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Utilization of Butterfly Pea (*Clitoria ternatea*) Plant in Rice to Lower Glucose Levels

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Abstract

Background of study: The increasing prevalence of diabetes and other glucose-related metabolic disorders has sparked a growing interest in functional foods that can help regulate blood sugar levels. Among staple foods, rice plays a crucial role in the diets of billions of people, particularly in Asia. However, white rice has a GI, contributing to rapid spikes in blood glucose levels after consumption. This presents a health challenge for individuals at risk of or currently managing diabetes. Recent studies suggest that anthocyanins from butterfly pea may inhibit enzymes involved in carbohydrate digestion (e.g., α-amylase and α-glucosidase), thereby slowing glucose absorption in the bloodstream. Additionally, incorporating butterfly pea extracts or powders into rice may not only reduce its GI but also enhance its nutritional value and sensory appeal, offering both functional and aesthetic benefits.
Aims and scope of paper: The primary aim of this paper is to investigate the potential of butterfly pea as a natural functional ingredient in rice-based products to reduce postprandial blood glucose levels. Specifically, the study seeks to evaluate the effects of incorporating butterfly pea extracts or powders into rice formulations on glycemic response, nutritional content, and overall product acceptability. This paper focuses on the functional food application of Butterfly Pea in rice, with an emphasis on reducing glycemic impact. It encompasses phytochemical analysis, food formulation, nutritional evaluation, and potential health benefits.
Methods: This review aims to evaluate and compile scientific evidence to substantiate the functional claims associated with butterfly pea. Therefore, it is crucial to systematically gather and analyze research findings that explore its functional properties based on empirical scientific investigations.
Result: We reviewed the existing literature related the butterfly pea. Several studies reported that butterfly pea has numerous functional properties, such as inhibitory activity against α-amylase and α-glucosidase enzymes.
Conclusion: The incorporation of Butterfly Pea into rice formulations presents a promising strategy for developing functional foods with a reduced glycemic impact. The study demonstrated that butterfly pea is rich in bioactive compounds particularly anthocyanins and flavonoids that contribute to its inhibitory effects on carbohydrate-digesting enzymes and its potential to lower postprandial glucose levels.

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INTRODUCTION

Diabetes mellitus is a multifactorial, long-term metabolic disorder marked by persistent hyperglycemia due to impaired insulin secretion, insulin resistance, or both. Globally, it represents a major public health issue, with its prevalence increasing rapidly and currently impacting more than 500 million people worldwide. The condition significantly contributes to morbidity and mortality due to its long-term complications, which include cardiovascular disease, nephropathy, retinopathy, and neuropathy. Diabetes is broadly classified into three main types: type 1 diabetes mellitus (T1D), type 2 diabetes mellitus (T2D), and gestational diabetes mellitus (GDM). T1D is primarily an autoimmune condition leading to the destruction of pancreatic β-cells, resulting in absolute insulin deficiency. T2D, which accounts for the majority of cases, is characterized by insulin resistance and relative insulin deficiency and is often associated with obesity, sedentary behavior, and genetic factors. GDM occurs during pregnancy and poses risks for both maternal and fetal health, with an increased likelihood of developing T2D later in life. Understanding the pathophysiology, risk factors, and molecular mechanisms underlying diabetes is essential for developing effective preventive, diagnostic, and therapeutic strategies to manage this growing public health challenge (Pop, Ichim, & Farcău, 2025; Stover-Kempers et al., 2025). The global burden of diabetes has reached epidemic proportions, with over 500 million individuals affected worldwide, according to the International Diabetes Federation (IDF). This condition poses significant health challenges, as it is associated with numerous complications including cardiovascular disease, neuropathy, nephropathy, and retinopathy. Effective management requires a multifaceted approach involving lifestyle modifications, pharmacotherapy, and continuous monitoring of blood glucose levels (Dimou et al., 2025).

