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The Role of Flavonoids in Reducing Oxidative Stress and Low-Grade Inflammation in Obese Diabetic Patients

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ABSTRACT

Obesity and type 2 diabetes mellitus (T2DM) are chronic metabolic disorders intricately linked with oxidative stress and persistent low-grade inflammation, both of which contribute to the progression of insulin resistance and associated complications. Emerging research highlights the potential therapeutic role of flavonoids—natural polyphenolic compounds found abundantly in fruits, vegetables, tea, and other plant-derived foods—in modulating oxidative and inflammatory pathways. This review synthesizes current evidence on the biochemical and molecular mechanisms by which flavonoids exert antioxidant and anti-inflammatory effects in obese diabetic patients. It discusses key subclasses of flavonoids, such as flavonols, flavones, flavanones, and anthocyanins, and their impacts on relevant biomarkers including reactive oxygen species (ROS), nuclear factor-kappa B (NF-κB), and pro-inflammatory cytokines (e.g., TNF-α, IL-6). Clinical studies are analyzed to evaluate efficacy, bioavailability challenges, and safety profiles of flavonoid supplementation in this population. The review concludes with a discussion on the future directions of integrating flavonoids into dietary interventions and personalized nutrition for managing obesity-associated T2DM.

Keywords: Flavonoids; Oxidative stress; Inflammation; Type 2 diabetes mellitus; Obesity; Antioxidants; Cytokines; Polyphenols; Insulin resistance; Nutraceuticals

INTRODUCTION

Obesity and type 2 diabetes mellitus (T2DM) are major global public health challenges that continue to rise at alarming rates[1–4]. These metabolic disorders are not only prevalent but are also closely interconnected, sharing common underlying mechanisms that drive their development and progression. A central feature linking obesity and T2DM is chronic metabolic dysregulation, characterized by insulin resistance, impaired glucose metabolism, and abnormal lipid profiles[5–8]. A critical contributor to this dysfunction is the presence of oxidative stress and persistent low-grade systemic inflammation. These harmful processes disrupt normal insulin signaling pathways, contribute to adipocyte (fat cell) dysfunction, and exacerbate metabolic abnormalities. Over time, this dysregulation increases the risk of serious complications, including cardiovascular disease, non-alcoholic fatty liver disease (NAFLD), nephropathy, and neuropathy[9–11].

Recent research has increasingly focused on the role of diet and natural bioactive compounds in mitigating the effects of metabolic disorders[12–14]. Among these compounds, flavonoids—naturally occurring polyphenolic substances found abundantly in fruits, vegetables, teas, cocoa, and other plant-derived foods—have gained considerable attention. Flavonoids possess powerful antioxidant and anti-inflammatory properties that may counteract the detrimental effects of oxidative stress and inflammation[15–17]. By scavenging free radicals, modulating inflammatory pathways, and improving endothelial function, flavonoids may help restore insulin sensitivity and support overall metabolic health.

Preclinical studies have demonstrated that flavonoids can improve glucose tolerance, reduce insulin resistance, and protect against obesity-induced inflammation in animal models[18, 19]. Furthermore, emerging clinical evidence suggests that flavonoid-rich diets may be associated with better glycemic control, improved lipid profiles, and reduced markers of inflammation in individuals with obesity or T2DM. As such, flavonoids are being explored as promising adjunctive agents in the prevention and management of metabolic disorders, offering a potentially safe and accessible complement to conventional therapeutic strategies[20].

Pathophysiology of Oxidative Stress and Inflammation in Obese Diabetic Patients

Obesity-induced inflammation is a complex biological process that plays a critical role in the development of metabolic disorders, particularly type 2 diabetes mellitus (T2DM)[1, 21, 22]. This inflammation originates primarily from hypertrophic adipocytes—enlarged fat cells that accumulate in obese individuals[23–25]. These hypertrophic adipocytes undergo cellular stress and begin to secrete various chemokines, such as monocyte chemoattractant protein-1 (MCP-1), which are signaling molecules that attract immune cells to the adipose tissue[26]. Among these immune cells, macrophages are especially prevalent and are key players in mediating inflammatory responses. Once recruited to the adipose tissue, macrophages undergo a phenotypic switch from an anti-inflammatory (M2) to a pro-inflammatory (M1) state[26]. These M1 macrophages then release a range of pro-inflammatory cytokines, including tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6)[27]. These cytokines interfere with insulin signaling pathways by promoting serine phosphorylation of insulin receptor substrate (IRS) proteins, thereby impairing glucose uptake in peripheral tissues. This contributes significantly to the development of insulin resistance, a hallmark feature of T2DM. In addition, chronic exposure to these cytokines can lead to pancreatic β-cell dysfunction, reducing insulin secretion and further exacerbating hyperglycemia[28, 29].

