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Recent important insight into nutraceuticals potential of pigmented rice cultivars: A promising ingredient for future food

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ABSTRACT

Many phytochemicals and nutraceuticals have historically been known to have positive effects on health, especially in ancient and modern health systems. Due to the presence of color, rice, a common basic meal, has anti-inflammatory, anti-cancer, and nutritional effects. It has been shown that polyphenols in rice extracts can alter important signaling pathways involved in cancer. It is also commonly used for its nutritional benefits and to promote general health. We cover the phytochemicals and potential health benefits of colored rice in this brief review. This article discusses the relatively limited *in vivo* research that has been done to date to formally establish the nutritional potential of rice. Importantly, the available literature supports and promotes the use of colored rice as an anti-diabetic agent, source of prebiotics, and cancer-preventing agent. To methodically evaluate the clinical efficacy and potential of colored rice, future research must focus on properly planned clinical trials in cancer and diabetes patients. Further scientific research on rice extract alone or colored rice flour as a nutritional food and/or functional food could pave the way for new ways to explore the health benefits of rice from experiment to the clinic to prevent disease.

ARTICLE HIGHLIGHTS

- This paper presents an analysis of colored rice, focusing on its bioactive chemical content, concentration, activities, and potential health benefits
- The updated information on the bioactive compounds of colored/pigmented rice varieties was presented
- The link between the antioxidants and health benefits was providing by current researches
- The current status of the application of pigmented rice was summarized, and further application was suggested
- Pigmented rice could have more potential in future food with high promising nutraceutical properties.

1. INTRODUCTION

Two-thirds of the world's population consumes rice (*Oryza sativa*) in their diet; therefore, it is considered one of the most used food grains. Due to its availability, nutritional value and high energy content, rice is the main source of food for humans [1]. A small portion of rice grains are employed as ingredients in the production of foods and non-foods, whereas the majority is consumed as cooked form [2]. Rice is a significant source of fiber, energy, minerals, proteins, vitamins, antioxidants, and other biomolecules that may work in concert and have a positive impact on health [1-4]. According to Zhang *et al*. [1], rice is a significant source of a variety of antioxidant compounds that are crucial for promoting good health.

Since the 1980s, when antioxidants first gained attention as a "miracle substance," research on antioxidant compounds has become a major topic of interest. Due to their therapeutic effects, antioxidant supplements are being used by the general public more frequently every day. However, when the impact of antioxidant supplementation was examined, the results of the randomized controlled trials were inconsistent. However, pre-clinical research and ongoing studies have proven the potentially beneficial benefits of antioxidant molecules in a variety of chronic and acute disorders [5]. Consuming nutritious foods always has a positive impact on one's health, and the antioxidant molecules found in food are crucial in this regard [1,6-11]. Eating foods high in antioxidants and consuming antioxidant molecules can prevent or treat diseases such as oxidative stress, inflammation, and neurodegenerative disorders as well as cardiovascular, metabolic, and gastrointestinal issues [8]. Numerous studies are being conducted to determine the health benefits of rice and to identify strong bioactive phytomolecules, especially pigmented rice. Numerous findings from regions where colored rice consumption is common suggested that rice may protect against diseases linked to oxidative stress [12,13]. Co-products of rice, such as husk, bran, and rice bran oil from these rice

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varieties, include various medicinal nutraceuticals and have impressive curative and preventive effects on a variety of chronic and acute disorders. The nutritional and therapeutic benefits of colored rice were also described in traditional literature. A variety of rice varieties are still employed in traditional medicine to treat a wide range of illnesses. A comprehensive compilation of data on the phytochemicals present in rice, therapeutic activity of rice part, analysis of the likely mechanism of action of rice/rice biomolecules in light of current investigations, and also reporting on the pharmaceutical application of pigmented rice will be helpful for researchers working in this field to encourage the use of colored rice/rice biomolecules for therapeutic purposes. The major objective of this review is to summarize the most recent research on the bioactive compounds present in colored rice, their therapeutic potential, and potential pharmaceutical uses. This review also explores the connections between the antioxidant effect and therapeutic impact as well as the underlying mechanisms of these effects.

2. SEARCHING METHODOLOGY AND ARTICLE SELECTION

Several scientific website databases, including Google Scholar, ScienceDirect, PubMed, SpringerLink, and the Wiley Online Library, were thoroughly searched. Search terms included anti-oxidants, antibacterial, anticancer, anti-diabetic, and anti-inflammatory properties of colored or pigmented rice. There were no limitations on the methodology of the study, size of sample, or outcome measurement. An article is considered eligible if it satisfies the following criteria: utilization of colored rice in various disorders, utilization of pigmented rice as an antioxidant, anti-diabetic, anticancer, and antibacterial agent, adherence to the language requirement of exclusively using English, inclusion in the Scopus database for article indexing, and publication within the past 5 years. Patient studies, review articles, letters, and conference abstracts without specific details were omitted from the analysis.

