



Green Synthesis of Silver Nanoparticles from Butterfly Pea and Ginger: A Review on Their Anti-Diabetic and Anti-Obesity Potential

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ABSTRACT

The field of medical research dedicated to exploring natural therapeutic alternatives for the treatment of diabetes and obesity is expanding due to the increasing prevalence of these metabolic disorders. The plant species *Clitoria ternatea*, commonly known as Butterfly Pea Flower, is recognized for its medicinal properties, offering a rich array of bioactive phytochemicals, including anthocyanins and flavonoids, along with beneficial phenolic acids and alkaloids. The antidiabetic, antioxidant, anti-inflammatory, and anti-obesity effects of these compounds stem from their capacity to enhance insulin sensitivity, reduce oxidative stress, and regulate lipid metabolism. Additionally, silver nanoparticles (AgNPs) produced through plant-mediated green nanotechnology represent a contemporary strategy for targeted drug delivery and enhancement of bioactivity. This review explores the role of *Clitoria ternatea* as a reducing agent in the synthesis of AgNPs, while also improving the properties of drugs in conjunction with *Zingiber officinale*, or ginger. Herbal tea solutions are investigated as multifunctional agents for both the creation of nutraceutical beverages and the synthesis of nanoparticles, offering a sustainable approach to managing chronic diseases. The development of plant-based solutions for diabetes and weight management appears promising through the integration of phytotherapy and nanotechnology. This review consolidates current evidence while addressing existing challenges to identify potential avenues for clinical application and scientific advancement.

1. Introduction

The increasing prevalence of metabolic disorders including type 2 diabetes and obesity, worldwide has led to a heightened interest in plant-based therapeutic options. The adverse side effects and temporary efficacy of pharmacological treatments have driven researchers to explore compounds derived from plants, known for their bioactivity and safety. Notably, *Clitoria ternatea* (Butterfly Pea Flower) and *Zingiber officinale* (Ginger) have gained attention due to their rich phytochemical profiles, which include flavonoids, anthocyanins, phenolic acids, and alkaloids. The phytoconstituents found in these plants exhibit three essential properties that aid in reducing insulin resistance and facilitating weight management. (Kumar & Verma, 2022; Chen & Huang, 2021)

The advancements in nanotechnology technology reveal innovative approaches to boost the biological availability and effectiveness of plant substances. A green synthesis of silver nanoparticles (AgNPs) through the usage of plant extracts represents an environmentally friendly and economical replacement to traditional chemical synthesis procedures. The phytochemicals from butterfly pea and ginger behave as therapeutic compounds during synthesis while functioning as natural agents for reducing and capping nanoparticles. The biosynthesized AgNPs obtain superior biological properties from their small size and high surface area together with the synergistic effects of phytoconstituents. (Singh & Patel, 2023; Ahmed & Zhao, 2023)

This review investigates their combined therapeutic and synthesis potential as well as offers a thorough synthesis of



data on the green synthesis of silver nanoparticles employing *Clitoria ternatea* and *Zingiber officinale*. The work explores the phytochemical mechanisms providing health benefits and assesses the synthesis techniques for nanoparticles, stressing their proven effectiveness in control of diabetes and obesity as shown by current experimental data. As this article describes, the combination of conventional herbal therapy with nanotechnology presents sustainable, plant-based approaches for treating metabolic diseases.(Shown in table-1)

Table-1: The following table delineates essential information concerning specific plant chemicals and nanoparticles employed in diabetes treatment, including their biological impacts and therapeutic attributes.