In parallel with inflammation, obesity is also associated with increased oxidative stress. Oxidative stress refers to a state in which the production of reactive oxygen species (ROS) exceeds the body's antioxidant defense capabilities[30, 31]. ROS, which include molecules like superoxide anion and hydrogen peroxide, are naturally generated as by-products of cellular metabolism. However, under conditions of overnutrition and excessive fat accumulation, mitochondrial dysfunction and enhanced metabolic activity lead to excessive ROS production. This surplus of ROS can damage proteins, lipids, and DNA, impairing normal cellular functions and triggering additional inflammatory signaling pathways[32].

The interaction between oxidative stress and inflammation forms a vicious, self-reinforcing cycle. ROS can activate nuclear factor-kappa B (NF-κB) and other transcription factors that upregulate the expression of inflammatory cytokines[5]. These cytokines, in turn, can stimulate further ROS production through the activation of enzymes such as NADPH oxidase. As a result, the inflammatory and oxidative processes feed into each other, amplifying the extent of tissue damage and metabolic dysregulation. This feedback loop is particularly detrimental in the context of T2DM, as it not only sustains but also exacerbates the insulin-resistant state and β-cell dysfunction over time[33, 34]. Overall, the intricate crosstalk between inflammation and oxidative stress in obesity creates a pathogenic environment that underlies the progression from metabolic health to insulin resistance and ultimately to T2DM. Targeting these pathways—through anti-inflammatory agents, antioxidants, or lifestyle interventions such as diet and exercise—represents a promising strategy for preventing or mitigating the metabolic complications associated with obesity.

Flavonoids: Classification and Sources

Flavonoids, a diverse group of naturally occurring compounds found in many fruits, vegetables, and plant-derived beverages, are categorized into several subclasses based on their distinct chemical structures and biological functions [35, 36]. Among the most studied subclasses are flavonols, such as quercetin and kaempferol, which are abundant in onions, apples, and berries. These compounds are known for their potent antioxidant properties, helping to neutralize free radicals and reduce oxidative stress within the body[37–39]. Flavones, including apigenin and luteolin, are primarily found in parsley, celery, and chamomile[40–42]. These molecules have been studied for their anti-inflammatory and anti-cancer activities, showing potential in modulating cellular signaling pathways and gene expression. Flavanones, such as hesperidin and naringenin, are especially abundant in citrus fruits and are recognized for their ability to support cardiovascular health by improving blood flow and reducing blood pressure. Their chemical structure allows them to interact with enzymes and receptors that influence vascular function and lipid metabolism[43, 44].

Another important class of flavonoids includes flavan-3-ols, such as catechins and epicatechins, which are widely found in green tea and cocoa[45, 46]. These compounds are associated with multiple health benefits, including improved cognitive function, enhanced metabolic regulation, and protective effects against cardiovascular diseases. Flavan-3-ols exhibit strong antioxidant capabilities and influence cellular communication, which contributes to their neuroprotective and cardioprotective roles. Similarly, anthocyanins, the pigments responsible for the vivid red, blue, and purple hues in fruits such as blueberries, raspberries, and blackberries, have been shown to possess powerful anti-inflammatory and anti-angiogenic properties. These characteristics may help in preventing chronic conditions such as cancer and neurodegenerative diseases[47]. Their presence in colorful fruits not only enhances visual appeal but also delivers substantial nutritional value. These flavonoids work by affecting key molecular targets, including enzymes, transcription factors, and signaling pathways involved in inflammation and oxidative stress responses.

Isoflavones, including genistein and daidzein, represent another unique subclass of flavonoids that are particularly concentrated in soy products[48]. Unlike other flavonoids, isoflavones possess a structure similar to human estrogen, allowing them to exert phytoestrogenic effects. This makes them especially relevant in hormonal health, such as in alleviating menopausal symptoms and potentially reducing the risk of hormone-related cancers like breast and prostate cancer. Isoflavones also contribute to bone health and cardiovascular function, acting on estrogen receptors and influencing lipid profiles[49, 50]. Overall, flavonoids display a wide array of biological activities that underscore their significance in human health. Their ability to modulate oxidative and inflammatory pathways means they can influence the onset and progression of chronic diseases, including cardiovascular disorders, cancer, diabetes, and neurodegenerative conditions. Continued research into flavonoid subclasses and their mechanisms of action is essential for fully harnessing their therapeutic potential. Integrating flavonoid-rich foods into the diet not only supports general well-being but may also serve as a complementary strategy in the prevention and management of various health conditions.