3. BIOACTIVE COMPOUNDS IN PIGMENTED RICE CULTIVARS

The secondary metabolites known as bioactive chemicals in plants have the potential to have toxicological or pharmacological effects on human life [14-20]. Aside from the major biosynthetic and metabolic chemicals, plants also produce secondary metabolites, which are chemical molecules having biological activity. By promoting the interaction of these metabolites with the environment, sometimes referred to as phytochemicals, with the environment, plants are better able to develop, reproduce, and disperse. In addition to their role in the creation of colors, tastes, perfumes, and insecticides, phytochemicals are also responsible for a number of food-based products' microbiological and nutraceutical qualities [14]. The number of secondary metabolites in plants, which are completely accumulated in various plant sections, is crucial for treating a wide range of illnesses that are connected to health. Most profusely available classes of plant phytochemicals are alkaloids, tannins, saponins, flavonoids, terpenoid, steroids and glycosides and are known to serve as an antioxidant, antiviral, antidiabetic, anticancer, and anti-inflammatory agents [14,21,22]. About half of the world's population eats rice (*O. sativa* L.), a staple grain that offers nutrients [23]. One of the distinguishing characteristics between colored rice and white rice is the superior antioxidant capacity of colored rice, which come from the bioactive compound intrinsic in rice. Unique polyphenol subgroups found in whole grain rice of various colors have a favorable effect on human health [1]. Increased whole grain consumption is strongly linked to a lower prevalence of chronic illnesses, according to the numerous epidemiological research [24]. Recent studies have shown that colored rice has high levels of antioxidants [2], which were identified by various cutting-edge method as ultra-performance liquid chromatography (UPLC), high-performance liquid chromatography (HPLC), liquid chromatography-mass spectrometry, ultra-HPLC Online-ABTS system. However, the antioxidant of rice mainly consists in the outer layer of rice and was little in core of grain. Due to their bioactive components' increased antioxidant and anti-inflammatory effects as well as additional medicinal properties, colored rice varieties - especially black and red rice - have lately attracted increased interest [2]. These substances have quantities of total phenolic and flavonoid chemicals [21,25-27]. Phenolic, flavonoid, Vitamin E derivatives, γ-oryzanol, and proanthocyanidin antioxidant substances were identified in colored rice [2]. However, different locations or cultivars could lead to a change in the profile of antioxidant compounds in rice. High level of cyanidin 3-O-glucoside (C3G), peonidin 3-O-glucoside (P3G), and delphinidin 3-O-glucoside were found in glutinous and non-glutinous rice varieties in Southern of Thailand by applying HPLC technique [28]. Using HPLC-PDA-MS2 found that anthocyanins, with C3G and P3G, were the primary compounds in colored rice [29]. Red rice was also distinguished by a significant number of oligomeric procyanidins, which accounted for >60% of the secondary metabolite content. Ferulic acid, p-coumaric acid, and vanillic acid are the three elementary phenolic compounds found in black and red rice varietals. White and red rice has much lower quantities of vanillic acid than black rice [30]. Flavonoids, a type of widely distributed and naturally formed polyphenolic substances found in fruits, vegetables, and drinks made from plants, are often divided into flavones, flavanones, isoflavones, flavonols, and anthocyanins. Supplements in the diet containing flavonoids are regarded as health enhancing and disease promoting [31]. There are notable variations between different types of rice, and the quantity and variety of flavonoids present are directly tied to the color of the grain. Black rice and other colored cereal grains contain a type of flavonoids called anthocyanins, which range in color from red to purple [32]. Whole-grain black rice had a considerably lower total anthocyanin concentration than bran black rice, indicating that the bran layer is where most anthocyanins are found [33]. Although red rice is often rich in proanthocyanidins, anthocyanins were found in Italian black and purple rice varietals [2]. The two anthocyanins found in rice that are most representative are C3G and P3G.

4. PHYSIOLOGICAL FUNCTIONS OF PIGMENTED RICE

Currently, pigmented rice was presented with many health perspectives as presented in Figure 1, which outlined and detailed information as sub-section below.

