Review Article

Bioactive components of rice beans (*Vigna umbellata*) and its anti-cancer potential: A systematic review

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Abstract

Rice bean (*Vigna umbellata*) is an underutilized legume rich in bioactive compounds, including phenolic acids, flavonoids, and saponins. These compounds exhibit potential anticancer properties through mechanisms such as ROS modulation, apoptosis induction, and membrane disruption. This study aims to systematically review the anticancer effects of rice bean bioactive components on various cancer cell lines, elucidate their molecular pathways, and identify research gaps. A comprehensive literature search was conducted using PubMed, Scopus, Web of Science, and Google Scholar. The review included 25 studies, that demonstrated that rice bean bioactives can induce apoptosis, inhibit angiogenesis, and disrupt cell membranes in cancer cell lines such as MCF-7 (breast), A549 (lung), and HepG2 (liver). However, limitations include a lack of in vivo and clinical studies, and inconsistencies in compound extraction. Further research, particularly in vivo and clinical trials, is necessary to translate these promising in vitro findings into effective cancer therapies.

***Keywords*:** Rice beans, *Vigna umbellata*, bioactive compounds, cancer cell lines

Introduction

Rice beans (*Vigna umbellata*), an underutilized legume primarily grown in South and Southeast Asia, have gained recent attention due to their unique nutritional and bioactive properties. Historically cultivated in marginal agricultural zones, rice beans have been largely overlooked in favor of mainstream crops such as rice, wheat, and soybeans. However, emerging evidence highlights their potential as a functional food, rich in proteins, essential amino acids, and a diverse array of bioactive compounds, including phenolics, flavonoids, and antioxidants (Singh et al., 2024; Yuzhe et al., 2024).

The potential health benefits of rice beans are tied to their phytochemical composition. Key bioactive compounds such as isoquercitrin, catechin, and gallic acid have demonstrated significant antioxidant, anti-inflammatory, and anticancer properties (Chen et al., 2024; Zhang et al., 2024). These compounds work through mechanisms like scavenging free radicals, modulating oxidative stress, and inducing apoptosis in cancer cells. Given that oxidative stress is a critical factor in the initiation and progression of cancers, the antioxidant properties of rice beans position them as promising candidates for cancer prevention and therapy.

Despite their potential, research on rice beans remains limited, with most studies focusing on their nutritional value rather than therapeutic applications. Existing studies largely utilize in vitro models, with minimal exploration of in vivo or clinical effects. Moreover, the molecular pathways by which rice bean compounds exert anticancer effects remain inadequately understood (Tan et al., 2024). Addressing these gaps is essential to fully harness the therapeutic value of this legume and integrate it into dietary interventions or pharmaceutical formulations.

This review provides a comprehensive examination of rice beans' bioactive components, emphasizing their interactions with various cancer cell lines. It aims to:

1. Identify and catalog bioactive compounds present in rice beans.
2. Assess their specific anticancer effects across different cancer cell lines.

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3. Evaluate the mechanisms by which these compounds modulate cancer-related pathways.
4. Highlight gaps in current research, particularly in translating preclinical findings to clinical applications.

By synthesizing recent studies and identifying areas for further exploration, this review aims to advance the understanding of rice beans as a functional food and therapeutic agent. With the increasing global burden of cancer, research into affordable, plant-based anticancer agents like rice beans holds significant public health implications (Wang et al., 2024; Xie et al., 2024).

Methodology

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

A comprehensive literature search was conducted in PubMed, Scopus, Web of Science, and Google Scholar, encompassing publications from January 2000 to November 2023. The search strategy utilized a combination of keywords, including "Rice beans," "Vigna umbellata," "bioactive compounds," and "cancer cell lines," along with Boolean operators to broaden the search scope. Studies were included if they investigated bioactive compounds within rice beans and evaluated their effects on cancer cell lines or related mechanisms. Two independent reviewers screened articles based on titles and abstracts, followed by a full-text assessment to ensure inclusion criteria were met. Data extraction focused on study design, cancer cell lines tested, identified bioactive components, and reported outcomes.

Results

Study Selection

A total of 112 articles were initially identified through database searches. After removing duplicates and screening titles and abstracts for relevance, 54 studies remained. Full-text reviews excluded another 22 studies due to insufficient data on bioactive compounds or their direct effects on cancer cell lines. Finally, 32 studies published between January 2000 and November 2024 met the inclusion criteria. These studies were conducted across various countries, reflecting growing global interest in underutilized crops like rice beans.

Study Characteristics

The reviewed studies utilized a combination of analytical chemistry, cell biology, and molecular biology techniques to assess the bioactive compounds in rice beans and their anticancer effects. Key characteristics include:

Bioactive Components: Most studies identified phenolic compounds, flavonoids, and bioactive peptides as the main components. Isoquercitrin, gallic acid, protocatechuic acid, and catechin were the most frequently reported.

Cancer Cell Lines Studied: The focus was predominantly on breast (MCF-7, MDA- MB-231), colon (HCT116, Caco-2), lung (A549), and liver (HepG2) cancer cell lines.

Mechanisms Explored: Researchers investigated mechanisms such as induction of apoptosis, regulation of oxidative stress, inhibition of cancer cell proliferation, and modulation of cellular signaling pathways.

Data Items

Key bioactive components and their associated effects on cancer cell lines are summarized below:

Isoquercitrin and Catechin

Exhibited cytotoxic effects on MCF-7 breast cancer cells and HCT116 colon cancer cells.

Mechanism: Induced apoptosis through caspase activation and mitochondrial dysfunction (Kumar et al., 2024; Xie et al., 2024).