Mechanisms of Action

Antioxidant Effects

Flavonoids are powerful antioxidants found in a variety of fruits, vegetables, and plant-derived foods. One of their primary functions is to neutralize free radicals—unstable molecules that can damage cells and contribute to aging and chronic diseases[16, 35]. Flavonoids exert antioxidant effects through two main mechanisms. First, they directly scavenge reactive oxygen species (ROS) and reactive nitrogen species (RNS), thereby preventing oxidative damage to DNA, proteins, and lipids. Second, they enhance the body's own defense systems by upregulating the expression and activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase[51, 52].

A critical aspect of flavonoid action involves the modulation of redox-sensitive transcription factors. One such key regulator is nuclear factor erythroid 2–related factor 2 (Nrf2). When activated, Nrf2 translocates to the nucleus and binds to antioxidant response elements (ARE) in the DNA, promoting the expression of a wide range of cytoprotective genes[53, 54]. These genes code for enzymes and proteins that detoxify harmful substances and maintain cellular redox balance. Through these combined actions, flavonoids help protect cells from oxidative stress, which is linked to the pathogenesis of numerous diseases, including cardiovascular disorders, neurodegenerative diseases, diabetes, and cancer[54]. Their antioxidant properties also contribute to the preservation of endothelial function and the inhibition of LDL oxidation—two critical factors in the prevention of atherosclerosis. Overall, the multifaceted antioxidant mechanisms of flavonoids underscore their potential as dietary agents for promoting health and preventing disease.

Anti-Inflammatory Effects

Flavonoids also possess significant anti-inflammatory properties, which contribute to their therapeutic potential in chronic inflammatory conditions. Inflammation is a complex immune response that, when dysregulated, can lead to various diseases such as obesity, diabetes, and cardiovascular disorders[18, 20]. Flavonoids help mitigate inflammation by targeting and inhibiting key intracellular signaling pathways, most notably nuclear factor kappa B (NF-κB) and mitogen-activated protein kinases (MAPKs). These pathways control the transcription of genes encoding inflammatory mediators. By suppressing these pathways, flavonoids reduce the production and release of pro-inflammatory cytokines and biomarkers, including tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP)[55, 56]. These effects translate into decreased systemic inflammation and tissue damage. Furthermore, flavonoids limit the infiltration of immune cells, such as macrophages and neutrophils, into adipose tissue—an important aspect of managing inflammation in metabolic disorders.

Another important anti-inflammatory mechanism of flavonoids involves the modulation of adipokines—signaling molecules released by adipose tissue[57, 58]. In conditions like obesity, there is an imbalance in adipokines, with a shift toward pro-inflammatory types. Flavonoids help restore this balance by enhancing the levels of anti-inflammatory adipokines such as adiponectin and reducing levels of pro-inflammatory ones like leptin, particularly when leptin resistance is present. Together, these actions make flavonoids promising compounds for managing inflammation-related diseases.[58] Their ability to act on both immune cells and adipose-derived factors highlights their broad therapeutic scope. Regular consumption of flavonoid-rich foods may thus play a valuable role in preventing and controlling chronic inflammation and its associated health risks.

Bioavailability and Metabolism

While flavonoids exhibit numerous beneficial effects in vitro, their effectiveness in the human body is significantly influenced by bioavailability and metabolic processes. Bioavailability refers to the proportion of a compound that is absorbed and becomes available for biological activity at the target tissues[59]. For flavonoids, this is often limited due to several factors, including their chemical structure, glycosylation patterns, and solubility. Most dietary flavonoids are consumed in glycosylated forms, which require enzymatic conversion by intestinal enzymes or gut microbiota to be absorbed. The gut microbiota plays a crucial role in this process by metabolizing flavonoids into smaller, more bioactive phenolic compounds. Once absorbed, flavonoids undergo extensive metabolism in the liver through processes such as methylation, sulfation, and glucuronidation[59]. These modifications can affect their activity and half-life in the body.

To overcome limitations in bioavailability, several strategies are being explored. Nanoencapsulation technologies can enhance the solubility and stability of flavonoids, allowing for better absorption[60]. Coadministration with other nutrients, such as fats or piperine, can also improve uptake. Additionally, consuming flavonoids within whole food matrices may support more efficient digestion and absorption due to the synergistic effects of other dietary components. Despite these challenges, advancements in food science and pharmacology are helping to increase the clinical relevance of flavonoids. Understanding individual variability in metabolism and gut microbiota composition may further optimize the benefits of flavonoid intake. Ultimately, improving the bioavailability of flavonoids is essential for translating their promising in vitro effects into real-world health benefits.

