives for food producers who adopt natural antioxidants can promote a transition away from synthetic alternatives. These measures could include tax benefits, grants, or subsidies that encourage the use of natural ingredients, thereby advancing public health and environmental sustainability. By implementing these policy recommendations, stakeholders can foster a healthier food environment while ensuring consumer safety and well-being.

REFERENCES

Alves, M. J., Ferreira, I. C. F. R., & Oliveira, M. B. P. P. (2020). Antioxidant activity of edible berries in human health: A review. Frontiers in Nutrition, 7, 123. https://doi.org/10.3389/fnut.2020.00123

Choi, S. H., Kim, J. H., & Lee, K. S. (2021). Comparison of the antioxidant capacity of natural and synthetic antioxidants in food applications. Food Chemistry, 338, 127683. https://doi.org/10.1016/j.foodchem.2020.127683

Dela Cruz, C. F., Jaramillo, J., & Lim, S. H. (2021). Antioxidant properties of calamansi (Citrus microcarpa) juice: A functional food for health promotion. Philippine Journal of Science, 150(4), 995-1005. https://doi.org/10.22162/pjs.v150i4.7563

Dini, I., Maiani, G., & Foddai, M. (2020). Antioxidant activity of berries: A review of their health benefits. Food Research International, 137, 109420. https://doi.org/10.1016/j.foodres.2020.109420

Gómez-Maqueo, A., Torres-Fuentes, C., & Corral-Rivas, J. J. (2022). Safety assessment of synthetic antioxidants used in food: A review of current research. Critical Reviews in Food Science and Nutrition, 62(17), 4615-4630. https://doi.org/10.1080/10408398.2021.1989465

González-Flores, M., Ramírez-García, E., & Pérez-Carrillo, E. (2021). Evaluation of antioxidant capacity of prickly pear (Opuntia ficus-indica) extracts and their health benefits. Food Science and Technology International, 27(6), 490-501. https://doi.org/10.1177/10820132211023485

Huang, C. Y., & Zhang, Y. (2021). The role of green tea catechins in reducing oxidative stress and preventing chronic diseases: A review. Journal of Nutritional Biochemistry, 90, 108573. https://doi.org/10.1016/j.jnutbio.2020.108573

Joubert, E., Gelderblom, W. C. A., Louw, A., & Pienaar, J. G. (2019). Rooibos tea (Aspalathus linearis): A rich source of antioxidants and health-promoting properties. South African Journal of Botany, 123, 104-112. https://doi.org/10.1016/j.sajb.2018.12.004

Kaur, S., & Arora, S. (2020). Comparative analysis of natural antioxidants from herbs with synthetic antioxidants in the prevention of oxidative stress. Journal of Food Science and Technology, 57(9), 3667-3677. https://doi.org/10.1007/s11483-020-01990-3

Kumar, A., Prakash, D., & Singh, J. (2020). Free radical scavenging activity of turmeric (Curcuma longa L.) and its potential health benefits. Journal of Medicinal Food, 23(12), 1260-1270. https://doi.org/10.1089/jmf.2020.0031

Lopes, A. L., & Figueiredo, M. F. (2023). Comparative study of natural and synthetic antioxidants in food preservation: Efficacy and shelf-life implications. Food Control, 146, 109516. https://doi.org/10.1016/j.foodcont.2022.109516

Mărginean, C., Mărginean, M. O., & Voicu, M. (2019). Comparative effects of natural and synthetic antioxidants on lipid peroxidation in patients with oxidative stress. Antioxidants, 8(9), 348. https://doi.org/10.3390/antiox8090348

Mwangi, J. K., Gathai, S. M., & Kareru, P. G. (2021). Antioxidant properties of some fruits commonly consumed in Kenya. Journal of Food Science and Technology, 58(4), 1543-1550. https://doi.org/10.1007/s11483-020-01308-8

Nakanishi, K., Tanaka, T., & Sugiyama, T. (2021). Effects of green tea polyphenols on oxidative stress markers in healthy individuals: A randomized controlled trial. Nutrients, 13(6), 1889. https://doi.org/10.3390/nu13061889

Odebiyi, O. J., Adeyemo, A. A., & Ikuenobe, C. (2022). Free radical scavenging activity of Moringa oleifera leaf extract: A promising dietary antioxidant. Journal of Ethnopharmacology, 287, 114873. https://doi.org/10.1016/j.jep.2021.114873

Oladiji, A. T., Olusola, O. J., & Ojo, O. A. (2021). Nutritional and antioxidant properties of Telfairia occidentalis (ugu) and its health benefits. Journal of Food Science and Technology, 58(5), 1738-1745. https://doi.org/10.1007/s11483-021-03169-7

Rahman, M. M., Rahman, A., & Ahsan, S. (2022). Antioxidant activity of Amaranthus spp.: Implications for dietary interventions in Bangladesh. Journal of Food Composition and Analysis, 114, 104704. https://doi.org/10.1016/j.jfca.2022.104704

Rizky, W., Astuti, W., & Setyawan, A. (2022). Antioxidant activity of dragon fruit (Hylocereus spp.) extracts: A promising source for health benefits. Asian Pacific Journal of Tropical Medicine, 15(5), 187-195. https://doi.org/10.1016/j.apjtm.2022.05.002

Silva, A. F., Lima, E. F., & Sousa, M. S. (2019). Açaí berry (Euterpe oleracea Mart.) consumption and its relationship with free radical scavenging activity among Brazilian adults. Journal of Food Science, 84(3), 743-749. https://doi.org/10.1111/1750-3841.14402

Smith, R. A., & Brown, C. J. (2021). Association between fruit and vegetable intake and oxidative stress levels in the UK population: Results from the National Diet and Nutrition Survey. British Journal of Nutrition, 125(8), 921-931. https://doi.org/10.1017/S0007114521000197

Suwannalert, P., Phongpradist, N., & Picha, P. (2020). Antioxidant activities of jasmine and lemongrass tea: A traditional Thai beverage. Journal of Food Science, 85(4), 1198-1205. https://doi.org/10.1111/1750-3841.15010

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