Plant Source	Key Phytoconstituents	Biological Activities	Role in Diabetes and Obesity Management	References
Butterfly pea <i>Clitoria ternatea</i>	Flavonoids (such as anthocyanins), alkaloids (including terpenoids), and polyphenols	- Strong antioxidant activity due to the presence of anthocyanins - Anti-inflammatory and neuroprotective effects. -The compounds within tend to enhance insulin sensitivity thus leading to antidiabetic activity. -The substance provides antioxidant help to both reduce oxidative	- The substance helps lower blood glucose through its insulin sensitizing effect. -The anti-inflammatory properties of this herb let users manage the inflammatory components of obesity. - The compound stimulates fat reduction	(Mohamed, 2024)

		stress while facilitating liver function maintenance .	in the body and it also reduces the risk of metabolic health problems. - Antioxidants perform a protective function by diminishing free radicals which prevent oxidative damage in cases of obesity.	
Ginger <i>Zingiber officinale</i>	Gingerol, shogaol, zingiberene, and paradol	-Exhibits potent anti-inflammatory and antioxidant characteristics. -The compound makes insulin more effective while reducing blood glucose content. -The substance maintains proper lipid metabolism by reducing triglyceride amounts. -The substance enhances digestive	-Ginger causes blood sugar decreases through its ability to make insulin work better. -Ginger delivers its active substance gingerol in a way that enhances lipid metabolism along with triglyceride reduction which helps control body	(Najmeh, 2019)



		health functions as well as immune system strength.	weight effectively . -Ginger contains antioxidants that fight oxidative stress which plays a role in developing insulin resistance and obesity. -This treatment improves body control of glucose while it minimizes fat deposition in the body..	
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Silver Nanoparticles	Silver ions (Ag ⁺), Silver nanoparticles (AgNPs)	- Antibacterial, antiviral, and antifungal properties. - Anti-inflammatory and antioxidant effects. - Insulin secretion becomes more effective while glucose uptake becomes better through	- The use of silver nanoparticles shows promise in anti-inflammatory treatment for obese patients which results in improved metabolic functions. - The antioxidants present in silver nanoparticles lower oxidative	(Susanta, 2024)
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		the consumption of this compound . -The control mechanism operates to reduce body fat via its influence on metabolic operations	stress which plays a crucial role in diabetic and obesity cases. -Insulin sensitivity enhances through their actions and they also improve glucose uptake mechanisms. -Silver nanoparticles show potential to serve in nanomedicine treatments of diabetes and obesity.	
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2. Medicinal Plants in Metabolic Disorders

Medicinal plants leverage their rich phytochemical content to effectively address diabetes and obesity, supported by their historical use in these areas. Numerous studies have investigated *Clitoria ternatea* (butterfly pea) and *Zingiber officinale* (ginger) due to their proven therapeutic roles in diabetes management. Recent research indicates that *Clitoria ternatea* exhibits antidiabetic properties. Investigations involving diabetic rat models revealed that an extract from butterfly pea flowers reduced blood glucose levels, attributed to its antioxidant and anti-inflammatory effects. Additionally, a randomized crossover study among healthy individuals demonstrated that consuming a beverage made from *Clitoria ternatea* flowers improved postprandial blood sugar levels while providing antioxidant advantages. (Sowmya, 2023; Dewi, 2023) (Shown in figure-1)



Scientific researchers have extensively investigated *Zingiber officinale* to determine its metabolic advantages. Ginger extract treatment of streptozotocin-induced diabetic rats decreased blood glucose levels while simultaneously improving lipid profile metrics. Supplementing type 2 diabetic patients with ginger showed evidence that their pro-inflammatory cytokines decreased according to results from a randomized controlled trial. This indicated how ginger functions to counteract insulin resistance brought on by inflammation. (Gumbarewicz, 2022; Nazish, 2016; Li, 2012)

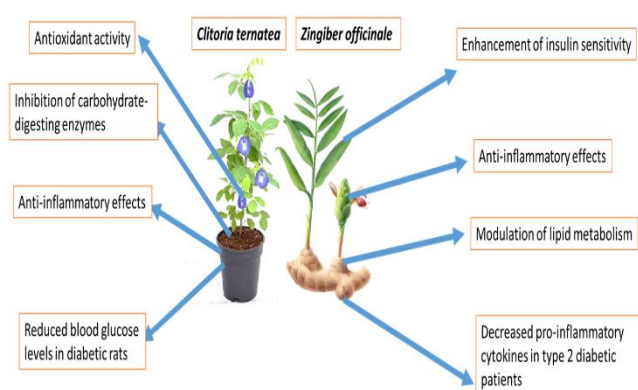


Figure-1: Illustrates and highlights the combined antidiabetic as well as anti-obesity effects of *Clitoria ternatea* (Butterfly Pea) and *Zingiber officinale* (Ginger). Their phytochemicals engage various biological processes, including antioxidant activity, anti-inflammatory effects, inhibition of carbohydrate-digesting enzymes, and improvements in insulin sensitivity, collectively contributing to metabolic regulation and alleviation of diabetes symptoms.