The increasing prevalence of type 2 diabetes mellitus (T2DM), a chronic metabolic disorder characterized by elevated blood glucose levels due to insulin resistance or impaired insulin secretion, has prompted the search for functional foods with hypoglycemic properties. Dietary interventions using natural plant-based compounds have gained considerable attention for their potential to complement conventional therapies in glycemic control. In the average human diet, between 40 and 80 percent of calories come from carbohydrates, which are the body's main energy source. This macronutrient is essential for providing energy, but because of the peculiarities of postprandial (after-meal) metabolism, diets heavy in carbs are sometimes seen as harmful, especially when it comes to weight control and energy imbalance. Using the glycemic index (GI), foods high in carbohydrates are categorized according to how they affect blood sugar. The immediate postprandial glycemic reaction, also known as a blood sugar rise, that happens after consuming a certain amount of digestible carbohydrates from a test food is measured by GI, which compares the response to an equivalent amount of carbs from a standard reference food. High GI foods quickly raise blood glucose levels, which in turn causes an increase in insulin release. On the other hand, because low-GI meals' carbs are absorbed and digested more slowly, their blood glucose levels rise more gradually, preventing postprandial hyperglycemia (Chusak et al., 2019).

Throughout history, a wide range of tribes and civilizations have relied heavily on fragrant and medicinal herbs for their usage in rituals, healing, nutrition, and aesthetics. Butterfly pea, a perennial climbing vine belonging to the Fabaceae family, typically attains a height of two to three meters and is commonly known as butterfly pea or blue pea (Figure 1.). Although it is also grown as an attractive plant and used in environmental restoration projects, this plant, which has a bright blue bloom, has been used for millennia as a natural food coloring in Southeast Asia (Jeyaraj, Lim, & Choo, 2021).

Figure 1. Image of butterfly pea

The edible herbal plant known as the butterfy pea is a member of the Fabaceae family. Asia, Australia, Central and South America, and Africa all have tropical regions where it can be found. The butterfy pea has bright, deep blue flowers, particularly the petals. They are rich in phenolic compounds with flavonoid groups called anthocyanins. Blue, purple, red, and orange hues can be produced by this water-soluble chemical. Among the many biological activities of the flowers are analgesic, anti-diabetic, anti-pyretic, anti-helminthic, anti-leprosy, anti-asthmatic, anti-hyperlipidemic, anti-fungal, anti-depressant, and anti-convulsant properties (Maneechot, Hahor, Thongprajukaew, Nuntapong, & Bubaka, 2023).

METHOD

Research Design

This article is a review paper that aims to evaluate and compile scientific evidence regarding the functional claims of butterfly pea. It synthesizes existing literature related to butterfly pea's functional properties, including its inhibitory activity against α-amylase and α-glucosidase enzymes. Therefore, it is a literature review or a systematic review (though the term "systematic" isn't explicitly used for the methodology beyond "systematically gather and analyze research findings".

The method of "sampling" involves

The research methodology involved systematically gathering and analyzing scientific findings that explore the functional properties of butterfly pea, based on empirical scientific investigations. This process included reviewing existing literature related to the butterfly pea plant.

Instrumentation (sample of questions, scoring method, and psychometric properties (validity and reliability))

Instrument

The overarching methodology of this review paper involved a multi-stage process. Initially, the research team clearly defined the paper's aim and scope: to investigate the potential of butterfly pea as a natural functional ingredient within rice-based products, specifically focusing on its ability to reduce postprandial blood glucose levels, while also considering its impact on glycemic response, nutritional content, and overall product acceptability. Following this, the core of the procedure involved systematically gathering and analyzing existing scientific evidence, meticulously examining research findings that explored the functional properties of butterfly pea. This systematic review of the literature specifically included studies that reported on the inhibitory activity of butterfly pea against enzymes like α-amylase and α-glucosidase. The final stage of the process involved synthesizing all compiled findings to draw conclusions regarding butterfly pea's rich content of bioactive compounds, particularly anthocyanins and flavonoids, and their demonstrated inhibitory effects on carbohydrate-digesting enzymes, as well as the plant's potential to lower postprandial glucose levels. It is noted that the article does not specify a time frame for the literature search or review process.

