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Original Article

Synthesis and characterization of nanoparticles from *Chamaecostus cuspidatus* (Nees & Mart.) C.D. Specht & D.W.Stev. And evaluation of natural lipid-based drug delivery system

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Abstract

Chamaecostus cuspidatus (Nees & Mart.) C.D. Specht & D.W.Stev. known by synonyms as Costus igneus N.E.Br. and Costus pictus D. Don. Commonly, it is also known as Insulin-Plant, Spiral Flag, etc. The plant is a perennial herb with a height of about 2-3 feet. C.cuspidatus plant is a member of the Costaceae family. C.cuspidatus is indigenous to Southeast Asia. C.cuspidatus offers multiple health benefits as the plant is traditionally used as a curative in the treatment of various health deteriorating conditions. C.cuspidatus has numerous pharmacological advantages, where it has the potential of being used as an anti-bacterial, anti-microbial, antioxidant, etc. However, it is mainly known for its anti-diabetic properties, which help maintain the insulin level.

Looking towards the plants exceptional pharmacological potentiality the present study aims to evaluate the probability of formulating a natural lipid-based drug delivery system from the phytochemical and fats present in the plant as this area of research has still not been explored well. Since lipid-based carriers can improve the solubility, absorption, dispersion and over all bioavailability of poor soluble drug utilizing the fat as a base from the C.cuspidatus it would be a novel approach for understanding the lipophilic nature of drug and emphasizing the medicinal importance of C.cuspidatus which indicate the potential role in formulation of natural lipid-based drug delivery system.

***Keywords**: Chamaecostus cuspidatus (Nees & Mart.), Costus igneus N.E.Br., Costus pictus D. Don., Insulin-Plant, Pharmacological, Phytochemical, Bioavailability, Lipophilic, Natural lipid-based drug delivery system (LBDDS).*

Introduction

Natural resources like plants are used traditionally as medicinal agents in the prevention and treatment of various health problems. Many modern drugs are formulated by isolating the required compound from the raw source, as the isolation of the required compound is referred to as its traditional use. Since plants are the primary raw source of supply for both traditional and conventional pharmaceutical products and medicinal drug which are used for the welfare of mankind, a huge percentage (80% approximately) of the global population is substantially dependent on natural medicines for their medicinal requirements to be fulfilled. Medicinal plants used in the traditional system of medicine are gaining weightage for the efficacy in treating different health problems and there is a fair increase in the use of medicinal plants as an alternative choice or option in prevention or treatment of long standing diseases in developing as well as developed nations around the globe as they have minimal to no major side effects which could be fatal.

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Since the traditional health care system primarily focuses on drug formulations based on an herbal medicinal approach found in a particular herb, as herbs are profoundly useful and easily available in rural parts, being proportionally cheap as compared to modern drugs. Nearly 70-80 % of the population around the globe fundamentally rely on the traditional health care system as being cost effective alternative to the modern health care system. According to the World Health Organization estimate about 80% of the population in underdeveloped countries solely stays dependent on plant-based preparations used in their respective traditional medicinal system and as the fundamental need for a primary health care option of mankind. Since the traditional medicinal system is based on herbal compounds or herbal drug components isolated from medicinal plants, this approach holds a strong historical and cultural value-based aspect over the wide variety of laboratory synthesized medication in modern times.

Therefore, a huge populace gets diverted towards traditional herbal medicinal system practitioners for their fundamental medicinal requirements. Looking towards the increase in the requirement of these herbal medicines there is a apprehension about their effect, safety, efficacy and over all potentiality which is a point of concern by developing as well as developed nations as these herbs possess a varied biological function with their bioactive as well as isolated compounds, that provoke the brainstorming aspects in the field of medicine (Arivu *et al*., 2023).

The present study, carried out primarily focused on the exploration of natural sources of diosgenin phytochemicals that help in preventing and managing multiple health diseases, where isolation of diosgenin was carried out, looking towards its valuable bioactive properties and wide use in pharmaceutical applications for its anti-inflammatory, antioxidant, and metabolic benefits, etc. Synthesis and characterization of diosgenin–silver nanoparticles was carried out to enhance the bioactivity, stability, and overall bioavailability of the compound using a safe, cost-effective, green nanotechnology approach. Where looking towards the insoluble nature of the silver nanoparticles, a step to develop a natural lipid-based drug delivery system to improve the solubility, absorption, and overall bioavailability of the formulated phytochemical–nanoparticle complex.

1. *Chamaecostus cuspidatus*: *Chamaecostus cuspidatus* (Nees & Mart.) C.D.Specht & D.W.Stev. *Costus igneus* Nak and *Costus pictus* D. Don are also known as Insulin plant, Spiral flag, etc. (Kankariya *et al*., 2015). Besides this, *Costus igneus* is also known by a synonym, *Chamaecostus cuspidatus*, which is also considered to be the accepted name. It is a medicinal herb that is traditionally well known for its medicinal uses and health benefits in the prevention and treatment of multiple health problems. The herb is a perennial plant that belongs to the family Costaceae, which spreads upright with a growth range of 2-2.5 feet approximately.