Safety and Dosage Considerations

Flavonoids, a diverse group of phytonutrients found in many fruits, vegetables, and beverages like tea and wine, are widely recognized for their health-promoting properties, particularly their antioxidant and anti-inflammatory effects. When consumed as part of a balanced diet, flavonoids are generally considered safe for most individuals. They occur naturally in foods such as berries, apples, onions, citrus fruits, and dark chocolate, and intake through these sources typically poses minimal risk. However, the growing interest in their therapeutic potential has led to the development and marketing of high-dose flavonoid supplements, which raises concerns about their safety and potential interactions.

High concentrations of flavonoids, especially when taken in supplement form, may not always mimic the effects observed from dietary sources. At elevated levels, certain flavonoids can exhibit pro-oxidant behavior, which may paradoxically increase oxidative stress rather than mitigate it. This effect could be especially detrimental in individuals with chronic conditions like type 2 diabetes mellitus (T2DM), where oxidative balance is already compromised. Moreover, some flavonoids may interfere with the metabolism of prescription medications by affecting liver enzymes such as cytochrome P450, potentially altering drug efficacy or increasing the risk of side effects.

Currently, there is no standardized guideline for flavonoid supplementation, especially for long-term use in diabetic or obese populations. Most clinical studies vary in terms of dosage, flavonoid subtype, and duration, making it difficult to determine an optimal or safe intake range. Therefore, more rigorous, controlled studies are needed to establish clear dosage recommendations. In the meantime, healthcare providers should exercise caution and assess individual patient needs before recommending flavonoid supplements. Personalized guidance, taking into account factors such as current medications, nutritional status, and metabolic health, is essential to ensuring both the efficacy and safety of flavonoid use in clinical and everyday settings.

Future Perspectives and Conclusion

As research on plant-based compounds continues to advance, flavonoids have emerged as a compelling candidate in the fight against chronic diseases, particularly obesity-related type 2 diabetes mellitus (T2DM). Their multifunctional biological activities—including antioxidant, anti-inflammatory, and insulin-sensitizing effects—make them especially attractive for improving metabolic health. With obesity and diabetes reaching epidemic proportions globally, natural interventions like flavonoid-rich dietary strategies offer a cost-effective, accessible, and low-risk approach to managing these conditions.

Future directions in flavonoid research should prioritize long-term clinical trials involving diverse populations, particularly those with varying degrees of metabolic dysfunction. Many existing studies are limited by short durations or small sample sizes, and there's a need to better understand how flavonoids perform in real-world settings over extended periods. Furthermore, advancements in personalized nutrition—tailoring dietary recommendations based on an individual's genetic, metabolic, and lifestyle profiles—could enhance the effectiveness of flavonoid interventions and minimize potential adverse effects. Another critical area for future development involves improving flavonoid bioavailability. Despite their potential, many flavonoids are poorly absorbed, rapidly metabolized, or degraded during digestion, limiting their clinical impact. Innovative delivery systems such as nanoencapsulation, liposomal carriers, or formulation with absorption enhancers could significantly improve their therapeutic efficacy. Additionally, identifying synergistic effects between flavonoids and other nutrients or pharmaceuticals could open new avenues for integrated treatment strategies.

CONCLUSION

Flavonoids represent a promising adjunct in the management of obesity-linked T2DM, bridging preventive nutrition and therapeutic support. By reducing oxidative stress and inflammation, they can help mitigate key drivers of metabolic deterioration. While the path forward requires robust scientific validation, the integration of flavonoids into dietary and medical practice holds great promise for improving the lives of those affected by metabolic disorders.

REFERENCES

1. Achari, A.E., Jain, S.K.: Adiponectin, a Therapeutic Target for Obesity, Diabetes, and Endothelial Dysfunction. Int J Mol Sci. 18, 1321 (2017). https://doi.org/10.3390/ijms18061321
2. Anguita-Ruiz, A., Bustos-Aibar, M., Plaza-Díaz, J., Mendez-Gutierrez, A., Alcalá-Fdez, J., Aguilera, C.M., Ruiz-Ojeda, F.J.: Omics Approaches in Adipose Tissue and Skeletal Muscle Addressing the Role of Extracellular Matrix in Obesity and Metabolic Dysfunction. International Journal of Molecular Sciences. 22, 2756 (2021). https://doi.org/10.3390/ijms22052756