Analysis plan (describe statistical tests and the comparisons made; ordinary statistical methods should be used without comment; advanced or unusual methods may require a literature citation)

The "analysis" in this review primarily involved the compilation and evaluation of scientific evidence to substantiate the functional claims associated with butterfly pea. This included reporting on various functional properties identified in the literature, such as its inhibitory activity against α-amylase and α-glucosidase enzymes. Furthermore, the review summarized the effects observed in *in vivo* models, highlighting aspects like reduced blood glucose levels and elevated serum insulin concentrations in diabetic rat models, enhanced antioxidant defense, anti-inflammatory effects, and improved glucose metabolism. The analysis also focused on identifying key bioactive compounds found in butterfly pea, including anthocyanins, flavonoids, catechins, and inositol, along with their reported properties. As this is a review paper, it did not conduct its own statistical tests or make new comparisons, but rather reported on comparisons that were already made and statistically analyzed in the original studies.

Scope and/or limitations of the methodology you used

The provided text does not explicitly detail the limitations of this specific review's methodology. However, common limitations inherent in such literature reviews, which would be relevant here, include a reliance on existing data quality: the validity of the findings is directly dependent on the quality, methodology, and scope of the primary research studies reviewed, as the review itself does not generate new experimental data. There is also a potential for publication bias, where the review can only synthesize what has been published, and a bias towards positive or significant results in the literature may lead to an incomplete picture. Heterogeneity of primary studies is another general limitation, as differences in experimental methodologies, plant growth conditions, extraction techniques, and analytical methods across the various reviewed studies can introduce variability and make direct comparisons challenging. While the article mentions specific characterization of butterfly pea simplicia powder and identified compounds, it does not explicitly state the variability across reviewed studies as a limitation of its methodology. Furthermore, the review clearly indicates limited in vivo evidence for human translation, stating that many reported biological activities are based on in vitro assays and that their translation to in vivo efficacy in humans requires further investigation. This points to a limitation within the body of literature reviewed rather than the review's methodology itself. Finally, the review has a specific scope, focusing on the functional food application of Butterfly Pea in rice, with an emphasis on reducing glycemic impact, encompassing phytochemical analysis, food formulation, nutritional evaluation, and potential health benefits. While this is a defined scope, it implies the review does not cover all possible applications or benefits of butterfly pea.

While the provided text doesn't explicitly list the limitations of this specific review's methodology, it implicitly highlights several common limitations inherent in such literature reviews. Foremost among these is a fundamental reliance on the quality of existing data, meaning the validity of the review's conclusions is directly contingent upon the rigor, methodology, and scope of the primary research studies it synthesizes, as the review itself does not generate new experimental data.

Another significant consideration is the potential for publication bias, where the review might present an incomplete picture due to a documented tendency in scientific literature to favor the publication of studies with positive or significant results. Furthermore, the heterogeneity of primary studies poses a challenge; differences in experimental methodologies, plant growth conditions, extraction techniques, and analytical methods across the various reviewed studies can introduce variability and complicate direct comparisons. Although the article references specific characterizations of butterfly pea simplicia powder and identified compounds, it does not explicitly acknowledge the broader variability across reviewed studies as a methodological limitation.

Additionally, the review implicitly points to a limited amount of *in vivo* evidence for human translation. It explicitly states that many reported biological activities are based on *in vitro* assays, and therefore, their translation to *in vivo* efficacy in humans necessitates further investigation. This highlights a gap in the broader body of literature reviewed rather than a direct flaw in the review's methodology itself. Finally, the review operates within a specific scope, focusing on the functional food application of butterfly pea in rice, particularly concerning glycemic impact, phytochemical analysis, food formulation, nutritional evaluation, and potential health benefits. While this defined scope allows for focused analysis, it inherently means the review does not encompass all possible applications or benefits of butterfly pea.