The herb has tremendous medicinal as well as health-benefiting properties with a wide range, primarily including anti-bacterial, anti-microbial, antioxidant, anti-cancerous, etc. Moreover, it is fundamentally known for its anti-diabetic property. The leaves are simple, entire, and arranged alternately to each other with a length of 4-8 inches. They show parallel venation and possess a distinctive characteristic of spiral phyllotaxy. The leaves are observed to have dark green coloration, the flowers show the presence of distinct orangish to yellow color, which has red strips over petals that end towards the outside, and are marked (Kaur and Mannan, 2021).

C.cuspidatus being a rhizomatous shrub, penetrates the earth's surface by its underground tuberous rhizome. The cylindrical rhizome, being fleshy and spongy, has a smooth, pale brown surface; the shrub has a pleasing scent. Full sunny or partial shade is suitable for spiral flag growth with a temperature ranging from 30 – 40°C. The plantation is generally carried out close to a source of water and needs rich soil and enough moisture to favor its growth and development. The offsets that grow below the flowers could be separated, divided into clumps, or removed as part of the propagation process. Mites and Nematodes are a threat to plants, which are particularly found in light, sandy soil.

However, the plant has no major illnesses that would disturb or hinder its growth at the moment. The stem contains steroid molecule compounds such as stigmasterol (a plant sterol) and the terpenoid lupeol (a cyclic compound found in many plants). The rhizome of *C.cuspidatus* has bioactive constituents like quercetin (a plant flavonoid) and diosgenin, which is a type of steroidal sapogenin (naturally occurring chemical compounds found in some plants). The elements K (potassium), Ca (calcium), Cr (chromium), Mn (manganese), Cu (copper), and Zn (zinc) are present in significant concentrations in the rhizomes and leaves of *C.cuspidatus*, *as identified by* trace elemental analysis. Clear, yellowish essential oils were obtained during steam distillation of the stems, leaves, and rhizomes of *C. igneus* (Kankariya *et al.*, 2015).

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(a) (b) (c) (d) (e)

(a-Costus plant, b- Spiral phyllotaxy arrangement of plant, c- Flower of Costus plant, d & e- Inflorescence pattern in Costus plant)

2. Phytoconstituents: The preliminary evaluation of phytochemical testing reveals the presence of phytochemicals like alkaloids, phytosterol, saponins, glycosides, carbohydrates, tannins, phenolic compounds, terpenoids lignin and flavonoids in the plant, where as a systematic screening of phytochemical carried out with the leave of *Costus igneus* demarks the presence iron, antioxidant components such as ascorbic acid, β-carotene, α-tocopherol, terpenoids, steroids and flavonoids moreover the leave is also rich in protein content (Arivu *et al*., 2023).
3. Antidiabetic effect: Costus is an ornamental plant which is used as in beautification of the land space, however it is traditionally been used as a herb it is also known as insulin plant or anti diabetic plant where the leaves of this plant stays a major part that signifies the anti-diabetic property of the plant more over it also decreases fasting & post prandial blood sugar levels (Mathew & Varghese., 2019).
4. Diosgenin: A naturally occurring phytochemical that is found in number of plants which has a peculiar chemical structure and it possess multiple pharmacological benefits therefore it is also considered as a unique steroidal saponin, because of its vast therapeutic uses which includes its role as anti-inflammatory, scavenging of free radical resulting showing anti-oxidant properties, diosgenin plays a role in inhibition of cell proliferation which ultimately cause apoptosis which helps understand its anti-cancer activity, moreover it also shows anti-bacterial, anti-microbial properties, where it is predominantly known for its anti-diabetic properties which helps regulate insulin activity in treatment of diabetes essentially on considering the benefits of diosgenin it is crucial to understand the physical, chemical properties which include the stability, biochemistry etc. As well as the biological activity of this compound, so as to learn about the biosynthesis pathways that are responsible for the prevention and management of various types of diseases (Chaudhary *et al*., 2024). Presently, diosgenin and other similar steroidal saponins are mainly obtained by extracting them from tubers of different Dioscorea plant species. However, the decreased availability of this plant and the increase in its demand is the reasons why researchers are trying to identify new and alternative natural sources of this compound (Pazhanichamy *et al*., 2012). Hence, the present study aims to analyze *C. cuspidatus* as an alternative source for the presence of diosgenin compound.
5. Nanotechnology: Silver nanoparticles function as an antitumor agent due to their antiproliferative and apoptosis-inducing properties. The present study focused on emphasizing the complete natural approach in experimentation, and thereafter, the nanomaterials synthesized with the help of biological techniques could typically show higher biocompatibility. Since the method followed is termed green synthesis, it excludes the use of harmful chemical substances and reagents that could be toxic and hazardous for humans and the environment. The method efficiently holds the ability to rapidly produce high quality of nanomaterials in an eco-friendly manner and also at a distinctive low cost (Jayachandran *et al*., 2023).
6. Lipid-Based Drug Delivery System: The use of silver nanoparticles for medicinal purposes is frequently disturbed due to their low solubility of sliver based material in the solution. To overcome this problem, the silver nanoparticles are conjugated with biocompatible substances so as to increase the solubility of the material. However, the conjunction leads to enhanced interaction with desired biomolecules, which does not disturb the natural properties of the compound and provides an effective, high quality of silver nanoparticles. To overcome the poor bioavailability of a particular compound. The approach of encapsulation of nanomaterials into the lipid bilayer or the formulation of liposomes is carried out. Hence, that helps to enhance the bioavailability of the nanomaterial. The present study focuses on the drawbacks related to the nanoparticles and emphasizes the approach to subdue the challenges and develop a well-structured, systematic lipid-based drug delivery system (Jayachandran *et al*., 2023).