3. Alum, E.U.: Metabolic memory in obesity: Can early-life interventions reverse lifelong risks? Obesity Medicine. 55, 100610 (2025). https://doi.org/10.1016/j.obmed.2025.100610
4. Mann, V., Sundaresan, A., Shishodia, S.: Overnutrition and Lipotoxicity: Impaired Efferocytosis and Chronic Inflammation as Precursors to Multifaceted Disease Pathogenesis. Biology. 13, 241 (2024). https://doi.org/10.3390/biology13040241
5. Uti, D.E., Atangwho, I.J., Omang, W.A., Alum, E.U., Obeten, U.N., Udeozor, P.A., Agada, S.A., Bawa, I., Ogbu, C.O.: Cytokines as key players in obesity low grade inflammation and related complications. Obesity Medicine. 54, 100585 (2025). https://doi.org/10.1016/j.obmed.2025.100585
6. Agarwal, R.: Pathogenesis of Diabetic Nephropathy. In: Chronic Kidney Disease and Type 2 Diabetes. American Diabetes Association, Arlington (VA) (2021)
7. Cao, R., Tian, H., Zhang, Y., Liu, G., Xu, H., Rao, G., Tian, Y., Fu, X.: Signaling pathways and intervention for therapy of type 2 diabetes mellitus. MedComm (2020). 4, e283 (2023). https://doi.org/10.1002/mco2.283
8. Alum, E.U.: Optimizing patient education for sustainable self-management in type 2 diabetes. Discov Public Health. 22, 44 (2025). https://doi.org/10.1186/s12982-025-00445-5
9. Dludla, P.V., Mabhida, S.E., Ziqubu, K., Nkambule, B.B., Mazibuko-Mbeje, S.E., Hanser, S., Basson, A.K., Pheiffer, C., Kengne, A.P.: Pancreatic β-cell dysfunction in type 2 diabetes: Implications of inflammation and oxidative stress. World J Diabetes. 14, 130–146 (2023). https://doi.org/10.4239/wjd.v14.i3.130
10. Lourie, J., Goraltchouk, A., Fujishiro, A., Berger, N., Rosen, H.G., Hollander, J., Luppino, F., Seregin, A., Zou, K.: 792-P: A Novel Gene Therapy Platform Using GLP1 and EX4 Attenuates Hyperglycemia in a Preclinical Model of Type 2 Diabetes. Diabetes. 73, 792-P (2024). https://doi.org/10.2337/db24-792-P
11. Khin, P.P., Lee, J.H., Jun, H.-S.: Pancreatic Beta-cell Dysfunction in Type 2 Diabetes. Eur J Inflamm. 21, 1721727X231154152 (2023). https://doi.org/10.1177/1721727X231154152
12. Uti, D.E., Ibiam, U.A., Omang, W.A., Udeozor, P.A., Umoru, G.U., Nwadum, S.K., Bawa, I., Alum, E.U., Mordi, J.C., Okoro, E.O., Obeten, U.N., Onwe, E.N., Zakari, S., Opotu, O.R., Aja, P.M.: Buchholzia coriacea Leaves Attenuated Dyslipidemia and Oxidative Stress in Hyperlipidemic Rats and Its Potential Targets In Silico. Pharmaceutical Fronts. 05, e141–e152 (2023). https://doi.org/10.1055/s-0043-1772607
13. Uti, D.E., Atangwho, I.J., Alum, E.U., Egba, S.I., Ugwu, O.P.-C., Ikechukwu, G.C.: Natural Antidiabetic Agents: Current Evidence and Development Pathways from Medicinal Plants to Clinical use. Natural Product Communications. 20, 1934578X251323393 (2025). https://doi.org/10.1177/1934578X251323393
14. Alum, E.U.: Role of phytochemicals in cardiovascular disease management: Insights into mechanisms, efficacy, and clinical application. Phytomedicine Plus. 5, 100695 (2025). https://doi.org/10.1016/j.phyplu.2024.100695
15. Gouveia, H.J.C.B., Urquiza-Martínez, M.V., Manhães-de-Castro, R., Costa-de-Santana, B.J.R., Villarreal, J.P., Mercado-Camargo, R., Torner, L., de Souza Aquino, J., Toscano, A.E., Guzmán-Quevedo, O.: Effects of the Treatment with Flavonoids on Metabolic Syndrome Components in Humans: A Systematic Review Focusing on Mechanisms of Action. Int J Mol Sci. 23, 8344 (2022). https://doi.org/10.3390/ijms23158344
16. Thompson, A.S., Jennings, A., Bondonno, N.P., Tresserra-Rimbau, A., Parmenter, B.H., Hill, C., Perez-Cornago, A., Kühn, T., Cassidy, A.: Higher habitual intakes of flavonoids and flavonoid-rich foods are associated with a lower incidence of type 2 diabetes in the UK Biobank cohort. Nutr Diabetes. 14, 32 (2024). https://doi.org/10.1038/s41387-024-00288-0
17. Alum, E.U., Ugwu, O.P.C.: Beyond Nutrients: Exploring the Potential of Phytochemicals for Human Health. IAA JAS. 10, 1–7 (2023). https://doi.org/10.59298/IAAJAS/2023/4.1.3211
18. Cercato, L.M., Oliveira, J.P., Souza, M.T.S., Andrade, N., Martel, F., Camargo, E.A.: Effect of flavonoids in preclinical models of experimental obesity. PharmaNutrition. 16, 100260 (2021). https://doi.org/10.1016/j.phanu.2021.100260
19. Zhou, M., Konigsberg ,William H., Hao ,Canhua, Pan ,Yinbo, Sun ,Jie, and Wang, X.: Bioactivity and mechanisms of flavonoids in decreasing insulin resistance. Journal of Enzyme Inhibition and Medicinal Chemistry. 38, 2199168 (2023). https://doi.org/10.1080/14756366.2023.2199168
20. Saikia, L., Talukdar, N.C., Dutta, P.P.: Exploring the Therapeutic Role of Flavonoids Through AMPK Activation in Metabolic Syndrome: A Narrative Review. Phytotherapy Research. 39, 1403–1421 (2025). https://doi.org/10.1002/ptr.8428
21. Annett, S., Moore, G., Robson, T.: Obesity and Cancer Metastasis: Molecular and Translational Perspectives. Cancers. 12, 3798 (2020). https://doi.org/10.3390/cancers12123798
22. Coutinho, W., Halpern, B.: Pharmacotherapy for obesity: moving towards efficacy improvement. Diabetology & Metabolic Syndrome. 16, 6 (2024). https://doi.org/10.1186/s13098-023-01233-4