An Overview of the Synergistic Benefits of Blue Tea, Ginger, and Silver Nanoparticles: Health Advantages, Safety Considerations, and Preparation Methods

The mixture of butterfly pea flower tea with ginger elements and silver nanoparticle (AgNPs) provides a beverage that merges age-old natural remedies with state-of-the-art nanotechnology. Blue tea gets its distinctive coloring and serves various health functions from its anthocyanin antioxidants which are plentiful in butterfly pea flowers. They aid brain functions and help regulate blood sugar levels. The consumption of ginger provides drinkers with the dual effects of reduced inflammation and digestive benefits which improve blood sugar levels while alleviating nausea. The use of silver nanoparticles derived from plant-based green synthesis demonstrates potential benefits against microorganisms while controlling oxidative stress patterns as an effective medical

intervention for metabolic disorders. (Chusak, 2018; Oguis, 2019)

Caution must be taken when consuming this mixture because several side effects exist. High amounts of butterfly pea flower tea can give rise to digestive distress while taking large quantities of ginger may result in stomach and heartburn issues among certain people. Scientists have not yet determined the permanent health impacts from silver nanoparticles in consumption and high doses could trigger safety concerns for people's health. Users should use the combined consumption of butterfly pea flower tea and ginger carefully and get professional healthcare advice before trying it. (Crichton, 2022 & Crichton, 2023)

Table-2: A comprehensive examination of Blue Tea infused with Ginger and Silver Nanoparticles

Component	Potential Benefits	Possible Side Effects	Preparation Method
Butterfly Pea Flower	Possesses antioxidant characteristics; has the potential to enhance cognitive abilities and manage blood glucose levels.	Gastrointestinal distress may occur if taken in large quantities.	Infuse dried flowers in hot water for a duration of 10 to 15 minutes; lemon juice may be added to improve both flavor and color.
Ginger	Reduces inflammation; supports digestive health; may assist in regulating blood glucose levels.	Increased doses may lead to heartburn, gastrointestinal discomfort, or diarrhea.	Simmer sliced fresh ginger in water for 10 to 20 minutes; include lemon juice or honey according to preference.
Silver Nanoparticles	Improved antimicrobial efficacy; capability to influence	Possible harmful effects at elevated concentrations; long-term	Formulated through environmentally friendly techniques utilizing botanical



	oxidative stress	consequences remain uncertain.	extracts; not typically employed in domestic recipes; professional advice is advised.
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3. The Mechanisms of Action in Diabetes and Obesity

The combined use of *Clitoria ternatea* (Butterfly Pea), *Zingiber officinale* (Ginger), and silver nanoparticles (AgNPs) has garnered significant interest among researchers due to their potential to enhance insulin sensitivity and regulate glucose uptake in individuals with diabetes. *Clitoria ternatea* contains the compounds anthocyanins and flavonoids that block the action of both α -glucosidase and α -amylase enzymes which delays carbohydrate breakdown and regulates postmeal blood sugar levels (Chusak et al., 2018). The antioxidant properties present in this plant act to reduce oxidative stress along with its role in causing insulin resistance. According to Crichton et al. (2023) the insulin receptor becomes more active when treated with gingerols and shogaols found in ginger which allows efficient GLUT4 translocation throughout tissues leading to better insulin sensitivity. The insulin-like effects of cells and glucose uptake in adipocytes and muscle cells improved with silver nanoparticles developed from plant extracts based on findings by Ferdous and Nemmar (2020).