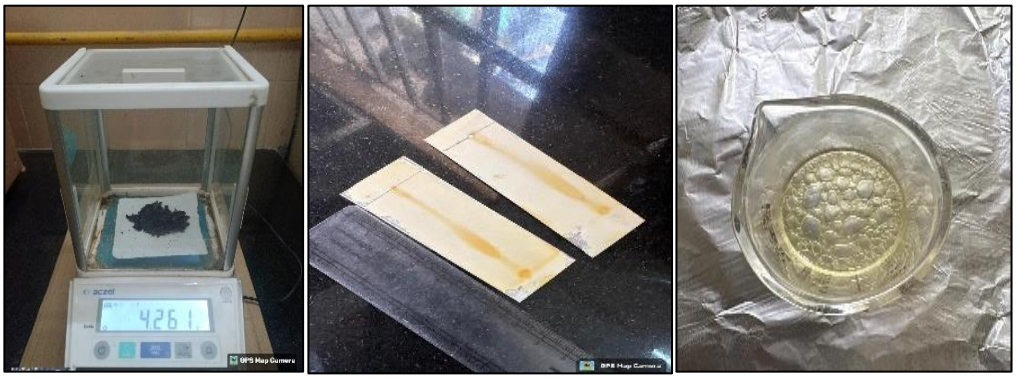
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Materials & METHODS

1. Extraction of diosgenin from *C. cuspidatus*: Extraction of Diosgenin from the Costus plant was carried out, where fresh rhizome material was obtained, it was cleaned, manually peeled, and chopped into pieces, and was weighed to 50gm followed by acid hydrolysis and Soxhlet extraction (Ashour *et al*., 2019).
2. Isolation of diosgenin from crude extract: The isolation step was carried out with the TLC method, where the solvent system (n-hexane: ethyl acetate – 7:3) was used, and the retardation factor (Rf value) was calculated (Devi, 2024).
3. Synthesis & Characterization of Silver nanoparticles (AgNPs) from *C. cuspidatus:* Initially 30gm of fresh leaves were weighed, thoroughly washed, and finely cut into pieces. The synthesis of nano material was carried out, where the change in colour on gentle mixing indicates AgNPs formation. Further, the analysis of AgNPs activity was carried out using a spectrophotometer (Jayachandran *et al*., 2023).
4. Lipid-based drug delivery formulation: Diosgenin-rich Costus plant extract was reacted with silver nitrate (AgNO3) solution and was mixed well, resulting in reduction activity, which leads to a color change that indicates the formation of silver nanoparticles. Preparation of oil phase, where olive oil was slightly warmed at 60-70 degrees Celsius so as oil helps to mix well. The AgNPs extract was added to the warm oil and mixed slowly so as to achieve even formation of oil droplets with the help of a vibrating machine. The size of the oil particle was reduced to tiny droplets (Jayachandran *et al*., 2023).