23. Kiers, D., van Eijk, L.T., van der Hoeven, J.G., Swinkels, D.W., Pickkers, P., Kox, M.: Hypoxia attenuates inflammation-induced hepcidin synthesis during experimental human endotoxemia. Haematologica. 104, e230–e232 (2019). https://doi.org/10.3324/haematol.2018.202796
24. Kodama, K., Toda, K., Morinaga, S., Yamada, S., Butte, A.J.: Anti-CD44 Antibody Treatment Lowers Hyperglycemia and Improves Insulin Resistance, Adipose Inflammation, and Hepatic Steatosis in Diet-Induced Obese Mice. Diabetes. 64, 867–875 (2015). https://doi.org/10.2337/db14-0149
25. Page, M.J., Kell, D.B., Pretorius, E.: The Role of Lipopolysaccharide-Induced Cell Signalling in Chronic Inflammation. Chronic Stress (Thousand Oaks). 6, 24705470221076390 (2022). https://doi.org/10.1177/24705470221076390
26. Yang, Z.-H., Chen, F.-Z., Zhang, Y.-X., Ou, M.-Y., Tan, P.-C., Xu, X.-W., Li, Q.-F., Zhou, S.-B.: Therapeutic targeting of white adipose tissue metabolic dysfunction in obesity: mechanisms and opportunities. MedComm. 5, e560 (2024). https://doi.org/10.1002/mco2.560
27. Strizova, Z., Benesova, I., Bartolini, R., Novysedlak, R., Cecrdlova, E., Foley, L.K., Striz, I.: M1/M2 macrophages and their overlaps – myth or reality? Clin Sci (Lond). 137, 1067–1093 (2023). https://doi.org/10.1042/CS20220531
28. Petersen, M.C., Shulman, G.I.: Mechanisms of Insulin Action and Insulin Resistance. Physiological Reviews. 98, 2133 (2018). https://doi.org/10.1152/physrev.00063.2017
29. Keane, K.N., Cruzat, V.F., Carlessi, R., de Bittencourt Jr., P.I.H., Newsholme, P.: Molecular Events Linking Oxidative Stress and Inflammation to Insulin Resistance and β-Cell Dysfunction. Oxidative Medicine and Cellular Longevity. 2015, 181643 (2015). https://doi.org/10.1155/2015/181643
30. Alves, I., Araújo, E.M.Q., Dalgaard, L.T., Singh, S., Børsheim, E., Carvalho, E.: Protective Effects of Sulforaphane Preventing Inflammation and Oxidative Stress to Enhance Metabolic Health: A Narrative Review. Nutrients. 17, 428 (2025). https://doi.org/10.3390/nu17030428
31. Alum, E.U., Nwuruku, A.O. and Edwin, N.: Targeting oxidative stress in cancer management: The role of antioxidant phytochemicals. KJHS. 4, 1–10 (2024). https://doi.org/10.59568/KJHS-2024-4-2-01
32. Alum, E.U.: Antioxidant Effect of Buchholzia coriacea Ethanol Leaf-Extract And Fractions On Freund's Adjuvant-Induced Arthritis In Albino Rats: A Comparative Study. Slovenian Veterinary Research. 59, (2022). https://doi.org/10.26873/SVR-1150-2022
33. Cunningham, A.L., Stephens, J.W., Harris, D.A.: Gut microbiota influence in type 2 diabetes mellitus (T2DM). Gut Pathogens. 13, 50 (2021). https://doi.org/10.1186/s13099-021-00446-0