RESULTS AND DISCUSSION

Results

The Butterfly Pea Flower was identified at the Laboratory of Ecology and Biosystematics, Faculty of Science and Mathematics, Diponegoro University, Indonesia. Samples were collected from the Martani flower garden of Purwomartani village, Kalasan District, Sleman Regency, Yogyakarta. The 2.10 kg of simplicia powder was produced after 48 hours of drying in a dehydrator. The fragmented epidermis of butterfly pea simplicia was depicted in Figure 2. along with vascular tissue, trichomes of varying curved lengths, stomata, and prism-shaped calcium oxalate (Lucianus et al., 2024).

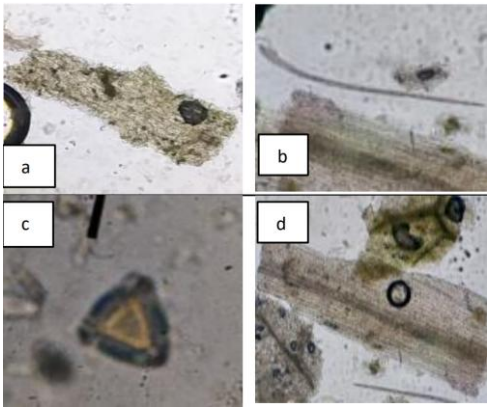

Figure 2. Identification of fragments of butterfly pea flower simplicia powder at 100x magnification (a) epidermis; (b) trichomes; (c) calcium oxalate crystals; (d) vascular tissue

Simplicia powder must be described in order to guarantee that traditional medicines fulfill material requirements for quality, safety, and efficacy. According to Table 1., butterfly pea flowers' simplicia satisfied current requirements (Lucianus et al., 2024).

Table 1. Characterisation of butterfly pea simplicial powder

Characterisation	Result
Water-soluble extract content	41.66 ± 2.0%
Ethanol-soluble extract content	34.33 ± 1.15%
Water content	5.33 ± 1.15%
Total ash content	5.95 ± 1.33%
Acid-insoluble ash content	0.50 ± 0.05%
Drying shrinkage	7.0 ± 0.87%

The butterfly pea has a rich phytochemical content that has been used traditionally to cure a wide range of health issues. Through LC-MS/MS analysis, several bioactive compounds have been identified in butterfly pea tea extract (CTE), including (+)-catechin 7-O-β-glucoside, inositol, 2-hydroxycinnamic acid, and delphinidin-3-O-(6-O-p-coumaroyl) glucoside-pyruvic acid (Widowati et al., 2024). Based on this study, it is known that CTE contains phenols and flavonoids with antioxidant properties. The effectiveness of inositol and catechin in the treatment of diabetes mellitus has been shown in previous studies. According to a different study by Al-Snafi et al., CTE is also abundant in glycosides, phenols, flavonoids, and tannins (Kj, N, & Kr, 2024). CTE has been reported to contain various phytochemicals, including triterpenoids, alkaloids, saponins, and anthocyanins, which collectively contribute to its potent antioxidant properties. CTE may possibly have anti-inflammatory and antioxidant properties.

Serum glucose and cholesterol values that are elevated are indicative of diabetes and dyslipidemia. In this study, rat models of diabetes mellitus and dyslipidemia were created by inducing STZ and NA, together with PTU and HFD. The rats' blood glucose and cholesterol levels both exceeded 250 and 200 mg/dL, respectively, according to the induction results. Rats' blood glucose levels can drop after receiving CTE treatment (Bhardwaj, Khanna, & Balakumar, 2014).

