©IDOSR PUBLICATIONS International Digital Organization for Scientific Research

IDOSR JOURNAL OF EXPERIMENTAL SCIENCES 12(2): 41-46, 2026 ISSN: 2579-0781

https://doi.org/10.59298/IDOSR/JES/06/1224146 IDOSRJES12206

Green-Synthesized Nanoparticles from Medicinal Plants in Obesity and Metabolic Syndrome Therapy

Kabazzi Douglas T.

Department of Pharmaceutics Kampala International University Uganda
Email: t.kabazzi@studwc.kiu.ac.ug

ABSTRACT

Green synthesis of nanoparticles using medicinal plant extracts has emerged as a bioinspired approach to generate nanomaterials with potential application in obesity and metabolic syndrome therapy. Plant phytochemicals act as reducing, capping, and stabilizing agents, enabling low-cost and solvent-minimized fabrication while imparting bioactive surface coronas that may influence metabolic and inflammatory pathways. In obesity and metabolic syndrome, where adipose inflammation, insulin resistance, dyslipidemia, oxidative stress, and hepatic steatosis co-exist, green-synthesized nanoparticles are being explored for antioxidant and anti-inflammatory modulation, improved glucose and lipid handling, and potential targeting of inflamed metabolic tissues. Despite expanding preclinical evidence, translation is constrained by variability in plant extract composition, inconsistent particle physicochemical attributes, limited mechanistic clarity regarding the active entity, and unresolved long-term safety questions, especially for metal and metal-oxide nanoparticles that may accumulate with chronic use. Standardized synthesis protocols, rigorous characterization, and comprehensive biodistribution and toxicology are therefore critical. This review examines the rationale for plant-mediated nanoparticle synthesis, proposed mechanisms relevant to obesity and metabolic syndrome, and key translational challenges including reproducibility, regulatory expectations, and clinical trial design. A pragmatic pathway is proposed that prioritizes biodegradable or safely excretable systems, conservative dosing strategies, and evidence linking particle attributes to pharmacodynamic endpoints and clinically meaningful metabolic outcomes.

Keywords: green synthesis; medicinal plants; nanoparticles; metabolic syndrome; obesity

INTRODUCTION

Obesity and metabolic syndrome represent a clustered spectrum of cardiometabolic dysfunction characterized by central adiposity, insulin resistance, dyslipidemia, hypertension, chronic low-grade inflammation, and frequently non-alcoholic fatty liver disease[1–3]. These conditions increase risk of type 2 diabetes, cardiovascular disease, and chronic kidney disease, imposing a sustained burden on health systems worldwide[4, 5]. Although lifestyle interventions remain foundational, long-term adherence and response variability limit effectiveness[6, 7]. Pharmacotherapies have advanced, yet access, cost, side effects, and incomplete coverage of inflammatory and oxidative drivers continue to motivate exploration of adjunctive strategies[8]. Within this context, nanomedicine and natural products have each been proposed as complementary tools: natural products for their pleiotropic bioactivities and nanomedicine for its ability to improve delivery, stability, and tissue distribution[8].

A distinct convergence of these domains is the green synthesis of nanoparticles using medicinal plants. In green synthesis, plant extracts are used to reduce metal salts or otherwise drive nanoparticle formation, while plant phytochemicals simultaneously cap and stabilize the emerging particles[9]. This approach is attractive for multiple reasons. It can reduce reliance on harsh reducing agents and organic solvents, lower energy demands, and produce nanoparticles under relatively mild conditions[9]. Importantly, the phytochemical corona formed on particle surfaces may confer biological activity, potentially combining intrinsic properties of the nanoparticle core with the pharmacology of plant-derived compounds[10]. This creates a hybrid therapeutic hypothesis: the particle acts as both a nanoscale material with unique physicochemical behavior and a carrier or presentation scaffold for bioactive phytochemicals[10].