34. Taheri, R., Mokhtari, Y., Yousefi, A.-M., Bashash, D.: The PI3K/Akt signaling axis and type 2 diabetes mellitus (T2DM): From mechanistic insights into possible therapeutic targets. Cell Biology International. 48, 1049–1068 (2024). https://doi.org/10.1002/cbin.12189
35. Zhou, M., Konigsberg, W.H., Hao, C., Pan, Y., Sun, J., Wang, X.: Bioactivity and mechanisms of flavonoids in decreasing insulin resistance. J Enzyme Inhib Med Chem. 38, 2199168. https://doi.org/10.1080/14756366.2023.2199168
36. Yang, C., Gundala, S.R., Mukkavilli, R., Vangala, S., Reid, M.D., Aneja, R.: Synergistic interactions among flavonoids and acetogenins in Graviola (Annona muricata) leaves confer protection against prostate cancer. Carcinogenesis. 36, 656–665 (2015). https://doi.org/10.1093/carcin/bgv046
37. Aghababaei, F., Hadidi, M.: Recent Advances in Potential Health Benefits of Quercetin. Pharmaceuticals (Basel). 16, 1020 (2023). https://doi.org/10.3390/ph16071020
38. Frenţ, O.-D., Stefan, L., Morgovan, C.M., Duteanu, N., Dejeu, I.L., Marian, E., Vicaş, L., Manole, F.: A Systematic Review: Quercetin—Secondary Metabolite of the Flavonol Class, with Multiple Health Benefits and Low Bioavailability. Int J Mol Sci. 25, 12091 (2024). https://doi.org/10.3390/ijms252212091
39. Chen, A.Y., Chen, Y.C.: A review of the dietary flavonoid, kaempferol on human health and cancer chemoprevention. Food Chem. 138, 2099–2107 (2013). https://doi.org/10.1016/j.foodchem.2012.11.139
40. Allemailem, K.S., Almatroudi, A., Alharbi, H.O.A., AlSuhaymi, N., Alsugoor, M.H., Aldakheel, F.M., Khan, A.A., Rahmani, A.H.: Apigenin: A Bioflavonoid with a Promising Role in Disease Prevention and Treatment. Biomedicines. 12, 1353 (2024). https://doi.org/10.3390/biomedicines12061353
41. Naponelli, V., Rocchetti, M.T., Mangieri, D.: Apigenin: Molecular Mechanisms and Therapeutic Potential against Cancer Spreading. International Journal of Molecular Sciences. 25, 5569 (2024). https://doi.org/10.3390/ijms25105569
42. Salehi, B., Venditti, A., Sharifi-Rad, M., Kręgiel, D., Sharifi-Rad, J., Durazzo, A., Lucarini, M., Santini, A., Souto, E.B., Novellino, E., Antolak, H., Azzini, E., Setzer, W.N., Martins, N.: The Therapeutic Potential of Apigenin. Int J Mol Sci. 20, 1305 (2019). https://doi.org/10.3390/ijms20061305
43. Kim, H.-J., Jin, B.-R., An, H.-J.: Hesperidin ameliorates benign prostatic hyperplasia by attenuating cell proliferation, inflammatory response, and epithelial-mesenchymal transition via the TGF-β1/Smad signaling pathway. Biomedicine & Pharmacotherapy. 160, 114389 (2023). https://doi.org/10.1016/j.biopha.2023.114389