The evaluation of lipid metabolism and adipogenesis functions by these three natural compounds represents their most notable potential. The inhibition of lipogenic key enzymes happens through ginger's activation of PPAR- γ transcription factor leading to both suppressed adipogenic processes and faster fat breakdown (Bodagh et al., 2018). Laboratory studies report that the extract from *Clitoria ternatea* possesses anti-lipidemic activity to reduce triglycerides together with total cholesterol levels in diabetic test subjects (Oguis et al., 2019). AgNPs generate positive effects on lipid metabolism by controlling gene regulatory patterns within adipocytes for reduced adipogenesis to occur. The combination of anti-inflammatory effects from nanoparticles generates extra benefits for metabolic success rates among obese patients. The bioactive agents function as an effective metabolic disorder control method by interacting with glucose control and lipid control systems.

4. Fabrication of Silver Nanoparticles Combining Butterfly Pea and Ginger

Silver nanoparticles (AgNPs) production using butterfly pea extracts combined with ginger materials avoids toxic reducing chemicals by implementing plant-based synthesis methods. The aqueous extract solution obtained from butterfly pea flowers provides its reducing potency as the extracts from ginger root roots supply capping ability in this formation process. The silver nitrate (AgNO_3) starting material undergoes production under defined light conditions together with pH value and temperature control. Bioactive phytochemicals of *Clitoria ternatea* and ginger reduce Ag^+ while forming silver metallic nanoparticles (Ag^0) as well as stabilized functionalized nanoparticle structures. Surface plasmon resonance in nanoparticles causes a pigment change from pale yellow to brown which indicates the formation of AgNPs (Sharma et al., 2020).

Determining the properties of synthesized AgNPs necessitates the use of tests to evaluate size and shape along with stability. The surface plasmon resonance peak detection of nanoparticle formation at 400–450 nm wavelength is mostly observed through UV-Visible spectroscopy analysis. High-resolution images of nanoscale features and size analysis become possible through Transmission Electron Microscopy (TEM). FTIR allows scientists to study phytochemical-derived compounds which protect nanoparticles by understanding their protective mechanisms during the synthesis process. The crystal structure analysis method uses X-ray Diffraction (XRD) while the measurement of particle sizes depends on Dynamic Light Scattering (DLS) according to Mishra et al. (2021). Green synthesis methodology has gained increasing popularity because it demonstrates environmental safety and biocompatible characteristics which make it suitable for antidiabetic and anti-obesity medical applications.

5. Toxicity and Biocompatibility Assessments - In Vitro and In Vivo Safety Evaluations

The safety characteristics of *Clitoria ternatea* and *Zingiber officinale* in traditional medicine should undergo evaluation through testing procedures when implementing their extracts in nanoparticle synthesis because of high concentration or new formulation methods. The research reveals *Clitoria ternatea* shows mild toxic effects in test tube and animal studies since 2000 mg/kg doses show minimal harmful side effects thus proving its safe usage (Pratheepa et al., 2019). The clinical evaluations have validated the safety of ginger when consumed as food or



medicine since toxicity studies prove humans can tolerate up to 2 g daily (Daily et al., 2015). High doses of ginger independently result in mild digestive discomfort whereas they simultaneously affect anticoagulant medications. The research shows that both extract concentration and time of exposure need special attention for botanical preparations particularly when used in formulated products.

6. Dose Optimization and Limitations of Silver Nanoparticles

The medical promise of silver nanoparticles (AgNPs) results in complicated toxicity-related problems during medical applications. AgNPs have been observed to cause DNA damage in human cells and to create mitochondrial dysfunction and oxidative stress based on laboratory experiments at elevated dose levels (Ferdous & Nemmar, 2020). Through in vivo studies researchers discovered silver nanoparticle accumulation patterns that most affect liver and kidney organs which can result in metabolic function changes and inflammatory reactions. Most biological applications require dose optimization because various tests show that safe exposure levels for AgNPs should remain below 10 µg/mL in cell cultures and 1–2 mg/kg in animal models yet these boundaries depend on coating materials and AgNP sizes. The incorporation of AgNPs with biocompatible plant extracts from ginger or *Clitoria ternatea* creates two benefits by protecting cells from damage and securing AgNPs' surface as described in the research of Singh et al. (2020). To ensure safety recommendations for functional food consumption and therapy the public must receive comprehensive long-term safety testing and regulatory approval. (Shown in table-3)