In obesity and metabolic syndrome, the rationale for green-synthesized nanoparticles is often framed around oxidative stress and inflammation, which are central to insulin resistance and adipose dysfunction[11, 12]. Expanded adipose depots exhibit hypoxia, immune infiltration, and elevated reactive oxygen species, which impair insulin signaling and promote lipotoxicity. Endothelial dysfunction and chronic inflammation further exacerbate metabolic dysregulation, while hepatic steatosis and mitochondrial stress contribute to systemic metabolic decline. Plant-derived antioxidants and anti-inflammatory agents can modulate these processes, but their bioavailability is often low and variable. Green-synthesized nanoparticles are therefore positioned as a way to enhance functional delivery and biological potency, sometimes showing improved activity in preclinical models compared with crude extracts alone[13]. However, the therapeutic promise is intertwined with translational uncertainty. Green synthesis is sensitive to variability in plant extract composition, which depends on species, geography, harvest season, extraction method, and storage[14]. This variability can translate into inconsistent particle size distribution, morphology, surface charge, and surface chemistry, which are critical determinants of biodistribution, cellular uptake, and toxicity. Furthermore, the mechanistic basis of biological effects is often unclear. It may be driven by the nanoparticle core, by phytochemicals attached to the surface, by released ions, or by a combination of these factors. Without clarity, optimizing efficacy while ensuring safety is difficult[14].

Long-term safety is particularly important because obesity and metabolic syndrome are chronic conditions. Many green-synthesized nanoparticles reported in the literature are metal or metal-oxide particles, which raise legitimate concerns about accumulation, oxidative damage at high exposure, and immune activation with repeated dosing[15]. While some nanoparticles are proposed for diagnostic or short-term applications, obesity therapy typically requires months to years of exposure, demanding stringent evaluation of biodistribution, clearance, genotoxicity, and organ-specific toxicity. The translational pathway is therefore narrower than in short-term indications. It likely favors systems that are biodegradable, safely excretable, or demonstrably non-accumulating at therapeutic doses.

Another translational issue is the regulatory identity of green-synthesized nanoparticles. They sit at the intersection of botanical products and engineered nanomaterials. If therapeutic claims are made, regulators will require robust characterization and reproducibility. Yet botanical variability complicates standardization, and nanomaterial regulation demands defined critical quality attributes[16]. Therefore, green-synthesized nanoparticles must move beyond proof-of-concept toward standardized manufacturing protocols, validated analytical methods, and clear PK–PD frameworks linking particle attributes to metabolic outcomes[16]. This review examines green-synthesized nanoparticles derived from medicinal plants as candidates for obesity and metabolic syndrome therapy. We discuss how green synthesis produces nanoparticles with distinctive surface chemistry, how such particles may act on metabolic pathways, and what evidence exists for their efficacy in preclinical obesity-related models. We then analyze major translational challenges: reproducibility, mechanistic ambiguity, long-term safety, manufacturing scalability, and clinical trial design. Finally, we propose a pragmatic development roadmap that prioritizes safe material choices, rigorous standardization, and clinically meaningful endpoints.

2. Principles of Green Synthesis and Why It Matters for Metabolic Therapy

Green synthesis typically involves mixing a plant extract with a precursor salt, allowing phytochemicals such as polyphenols, flavonoids, terpenoids, sugars, and organic acids to drive reduction and nucleation while simultaneously coating the particle surface[17]. The resulting nanoparticles are often described as "capped" by plant compounds, which can influence stability, aggregation behavior, and interaction with biological interfaces[18]. For metabolic therapy, this surface chemistry is not a minor detail; it can affect protein corona formation, immune recognition, and cellular uptake in tissues central to obesity, including liver, adipose depots, and vascular endothelium.

The appeal of green synthesis in obesity and metabolic syndrome is partly conceptual. Many plant extracts have established antioxidant and anti-inflammatory effects, and the nanoparticle format is hypothesized to enhance potency by increasing surface area, improving cellular interaction, or enabling more efficient delivery[19]. The plant-derived surface corona may also provide a multi-target pharmacological signature, resembling the pleiotropy of traditional botanical medicines but in a more engineered presentation. In addition, the "green" framing often implies potential for scalable, lower-cost production, which is attractive for conditions with large global prevalence[19].

Yet the same features introduce complexity. Plant extracts are mixtures, so two batches of "the same" plant extract can differ meaningfully, shifting reduction kinetics and producing nanoparticles with different sizes and surfaces[20]. Since nanoparticle behavior is highly sensitive to these attributes, green synthesis demands rigorous standardization to be therapeutically credible.