Observation & Result

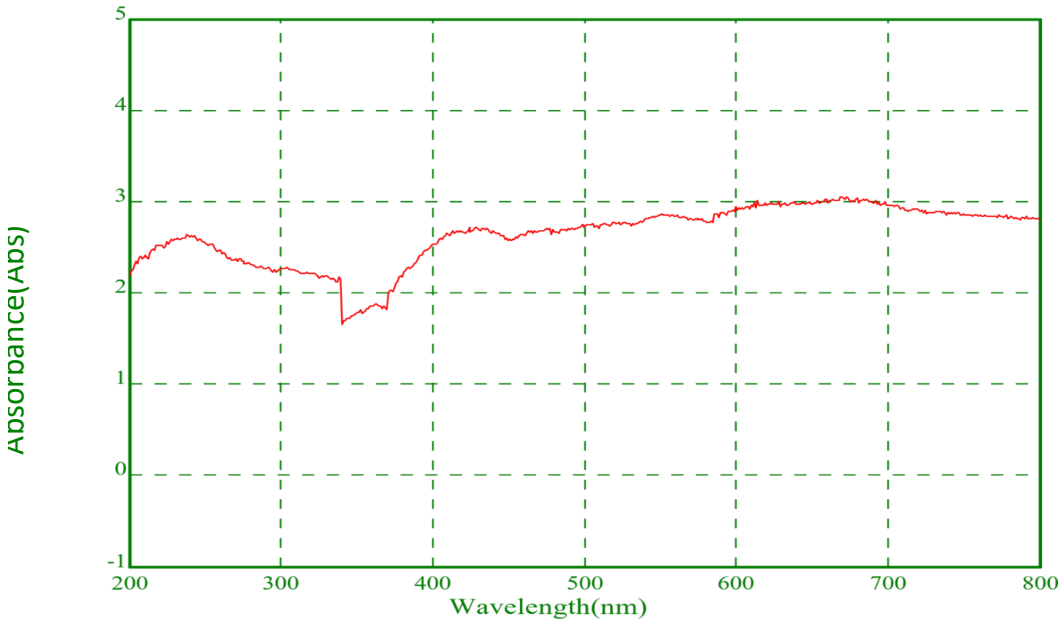
The extraction of diosgenin from the plant was carried out for the preparation of plant extract, followed by acid hydrolysis and the Soxhlet extraction method, which resulted into production of crude sapogenin extract that contained diosgenin. The isolation of diosgenin from the crude sample was further carried out with the TLC method using n-hexane: ethyl acetate (7:3) as the mobile phase and the Silica plate as the Stationary phase, resulting in a Retardation Factor (Rf) value of 0.26 with a single distinct band separation. The synthesis of nanoparticles (AgNPs) was achieved by reacting the plant extract with AgNO3 (Silver Nitrate), during which reduction occurs and a color change from yellow to brown is observed. Furthermore, the nanoparticle activity was analysed with a spectrophotometer, revealing that the particles showed maximum activity in the 600-700 nm wavelength range, as shown in the graphical representation below (Figure 1). Subsequently, a lipid-based drug delivery system was formulated, where the extract was reacted with AgNPs, and the AgNPs were then found to be encapsulated within olive oil. The oil served as a lipid layer or outer covering, incorporating the AgNPs into this layer.



(f) (g) (h)

(f- Crude Sapogenin Extract containing Diosgenin, g- Separation of diosgenin TLC Method, h- Oil Droplet Formation and Encapsulation of AgNPs)

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Graphical Representation of AgNPs of Diosgenin
(Figure 1)

Discussion

The results obtained during the experimentation process are preliminary. The diosgenin obtained is in the crude extract form and may contain other chemicals that may inhibit its properties. Further purification of the extract is required. Through the analysis of nanoparticles, characterization is needed to be done by SEM, TEM, and FTIR to confirm the nature of the nanoparticles, and the presence of the functional groups should be confirmed so as to evaluate the biochemical activities of the Phyto steroid. Considering the preliminary screening done, diosgenin seems to have positive properties as a lipid-based drug delivery system.

The research experiment carried out provides significance with ensuring efficient extraction and purification of high quality of diosgenin from *C.cuspidatus* where it covers and combines multi-disciplinary aspects like, phytochemistry, nanotechnology, lipid based drug delivery systems (LBDDS) where Green Synthesis of nanoparticles improves the stability and effectiveness, characterization confirms the particles size, purity functional group and its performance as a well-established cost effective method. The natural lipid-based drug delivery system inhibits the intermediate degradation of the drug, enhancing the solubility, absorption, and overall bioavailability.

Conclusion

The plant *C.cuspidatus* shows strong potential as a natural source of therapeutic phytochemicals. Diosgenin is found to be a valuable bioactive compound, where further purification is essential for enhancing its efficacy and potential. Green synthesis of diosgenin AgNPs demonstrates its potential for nanoparticle activity. The emulsification and encapsulation of AgNPs indicate the potential therapeutic drug effect.

Looking towards the future prospect of the experiment, a new herbal drug can be formulated from *C.cuspidatus* which could be safer, cost-effective, and more efficient. The integration of nanoparticles (AgNPs) with lipid-based drug delivery systems can be used to develop various products like gels, capsules, and sprays. The method can be used to improve the large-scale production of natural herbal therapeutic products. Also, to analyze the effect, in vitro studies with animal models and clinical studies can be carried out to evaluate the efficacy and effectiveness of the formulated drug.

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