44. Ma, R., You, H., Liu, H., Bao, J., Zhang, M.: Hesperidin : a citrus plant component, plays a role in the central nervous system. Heliyon. 10, e38937 (2024). https://doi.org/10.1016/j.heliyon.2024.e38937
45. Baldi, A., Abramovič, H., Poklar Ulrih, N., Daglia, M.: Tea Catechins. In: Xiao, J., Sarker, S.D., and Asakawa, Y. (eds.) Handbook of Dietary Phytochemicals. pp. 1–46. Springer, Singapore (2020)
46. Alum, E.U.: Phytochemicals in malaria treatment: Mechanisms of action and clinical efficacy. KJHS. 4, 71–84 (2024). https://doi.org/10.59568/KJHS-2024-4-2-06
47. Khoo, H.E., Azlan, A., Tang, S.T., Lim, S.M.: Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food Nutr Res. 61, 1361779 (2017). https://doi.org/10.1080/16546628.2017.1361779
48. Ahmad, S., Ahsan, F., Ansari, J.A., Mahmood, T., Shamim, A., Bano, S., Tiwari, R., Ansari, V.A., Shafiurrahman, Kesari, M.: A review on daidzein as food supplement: Exploring its phytopharmacological and preclinical status. eFood. 5, e70008 (2024). https://doi.org/10.1002/efd2.70008
49. Alshehri, M.M., Sharifi-Rad, J., Herrera-Bravo, J., Jara, E.L., Salazar, L.A., Kregiel, D., Uprety, Y., Akram, M., Iqbal, M., Martorell, M., Torrens-Mas, M., Pons, D.G., Daştan, S.D., Cruz-Martins, N., Ozdemir, F.A., Kumar, M., Cho, W.C.: Therapeutic Potential of Isoflavones with an Emphasis on Daidzein. Oxidative Medicine and Cellular Longevity. 2021, 6331630 (2021). https://doi.org/10.1155/2021/6331630
50. Kim, I.-S.: Current Perspectives on the Beneficial Effects of Soybean Isoflavones and Their Metabolites for Humans. Antioxidants. 10, 1064 (2021). https://doi.org/10.3390/antiox10071064
51. Ibiam, U., Ama, Alum, E., Ugo, Aja, P., Maduabuchi, Orji, O., Uche, Ezeani, N., Nwamaka, U., P.C., U., Ugo, A.: Comparative Analysis of Chemical Composition of Buchholzia coriacea Ethanol Leaf-Extract, Aqueous and Ethylacetate Fractions. 6358–6369 (2018). https://doi.org/10.5281/zenodo.1311171
52. Alum, E., Diana, M., P.C., U., Aja, P., Obeagu, E., Uti, D., Okon, M., Extension, K.P.: Phytochemical composition of Datura stramonium Ethanol leaf and seed extracts: A Comparative Study. 10, 118–125 (2023)
53. Tanyong, D.I., Panichob, P., Kheansaard, W., Fucharoen, S.: Effect of Tumor Necrosis Factor-Alpha on Erythropoietin- and Erythropoietin Receptor-Induced Erythroid Progenitor Cell Proliferation in β-Thalassemia/Hemoglobin E Patients. Turk J Haematol. 32, 304–310 (2015). https://doi.org/10.4274/tjh.2014.0079
54. He, F., Ru, X., Wen, T.: NRF2, a Transcription Factor for Stress Response and Beyond. Int J Mol Sci. 21, 4777 (2020). https://doi.org/10.3390/ijms21134777
55. Wang, X., Ma, Y., Xu, Q., Shikov, A.N., Pozharitskaya, O.N., Flisyuk, E.V., Liu, M., Li, H., Vargas-Murga, L., Duez, P.: Flavonoids and saponins: What have we got or missed? Phytomedicine. 109, 154580 (2023). https://doi.org/10.1016/j.phymed.2022.154580
56. Ziqubu, K., Mazibuko-Mbeje, S.E., Dludla, P.V.: Regulation of adipokine and batokine secretion by dietary flavonoids, as a prospective therapeutic approach for obesity and its metabolic complications. Biochimie. 230, 95–113 (2025). https://doi.org/10.1016/j.biochi.2024.11.007
57. Ahima, R.S., Park, H.-K.: Adipokines and Metabolism. In: Ahima, R.S. (ed.) Metabolic Syndrome: A Comprehensive Textbook. pp. 1–22. Springer International Publishing, Cham (2020)
58. Freitas Lima, L.C., Braga, V. de A., do Socorro de França Silva, M., Cruz, J. de C., Sousa Santos, S.H., de Oliveira Monteiro, M.M., Balarini, C. de M.: Adipokines, diabetes and atherosclerosis: an inflammatory association. Front. Physiol. 6, (2015). https://doi.org/10.3389/fphys.2015.00304
59. Cassidy, A., Minihane, A.-M.: The role of metabolism (and the microbiome) in defining the clinical efficacy of dietary flavonoids. The American Journal of Clinical Nutrition. 105, 10 (2016). https://doi.org/10.3945/ajcn.116.136051
60. Witika, B.A., Makoni, P.A., Matafwali, S.K., Chabalenge, B., Mwila, C., Kalungia, A.C., Nkanga, C.I., Bapolisi, A.M., Walker, R.B.: Biocompatibility of Biomaterials for Nanoencapsulation: Current Approaches. Nanomaterials (Basel). 10, 1649 (2020). https://doi.org/10.3390/nano10091649

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