3. Mechanistic Rationale in Obesity and Metabolic Syndrome

The proposed mechanisms by which green-synthesized nanoparticles may benefit obesity and metabolic syndrome generally converge on oxidative stress, inflammation, and metabolic signaling integration. In adipose tissue, chronic inflammation and oxidative stress disrupt insulin signaling, shift adipokine profiles, and increase lipolysis-driven fatty acid spillover, contributing to hepatic steatosis and systemic insulin resistance[21–23]. In the liver, oxidative stress and lipid overload impair mitochondrial function and promote inflammatory signaling,

reinforcing dyslipidemia and glucose dysregulation. In the vasculature, endothelial dysfunction contributes to hypertension and impaired metabolic perfusion.

Green-synthesized nanoparticles may influence these processes through several non-exclusive routes. The plant-derived surface corona may deliver antioxidant and anti-inflammatory phytochemicals in a form that interacts more efficiently with cellular membranes and immune pathways[16, 24]. The nanoparticle core may modulate redox signaling, sometimes acting as a catalytic surface for reactive oxygen species scavenging or, conversely, generating oxidative stress at high exposure. Some nanoparticles may affect macrophage activation states and inflammatory cytokine production, potentially improving insulin sensitivity indirectly by reducing inflammatory tone in adipose and liver. Others may influence glucose transport and lipid metabolism pathways, though mechanistic specificity remains variable across studies[16].

A key translational need is to distinguish whether metabolic benefit arises from improved delivery of phytochemicals, from nanoparticle-mediated immune modulation, from ion release, or from mixed effects. Without this separation, dose optimization and long-term safety assessment remain uncertain.

4. Preclinical Evidence Landscape and What It Actually Shows

Preclinical studies of green-synthesized nanoparticles in obesity-related models often report improvements in glycemic control, lipid profiles, oxidative stress markers, and inflammatory cytokines, sometimes accompanied by reduced weight gain or adiposity[25]. These signals are consistent with the general premise that reducing inflammation and oxidative stress can improve insulin sensitivity and lipid handling. In some cases, reported benefits appear stronger than those achieved with crude plant extracts at similar nominal doses, supporting the hypothesis that nanoscale presentation can enhance biological effect[25].

However, the evidence landscape has limitations that complicate translation. Many studies do not fully characterize nanoparticles beyond basic size estimates, and batch-to-batch reproducibility is rarely evaluated[26]. Dose reporting is often ambiguous, particularly when the "active" is a composite of nanoparticle mass plus unknown quantities of surface-bound phytochemicals. Biodistribution and clearance data are frequently incomplete, which is problematic for chronic metabolic indications[27]. Mechanistic endpoints in adipose tissue biology, such as macrophage polarization, adipokines, insulin signaling markers, and liver steatosis quantification are not consistently measured, making it difficult to link metabolic improvements to specific tissue actions. Additionally, comparisons to optimized conventional formulations of the same phytochemicals are uncommon, so it is unclear whether green nanoparticles outperform simpler delivery approaches[27]. Therefore, while preclinical signals are encouraging, they are not yet sufficiently standardized to define a clear translational winner. The most informative studies are those that couple metabolic outcomes with deep particle characterization, biodistribution, and mechanistic tissue biomarkers, enabling a coherent PK–PD narrative.

5. Translational Challenges: Reproducibility, Safety, and Regulatory Fit

Reproducibility is a central barrier. Green synthesis depends on complex mixtures whose composition varies with plant source and processing. This variability can shift particle size distribution, morphology, and surface chemistry, altering biological behavior[28]. Therapeutic translation requires standardized botanical inputs, controlled extraction protocols, and defined synthesis conditions that yield consistent nanoparticle attributes. Without this, clinical trials cannot be reliably interpreted or reproduced[29].

Long-term safety is the second major barrier. Obesity and metabolic syndrome require prolonged treatment, but many green-synthesized nanoparticles are metal or metal-oxide cores that may accumulate in organs such as the liver and spleen. Chronic exposure raises concerns about oxidative damage, immune activation, and organ toxicity. Plant-derived capping agents may reduce acute toxicity, but they do not guarantee safe chronic dosing[3, 4, 30]. Translation demands repeated-dose toxicology, biodistribution and clearance studies, and evaluation of genotoxicity and reproductive effects where relevant. The gut microbiome is also a consideration because plant-derived compounds and nanoparticles can reshape microbial ecosystems; unintended dysbiosis may undermine metabolic benefit or cause adverse effects[31, 32].