Among the chemical components found in butterfly pea plants are sugars, tannins, saponins, triterpenoids, flavonoids, phenols, flavonol glycosides, alkaloids, proteins, anthraquinones, and anthocyanins. Leaf extract from butterfly pea has been demonstrated in studies to have a favorable effect on insulin levels and lower blood glucose. Butterfly pea flower extract demonstrated beneficial effects on metabolic and immune homeostasis in a mouse model of low-grade inflammation. Supplementation with butterfly pea significantly reduced metabolic endotoxemia by decreasing plasma levels of glucose, lipopolysaccharide (LPS), and tumor necrosis factor-alpha (TNF-α). Additionally, it contributed to the restoration of lipid metabolism and modulated

immune function by rebalancing regulatory T cells (Treg) and T helper 17 cells (Th17), thereby mitigating dysfunction in hepatic and abdominal white adipose tissues (Yu et al., 2023).

Butterfly pea flower extract has been shown to contain several bioactive compounds, including delphinidin-3-O-(6-O-p-coumaroyl) glucoside-pyruvic acid, inositol, (+)-catechin 7-O-β-glucoside, and 2-hydroxycinnamic acid. Experimental studies in diabetic rat models have demonstrated its potential hypoglycemic effect, evidenced by reduced blood glucose levels and elevated serum insulin concentrations. Additionally, the extract enhances antioxidant defense by increasing serum catalase (CAT) and superoxide dismutase (SOD) activities while reducing malondialdehyde (MDA) levels. It also exerts anti-inflammatory effects, marked by a decrease in pancreatic pro-inflammatory cytokines IL-6 and IL-18. Furthermore, the extract promotes glucose metabolism by elevating glycogen content and downregulating the expression of glycogen synthase kinase-3β (GSK-3β). Additionally, the extract lessens the quantity of necrotic cells and hepatic lipid breakdown in diabetic rats. Because butterfly pea extract has anti-inflammatory, antioxidant, and glycogen-boosting properties, it thus exhibits great promise as a treatment for diabetic mellitus (Widowati et al., 2023).

Discussion

The escalating global prevalence of diabetes and related glucose metabolic disorders has ignited a significant interest in identifying functional foods capable of effectively regulating blood sugar levels. A crucial aspect of this challenge lies with staple foods like white rice, which, due to its high Glycemic Index (GI), commonly leads to sharp and rapid increases in blood glucose following consumption. In this context, butterfly pea emerges as a promising intervention; its rich anthocyanin content is theorized to inhibit key carbohydrate-digesting enzymes, such as α-amylase and α-glucosidase, thereby serving to slow down the absorption of glucose into the bloodstream. This mechanism suggests that the strategic incorporation of butterfly pea extracts or powders into rice could effectively mitigate its glycemic impact, simultaneously enhancing its nutritional profile and potentially improving its sensory characteristics.

Understanding the GI categorization is vital, as carbohydrate-rich foods are classified based on their direct effect on blood sugar levels, with low-GI options ensuring a more gradual and sustained rise in glucose, which is crucial for preventing postprandial hyperglycemia. Beyond its enzyme-inhibiting properties, previous studies have already demonstrated the efficacy of specific compounds found in butterfly pea, such as inositol and catechin, in the management of diabetes mellitus. Collectively, the anti-inflammatory, antioxidant, and glycogen-boosting attributes inherent in butterfly pea extract indicate its considerable potential as a multifaceted therapeutic agent in the comprehensive treatment and management of diabetes mellitus.

Implications

This article stands as a comprehensive review paper, meticulously designed to evaluate and compile the scientific evidence pertaining to the diverse functional claims associated with butterfly pea (*Clitoria ternatea*). Its core objective is to synthesize the existing body of literature, particularly focusing on the plant's functional properties, notably its demonstrated inhibitory activity against key carbohydrate-digesting enzymes such as α-amylase and α-glucosidase. Through this synthesis, the paper aims to consolidate current knowledge regarding butterfly pea's health benefits.