Table-3: Summary of Toxicity and Biocompatibility for *Clitoria ternatea*, *Zingiber officinale*, and Silver Nanoparticles

Substance	Safe Dose Range	Observed Side Effects	Safety Notes	References
<i>Clitoria ternatea</i>	Up to 2000 mg/kg (oral, in vivo)	None significant in animal models	Generally safe; low cytotoxicity in vitro	(Pratheepa et al., 2019)
<i>Zingiber officinale</i>	Up to 2 g/day (humans)	Mild gastrointestinal discomfort	Widely used; well-tolerated	(Daily et al., 2015)

	an oral intake)	, possible drug interactions	in clinical studies	
Silver Nanoparticles	≤10 µg/mL (in vitro), ≤2 mg/kg (in vivo)	Oxidative stress, DNA damage, organ accumulation (in high doses)	Requires cautious use; plant-based syntheses may reduce toxicity	(Ferdous & Nemmar, 2020; Singh et al., 2020)

7. Future Perspectives and Challenges

Clinical prospects for managing diabetes and obesity exist through the combination of *Clitoria ternatea* and *Zingiber officinale* along with biosynthesized silver nanoparticles (AgNPs). Multiple therapeutic applications become viable because these compounds show combined antioxidant activity alongside anti-inflammatory properties and hypoglycemic effects with lipid-lowering actions. The compatibility between plant-derived agents and increased bioactivity of AgNPs positions them for future product development in functional foods and dietary supplements as well as nanoformulated pharmaceuticals. Nanotechnology along with green synthesis methods developed new eco-friendly methods of scalable production. These natural ingredients show potential for incorporation into personalized therapies because the growing fields of nutraceuticals and personalized medicine focus on them particularly for populations with metabolic syndrome.

Nonetheless, several significant scientific deficiencies and legal barriers hinder clinical acceptance. The absence of robust human clinical trials evaluating safety, efficacy, appropriate dosage, and long-term effects means that most existing data is confined to in vitro and preclinical animal studies. Additionally, the pharmacokinetics and toxicity of silver nanoparticles, especially in oral or systemic applications, remain inadequately understood. The lack of standardized systems for certifying plant-nanoparticle hybrids complicates the ability of regulatory bodies such as the The Food and Drug Administration (FDA) and the European Medicines Agency (EMA) to ensure quality, consistency, and safety. Future research must focus on addressing ethical concerns and establishing proper regulatory oversight to translate laboratory findings into practical therapeutic applications, while also prioritizing



toxicological profiling, elucidating mechanisms, and conducting controlled clinical trials.

8. Conclusion

An innovative treatment approach has been developed for managing diabetes and obesity through the therapeutic synergy of butterfly pea (*Clitoria ternatea*), ginger (*Zingiber officinale*), and biosynthesized silver nanoparticles. The natural phytochemicals derived from these plants exhibit antioxidant, hypoglycemic, lipid-lowering, and anti-inflammatory effects, which are enhanced by silver nanoparticles that facilitate nanoscale delivery and improve cellular absorption. These therapeutic substances benefit metabolic healthcare by maintaining insulin levels and boosting glucose function along with preventing excess fat deposition and decreasing oxidative damage in the body. The substances and their synthetic processes derive from botanical origins while following sustainable and green therapeutic rules currently applied in medicine. Laboratory achievements in drug development meet multiple challenges before adapting for clinical practice. Research must progress into human trials for clinical assessment of extended medication effects and dose determination and full safety tests and evaluation of multi-drug combinations. Traditional medical practice needs standardized synthesis protocols and quality assurance procedures as well as regulatory approvals before nanoparticles can be integrated. When *Clitoria ternatea* extract and ginger work with silver nanoparticles in medical interventions they create a novel treatment for metabolic diseases which demonstrates rising international interest in natural nanotechnology-based remedies.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

CONSENT FOR PUBLICATION

Not applicable

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