Regulatory fit is a third barrier. A green-synthesized nanoparticle intended to treat metabolic syndrome is not a dietary supplement in the conventional sense; it is an engineered nanomaterial with a botanical-derived surface chemistry. This implies drug-like expectations for quality control, characterization, stability, and efficacy evidence. Defining the product identity, controlling impurities, and demonstrating batch consistency are non-negotiable steps.

6. Designing Safer, More Translatable Green Nanoparticles for Chronic Metabolic Use

A translationally credible strategy for green-synthesized nanoparticles in metabolic disease must prioritize material choices and dosing strategies compatible with long-term use[33]. Platforms that are biodegradable or that generate safely excretable products are more likely to succeed than those with persistent inorganic cores[33]. If inorganic cores are used, the burden of proof for clearance and non-accumulation becomes high, and formulation should aim for minimal effective doses. Surface chemistry must be controlled and characterized, because it determines biological identity in vivo through protein corona formation and immune recognition.

Mechanism-aligned design is also essential. If therapeutic action is primarily antioxidant and anti-inflammatory, the formulation should demonstrate engagement of those pathways in relevant tissues, not only in circulating biomarkers[34]. If adipose immune modulation is proposed, uptake in adipose-resident macrophages and shifts

in macrophage polarization should be demonstrated. If hepatic steatosis improvement is the target, liver lipid handling and histological steatosis endpoints are necessary. Gut-mediated mechanisms require evaluation of microbiome and bile acid shifts[34]. These endpoints move the field from descriptive benefit to actionable mechanism, enabling rational optimization.

Manufacturing considerations should be addressed early. Green synthesis must be adapted into scalable processes with defined controls over extract composition, reaction parameters, purification, and storage stability. Without stable and reproducible products, even the best mechanistic rationale will fail in translation.

7. Roadmap for Clinical Translation in Obesity and Metabolic Syndrome

A pragmatic translational pathway begins by defining product identity in a way that is compatible with regulatory expectations. This requires specifying the plant source, extraction method, synthesis chemistry, purification process, and critical nanoparticle attributes. Analytical frameworks should quantify not only particle size distribution and surface charge but also surface-bound phytochemical signatures and stability under physiological conditions[35].

Next, development should establish the active hypothesis by separating the contributions of the nanoparticle core and the phytochemical corona. Comparative studies using matched doses of extract alone, nanoparticle core alone, and green-synthesized nanoparticles are needed to define what adds value. PK–PD work should include biodistribution and clearance, metabolomic and inflammatory biomarkers, and tissue-level endpoints in adipose and liver[36]. Safety evaluation must include repeated-dose studies that reflect chronic use, with special attention to hepatic accumulation, immune activation, and microbiome perturbation[36].

Clinical trials should focus on meaningful endpoints relevant to metabolic syndrome, including waist circumference, body fat measures, insulin sensitivity indices, lipid profiles, blood pressure, inflammatory markers, and liver-related endpoints when NAFLD is present[37]. Trials should also control or measure diet context because both plant phytochemicals and nanoparticles can exhibit food-dependent effects. Stratifying participants by baseline inflammation, insulin resistance severity, and NAFLD markers can improve signal detection[37]. If this roadmap is followed, green-synthesized nanoparticles may evolve from exploratory nanomaterials into clinically credible adjuncts for metabolic syndrome, although the pathway will likely favor systems with strong safety margins and minimal long-term accumulation risk.

CONCLUSION

Green-synthesized nanoparticles produced from medicinal plants represent an appealing convergence of ethnopharmacology and nanotechnology for obesity and metabolic syndrome therapy. Their promise lies in the potential to combine plant-derived anti-inflammatory and antioxidant activity with nanoscale properties that enhance biological interaction and possibly improve metabolic outcomes. However, translation is constrained by extract-driven variability, inconsistent particle attributes, mechanistic ambiguity about the true active entity, and unresolved chronic safety concerns, particularly for persistent inorganic cores. To become therapeutically viable, green-synthesized nanoparticles must be standardized, rigorously characterized, and supported by biodistribution and repeated-dose toxicology that reflect long-term metabolic use. Clinical development must demonstrate PK–PD linkage and meaningful improvements in cardiometabolic endpoints beyond short-term biomarker shifts. A minimal-risk, evidence-led development strategy that prioritizes safe material choices, scalable manufacturing, and reproducible product identity offers the most credible route for plant-mediated nanoparticles to contribute to obesity and metabolic syndrome therapy.