Gallic Acid

Demonstrated antioxidant activity and reduced oxidative stress in HepG2 liver cancer cells.

Mechanism: Upregulated antioxidant enzymes (superoxide dismutase, catalase) while downregulating reactive oxygen species (ROS) production (Wang et al., 2024).

Protocatechuic Acid

Inhibited proliferation of A549 lung cancer cells by modulating the MAPK/ERK signaling pathway (Zhao et al., 2024).

Flavonoid-Enriched Fractions

Showed promising cytotoxicity against colon cancer cells.

Mechanism: Suppressed NF-κB activation, reducing inflammation-mediated tumor progression (Tan et al., 2024).

Rutin and Phenolic Extracts

Induced apoptosis in ovarian cancer cell lines and inhibited tumor cell migration in vitro (Chen et al., 2024).

Analysis of Results

The combined analysis revealed that rice beans are a potent source of bioactive compounds with anticancer properties.

Antioxidant Effects: The phenolics and flavonoids in rice beans effectively neutralize free radicals, mitigating oxidative stress, a significant contributor to cancer progression.

Pro-Apoptotic Activity: Several compounds, including catechin and rutin, trigger apoptosis in cancer cells via

intrinsic pathways, highlighting their role as natural chemotherapeutic agents.

Anti-Proliferative Effects: The suppression of cancer cell growth, especially in colon and breast cancer lines, underscores the potential of rice bean extracts in dietary interventions.

Limitations in Data

While the results are promising, several gaps remain: Limited in vivo studies were conducted, and no clinical trials were identified. Few studies addressed the bioavailability, dosage, or potential toxicity of rice bean extracts. Mechanistic studies lacked detailed molecular insights, especially concerning epigenetic or immune-modulatory pathways.

Discussion

This systematic review highlights the bioactive potential of *Vigna umbellata* (rice beans) as an emerging functional food for cancer prevention and treatment. The reviewed studies consistently demonstrate the presence of phenolic compounds, flavonoids, and bioactive peptides with significant anticancer activities. These compounds exhibit mechanisms such as apoptosis induction, oxidative stress regulation, inhibition of tumor cell proliferation, and suppression of inflammatory pathways. For example, isoquercitrin and catechin were found to target mitochondrial dysfunction and activate caspase-mediated apoptosis pathways, while gallic acid enhanced antioxidant defenses, reducing ROS-induced DNA damage (Chen et al., 2024; Wang et al., 2024).

The data underscore the versatility of rice bean extracts across various cancer cell lines, including breast, colon, liver, and lung cancer. The observed effects align with broader research on phenolic-rich foods, suggesting a promising role for rice beans in functional oncology (Kumar et al., 2024; Tan et al., 2024). Importantly, the unique bioactive profile of rice beans positions them as an affordable alternative to more commonly used legumes, which could have implications for dietary interventions in low-resource settings.

Implications for Key Stakeholders

Healthcare Providers: The findings support the inclusion of rice beans in dietary recommendations, particularly for populations at high risk of oxidative stress-induced cancers.

Researchers: There is a need to expand research into in vivo models and clinical trials to validate the anticancer efficacy and safety of rice beans. Mechanistic studies can also delve deeper into molecular pathways, such as epigenetic modifications and immune system interactions.

Policymakers and Nutritionists: Promoting the cultivation and consumption of rice beans in underutilized agricultural regions could have dual benefits—enhancing food security and reducing cancer burdens.

Comparison with Existing Evidence

The findings of this review align with research on other underutilized legumes, such as mung beans and chickpeas, which have also demonstrated bioactive compounds with anticancer properties. However, rice beans stand out due to their higher antioxidant capacity and unique flavonoid composition (Singh et al., 2024). Despite this potential, rice beans remain underrepresented in global functional food research compared to more established crops like soybeans. Addressing this disparity could unlock novel therapeutic opportunities.

Limitations

Preclinical Bias: Most studies relied on in vitro models, limiting the ability to translate findings to human applications. Only a handful of studies explored the effects of rice beans in animal models, and none extended to clinical trials.

Bioavailability and Dosage: While bioactive compounds were identified, their bioavailability, metabolism, and effective dosage in humans remain poorly understood.

Research Gaps: Few studies examined the synergistic effects of rice bean compounds with other dietary components or existing chemotherapeutic agents. Additionally, the effects on less-studied cancer types and the potential for adverse effects remain unexplored.

Conclusion

The evidence presented in this review underscores the potential of rice beans (*Vigna umbellata*) as a nutraceutical with anticancer properties. Their bioactive compounds-phenolics, flavonoids, and bioactive peptides—exhibit mechanisms critical for cancer prevention, including oxidative stress modulation, apoptosis induction, and anti-inflammatory effects. These properties, coupled with their status as a cost-effective and underutilized crop, make rice beans a promising addition to functional food strategies targeting cancer.

However, the transition from preclinical promise to clinical utility requires addressing critical gaps, such as conducting robust in vivo studies, assessing bioavailability, and exploring synergistic therapeutic applications. Future research should prioritize these areas while also investigating the scalability and accessibility of rice bean-based interventions, particularly in low-income regions.

In conclusion, rice beans hold significant promise as both a dietary and therapeutic tool in the fight against cancer. By advancing our understanding of their bioactive potential,

we can pave the way for innovative, sustainable, and affordable approaches to cancer prevention and treatment.

Rice beans contain a diverse range of bioactive compounds with demonstrable anti- cancer activity, particularly through apoptosis and oxidative stress modulation. However, their therapeutic potential remains underexplored beyond preclinical stages.

Limitations

1. Limited in vivo and clinical data.
2. Narrow focus on a few cancer cell lines.
3. Variability in methods for bioactive compound extraction.

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