Furthermore, this paper distinguishes itself by specifically concentrating on the application of butterfly pea as a functional food ingredient, particularly within rice-based products, with a primary emphasis on its potential to reduce glycemic impact. To achieve this, the review systematically gathers and analyzes research findings that explore butterfly pea's functional properties based on robust empirical scientific investigations. This focused approach encompasses various aspects, including phytochemical analysis, strategies for food formulation, nutritional evaluation, and a thorough assessment of its potential health benefits in the context of improving the glycemic response of staple foods like rice.

Research Contribution

This article is a review paper that aims to evaluate and compile scientific evidence regarding the functional claims of butterfly pea. It synthesizes existing literature related to butterfly pea's functional properties, including its inhibitory activity against α-amylase and α-glucosidase enzymes. The paper specifically focuses on the functional food application of butterfly pea in rice, with an emphasis on reducing glycemic impact, encompassing phytochemical analysis, food formulation, nutritional evaluation, and potential health benefits. This is achieved by systematically gathering and analyzing research findings that explore butterfly pea's functional properties based on empirical scientific investigations.

Limitations

While the provided text does not explicitly detail the limitations inherent to this specific review's methodology, it implicitly highlights several common constraints that apply to such literature syntheses. Foremost among these is the fundamental reliance on the quality of existing data. The validity of this review's findings is thus directly contingent upon the rigor, methodology, and scope of the primary research studies it incorporates, as the review itself does not generate any new experimental data. Compounding this, there is a potential for publication bias; since the review can only synthesize what has been published, the scientific literature may exhibit a bias towards studies reporting positive or significant results, potentially leading to an incomplete or overly optimistic overall picture.

A significant challenge also arises from the heterogeneity of primary studies. Variations in experimental methodologies, plant growth conditions, extraction techniques, and analytical methods across the diverse primary studies reviewed can introduce considerable variability, making direct comparisons and uniform synthesis challenging. Although the article mentions the specific characterization of butterfly pea simplicia powder and identified compounds, it does not explicitly acknowledge this broader variability across the reviewed studies as a direct limitation of its own methodological approach.

Furthermore, a critical observation pertains to the limited *in vivo* evidence available for human translation. The review clearly indicates that many of the reported biological activities of butterfly pea are based predominantly on *in vitro* (test tube or cell culture) assays. Consequently, the definitive translation of these observed effects to *in vivo* efficacy in humans necessitates further, more extensive investigation. This particular point highlights a limitation within the broader body of literature that the review draws upon, rather than a direct flaw in the review's methodology itself. Lastly, the review operates within a specific scope, focusing intently on the functional food application of butterfly pea in rice, with a precise emphasis on reducing glycemic impact, and encompassing phytochemical analysis, food formulation, nutritional evaluation, and potential health benefits. While this defined focus is intentional and allows for in-depth analysis of a particular area, it inherently means that the review does not encompass all possible applications or a full spectrum of benefits associated with butterfly pea.

CONCLUSION

Despite being the main source of energy in the human diet, postprandial effects of carbohydrates, especially those from foods with a high GI, can cause metabolic imbalances and make it difficult to control weight. Foods high in carbohydrates can be categorized using the glycemic index according to how they affect blood glucose levels, foods with a low GI are thought to improve glycemic control. Anthocyanins and flavonoids, two bioactive substances found in butterfly pea, have drawn interest because they have strong anti-inflammatory, antioxidant, and diabetes-lowering effects. Studies reveal that butterfly pea extract has the potential to be a natural treatment for diabetes and associated metabolic diseases by lowering blood sugar, raising insulin levels, lowering oxidative stress, and improving glycogen storage. By including these natural cures into dietary plans, health outcomes could be improved in a sustainable and efficient manner.

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AUTHOR CONTRIBUTION STATEMENT

Jocelyn Louice: Conceptualization, Investigation, and Writing. **Victor Christian Kaharso:** Investigation. **Natasya Hermawan:** Conceptualization. **Nerissa Arviana Tristanto**: Resources, Writing - review & editing.

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