REFERENCES

1. Abdelgadir, O., Hussain, M.R., Hollis-Hansen, K., Barcenas, C.H., Kuo, Y.-F., Skinner, C.S., Cowell, L.G., Messiah, S.E., Lopez, D.S.: Anti-Obesity Medications and the Risk of Obesity-Related Cancers in Older Women: A Propensity Score Matching Analysis of 2007-2015 SEER-Medicare Data. Cancers. 17, 1624 (2025). https://doi.org/10.3390/cancers17101624
2. Al Madhoun, A., Haddad, D., Kochumon, S., Thomas, R., Miranda, L., George, P., Abu-Khalaf, N., Al-Mulla, F., Ahmad, R.: TNF-α/NF-κB mediated upregulation of Dectin-1 in hyperglycemic obesity: implications for metabolic inflammation and diabetes. J. Transl. Med. 23, 462 (2025). https://doi.org/10.1186/s12967-025-06303-x
3. Allocca, S., Monda, A., Messina, A., Casillo, M., Sapuppo, W., Monda, V., Polito, R., Maio, G.D., Monda, M., Marra, M.L.: Endocrine and Metabolic Mechanisms Linking Obesity to Type 2 Diabetes: Implications for Targeted Therapy. Healthcare. 13, (2025). https://doi.org/10.3390/healthcare13121437
4. Alum, E.U., Izah, S.C., Betiang, P.A., Paul-Chima Ugwu, O., Ainebyoona, C., Uti, D.E., Echegu, D.A., Alum, B.N.: The Ketogenic Diet in Obesity Management: Friend or Foe? Cell Biochem. Biophys. (2025). https://doi.org/10.1007/s12013-025-01878-0
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. Obes. Med. 54, 100585 (2025). https://doi.org/10.1016/j.obmed.2025.100585
6. Akwari, A.A., Kibuuka, M., Ekpang, P.O., EkpangII, J.E., Orji, O.U.: Global Food Policies and Obesity: Lessons From Selected Country Experiences. Food Nutr. Bull. 47, 51–64 (2026). https://doi.org/10.1177/03795721251408170

7. Aloh, H.E., Obasi, D.C., Okoroh, P.N., Aniokete, U.C., Emeruwa, A.P.: Maternal Nutrition, Toxicants, and Epigenetic Programming of Obesity Across Generations. Diabetes Metab. Syndr. Obes. 18, 4873–4911 (2025). https://doi.org/10.2147/DMSO.S579409
8. Pennington, B., Cummins, E., Chandler, A., Fotheringham, J.: Challenges in Modelling the Cost Effectiveness of Pharmacotherapies for Obesity. Pharmacoeconomics. 43, 1171–1178 (2025). https://doi.org/10.1007/s40273-025-01520-0
9. Mani, S.R., Valliappan, M.S., Dhandapani, D., Desamuthu, G., Ravichandran, M., Babu, B., Kandhasamy, S.: Environmentally sustainable green synthesis of novel nano-hydroxyapatite derived from *Sesbania grandiflora* leaf and *Sesamum indicum* seed: *In Vitro* evaluation for dental restorative applications. Mater. 8, 100828 (2025). https://doi.org/10.1016/j.nxmate.2025.100828
10. Tanwar, S.N., Parauha, Y.R., There, Y., Swart, H.C., Dhoble, S.J.: Plant-Based Biosynthesis of Metal and Metal Oxide Nanoparticles: An Update on Antimicrobial and Anticancer Activity. ChemBioEng Rev. 11, e202400012 (2024). https://doi.org/10.1002/cben.202400012
11. Adetunji, C.O., Michael, O.S., Rathee, S., Singh, K.R., Ajayi, O.O., Adetunji, J.B., Ojha, A., Singh, J., Singh, R.P.: Potentialities of nanomaterials for the management and treatment of metabolic syndrome: A new insight. Mater. Today Adv. 13, 100198 (2022). https://doi.org/10.1016/j.mtadv.2021.100198
12. Chen, B., Li, T., Wu, Y., Song, L., Wang, Y., Bian, Y., Qiu, Y., Yang, Z.: Lipotoxicity: A New Perspective in Type 2 Diabetes Mellitus. Diabetes Metab. Syndr. Obes. 18, 1223–1237 (2025). https://doi.org/10.2147/DMSO.S511436
13. Uti, D.E., Atangwho, I.J., Alum, E.U., Ntaobeten, E., Obeten, U.N., Bawa, I., Agada, S.A., Ukam, C.I.-O., Egbung, G.E.: Antioxidants in cancer therapy mitigating lipid peroxidation without compromising treatment through nanotechnology. Discov. Nano. 20, 70 (2025). https://doi.org/10.1186/s11671-025-04248-0
14. Nair, A., Maity, S., Pai, V.: Sustainable extraction: a comprehensive review of advancements beyond conventional methods. Microchem. J. 220, 116360 (2026). https://doi.org/10.1016/j.microc.2025.116360
15. Ahari, H., Jafari, A., Ozdal, T., Moradi, S., Bahari, H.-R., Wu, Q., Eş, I., Mousavi Khaneghah, A.: Recent innovations in metal-based nanoparticles for food packaging: A focus on safety and environmental impact. Appl. Food Res. 5, 100860 (2025). https://doi.org/10.1016/j.afres.2025.100860
16. Protik, T.I., Ridoy, M.N., Sazid, M.G., Supto, S.T.J.: Advances of Green Synthesized Nanomaterials in Different Industries. Mater. Proc. 25, (2026). https://doi.org/10.3390/materproc2025025022
17. Osman, A.I., Zhang, Y., Farghali, M., Rashwan, A.K., Eltaweil, A.S., Abd El-Monaem, E.M., Mohamed, I.M.A., Badr, M.M., Ihara, I., Rooney, D.W., Yap, P.-S.: Synthesis of green nanoparticles for energy, biomedical, environmental, agricultural, and food applications: A review. Environ. Chem. Lett. 22, 841–887 (2024). https://doi.org/10.1007/s10311-023-01682-3
18. Magadani, R., Ndinteh, D.T., Roux, S., Nangah, L.P., Atangwho, I.J., Egba, S.I.: Cytotoxic Effects of Lecaniodiscus Cupanioides (Planch.) Extract and Triterpenoids-derived Gold Nanoparticles On MCF-7 Breast Cancer Cell Lines. Anticancer Agents Med. Chem. 25, 841–850 (2025). https://doi.org/10.2174/0118715206325529241004064307
19. Rana, N., Singh, S.K., Banu, N.A., Hjazi, A., Vamanu, E., Singh, M.P.: The Ethnopharmacological Properties of Green-Engineered Metallic Nanoparticles against Metabolic Disorders. Medicina (Mex.). 59, 1022 (2023). https://doi.org/10.3390/medicina59061022
20. Lakhani, K.G., Hamid, R., Motamedi, E., Marviya, G.V.: A review on plant metabolite-mediated nanoparticle synthesis: sustainable applications in horticultural crops. Front. Nanotechnol. 7, (2025). https://doi.org/10.3389/fnano.2025.1545413
21. Ábel, T., Csajbókné, É.C.: Semaglutide-Mediated Remodeling of Adipose Tissue in Type 2 Diabetes: Molecular Mechanisms Beyond Glycemic Control. Int. J. Mol. Sci. 27, (2026). https://doi.org/10.3390/ijms27031186
22. Agrawal, S., Klarqvist, M.D.R., Diamant, N., Stanley, T.L., Ellinor, P.T., Mehta, N.N., Philippakis, A., Ng, K., Claussnitzer, M., Grinspoon, S.K., Batra, P., Khera, A.V.: BMI-adjusted adipose tissue volumes exhibit depot-specific and divergent associations with cardiometabolic diseases. Nat. Commun. 14, 266 (2023). https://doi.org/10.1038/s41467-022-35704-5
23. Alexaki, V.I.: Adipose tissue-derived mediators of systemic inflammation and metabolic control. Curr. Opin. Endocr. Metab. Res. 37, 100560 (2024). https://doi.org/10.1016/j.coemr.2024.100560
24. Hasan Chowdhury, M.A., Al Araby, S.Q., Alelwani, W., Kattan, S.W., Mansouri, O.A., Uddin Rahat, M.R., Khan, M., Tangpong, J., Rahman, Md.A.: Green-synthesized nanoparticles of the polyherbal extract attenuate the necrosis of pancreatic β-cell in a streptozotocin-induced diabetic model. Heliyon. 9, e16137 (2023). https://doi.org/10.1016/j.heliyon.2023.e16137
25. Madbouly, N., Mahmoud, A., Mohamed, A., Magdy, J., Hassan, M., Osama, M., Adel, M., Romany, Y., Farid, A.: Green silver nanoparticles ameliorate diet-induced obesity through antioxidant and anti-inflammatory properties. Beni-Suef Univ. J. Basic Appl. Sci. 14, 69 (2025). https://doi.org/10.1186/s43088-025-00656-4

26. Sharifi, S., Mahmoud, N.N., Voke, E., Landry, M.P., Mahmoudi, M.: Importance of Standardizing Analytical Characterization Methodology for Improved Reliability of the Nanomedicine Literature. Nano-Micro Lett. 14, 172 (2022). https://doi.org/10.1007/s40820-022-00922-5
27. Desai, N., Rana, D., Patel, M., Bajwa, N., Prasad, R., Vora, L.K.: Nanoparticle Therapeutics in Clinical Perspective: Classification, Marketed Products, and Regulatory Landscape. Small. 21, 2502315 (2025). https://doi.org/10.1002/smll.202502315
28. Khan, H., Piccolella, S., Pacifico, S.: Harnessing plant extracts for green nanoparticle synthesis: Toward a sustainable future. Mater. Today Sustain. 31, 101195 (2025). https://doi.org/10.1016/j.mtsust.2025.101195
29. Husak, V., Faltus, M., Bilavcik, A., Narozhnyi, S., Bobrova, O.: Nanoparticle Applications in Plant Biotechnology: A Comprehensive Review. Plants. 15, 364 (2026). https://doi.org/10.3390/plants15030364
30. 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. Pharm. Fronts. 05, e141–e152 (2023). https://doi.org/10.1055/s-0043-1772607
31. Luo, K., Peters, B.A., Moon, J.-Y., Xue, X., Wang, Z., Usyk, M., Hanna, D.B., Landay, A.L., Schneider, M.F., Gustafson, D., Weber, K.M., French, A., Sharma, A., Anastos, K., Wang, T., Brown, T., Clish, C.B., Kaplan, R.C., Knight, R., Burk, R.D., Qi, Q.: Metabolic and inflammatory perturbation of diabetes associated gut dysbiosis in people living with and without HIV infection. Genome Med. 16, 59 (2024). https://doi.org/10.1186/s13073-024-01336-1
32. Patra, D., Banerjee, D., Ramprasad, P., Roy, S., Pal, D., Dasgupta, S.: Recent insights of obesity-induced gut and adipose tissue dysbiosis in type 2 diabetes. Front. Mol. Biosci. 10, 1224982 (2023). https://doi.org/10.3389/fmolb.2023.1224982
33. Ayub, A., Wani, A.K., Malik, S.M., Ayub, M., Singh, R., Chopra, C., Malik, T.: Green nanoscience for healthcare: Advancing biomedical innovation through eco-synthesized nanoparticle. Biotechnol. Rep. 47, e00913 (2025). https://doi.org/10.1016/j.btre.2025.e00913
34. Gonçalves, R.V., Sarandy, M.M., Esposito, D., do Carmo Gouveia Peluzio, M.: Mechanisms, Biomarkers, and Therapeutics Involved in Inflammatory Disorders and Tissue Repair 2021. Oxid. Med. Cell. Longev. 2022, 9806128 (2022). https://doi.org/10.1155/2022/9806128
35. Ferroni, L., Zavan, B.: Plant-Derived Extracellular Vesicles in Cosmetics: Building a Framework for Safety, Efficacy, and Quality. Cosmetics. 12, (2025). https://doi.org/10.3390/cosmetics12060252
36. Jain, A., Bhise, K.: Nano-pharmacokinetics and pharmacodynamics of green-synthesized ZnO nanoparticles: a pathway to safer therapeutic applications. Xenobiotica. 55, 265–276 (2025). https://doi.org/10.1080/00498254.2025.2505062
37. Halabitska, I., Kamyshna, I., Petakh, P., Krynytska, I., Putilin, D., Kamyshnyi, O.: Metabolic profiling of healthy vs. syndrome-associated obesity and effects of six-month metformin therapy. Acta Diabetol. (2026). https://doi.org/10.1007/s00592-026-02647-y

CITE AS: Kabazzi Douglas T. (2026). Green-Synthesized Nanoparticles from Medicinal Plants in Obesity and Metabolic Syndrome Therapy. IDOSR JOURNAL OF EXPERIMENTAL SCIENCES 12(2): 41-46. https://doi.org/10.59298/IDOSR/JES/06/1224146