4.1. Antioxidant Properties of Colored Rice

The diverse antioxidant activities that the phytochemical components of rice - rice bran, rice hulls, and so forth - possess are linked to their potential health benefits. A number of antioxidant compounds, including vitamin E, γ-oryzanol, phenolic acids, anthocyanin, and proanthocyanidin, and flavonoids, are reported to be present in rice and are considered to be good sources of them. Phenolic compounds in rice are very diverse in composition, which could be divided into two main types such as free and bound phenolic. Phenolic compounds and antioxidation are significantly positively correlated [23,30,34]. Analytical techniques such the reducing power assay (FRAP - ferric reducing antioxidant power), nitric oxide, hydroxyl radical, hydrogen peroxide radical, and 2,2-diphenyl-1-picrylhydrazyl

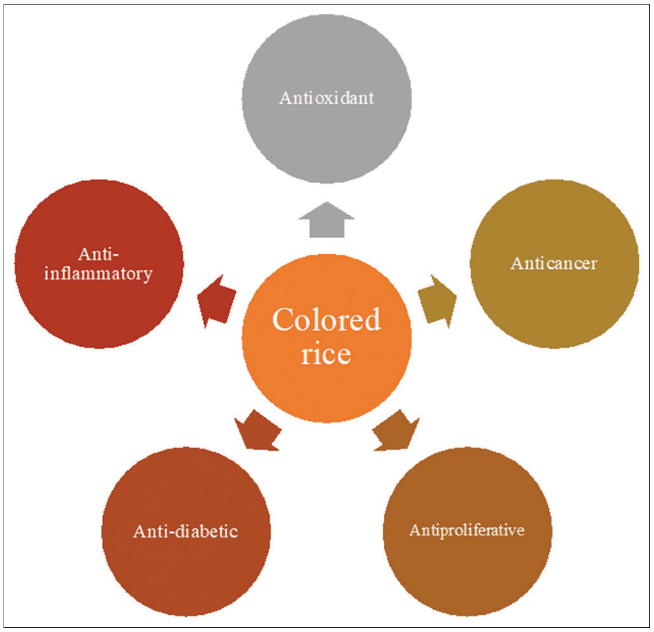

Figure 1: Physiological functions of pigmented/colored rice cultivars.

(DPPH) have been used to establish the substance's antioxidant ability [35,36]. Recently, comparative study of Colombo *et al*. [2] on Italian colored rice varieties shown that the black rice cultivar has the higher antioxidant activity (DPPH assay) than the orange and non-pigmented rice varieties. The reducing antioxidant activity due to the polishing process was reported, which mainly because of the losses of rice bran. The reported data from this study also were comparable with study of Melini *et al*. [37] on France and Italian rice on Italian market. Anthocyanin and proanthocyanidins (oligomers and polymers) of unpolished black rice kernels and bran extract displayed potent protective effects against oxidative stress [38]. Intermediates of anthocyanin and proanthocyanidins also have the ability to prevent activation and deactivation of different signaling pathways, including inflammatory pathway responsible to produce oxidative stress [39]. Indian rice was reported by Singh *et al*. [6], which revealed that pigmented rice possess the rich antioxidant compounds. According to reports, eleven rice varieties from Northeast India - black, red, and white - were examined for their antioxidant capacity, mineral content, and protein content in this study. Total phenolic content was 94.8 mg GAE/100 g in Idwa rice, whereas Lumre rice has 900.90 mg GAE/100 g. The range for the total flavonoid concentration was 3.46 (Idaw) to 286.76 mg QE/100 g (Menil mibabaret). Between 0.23 (Farel) and 93.52 mg/100 g (Chakhao poireiton), total anthocyanin concentration varied. The pigmented rice also contains high levels of the antioxidant enzymes catalase, ascorbate peroxidase, and superoxide dismutase, all of which are effective at reducing the oxidative stress response [6].

Anthocyanins are abundant in black rice, and consumers are aware of their antioxidant properties [3]. The results demonstrated that black rice anthocyanin extract boosted antioxidant enzyme activities and reduced reactive oxygen species and malondialdehyde accumulation in PC12 cells brought on by H_2O_2. Besides, the study of Pattananandecha *et al*. [28] also showed that potential antioxidant activity of pigmented rice through various analyses such as ABTS assay, lipid peroxidation, superoxide anions, a suppression effect on nitric oxide and an inducible nitric oxide synthase production in combined lipopolysaccharide-interferon-γ-activated RAW 264.7 murine macrophage cells through IC_{50} values. However, further studies should be considered application in various industries, especially it also could be the promising ingredient for food application.

4.2. Pigmented Rice as a Source of Anti-proliferative and Anti-cancer Agent

The presence of bioactive compound in the colored rice acts as the potent anti-cancerous agent. They impede the metastasis cascade mechanism, boost anti-angiogenic activity, and cause proptosis in the body to stop the carcinogens through the inhibition of cancer cell motility. The anti-proliferative activity of rice extract was recently assessed by using the neutral red assay, in human T-lymphocyte (Jurkat), hepatocellular carcinoma, colorectal carcinoma (HCT116), melanoma, and noncancerous cells [40]. This research showed that, due to high content of antioxidant compounds, the anti-proliferative activity of black glutinous rice was also high. Besides, by causing apoptosis and the activity of caspase 3/7, black glutinous rice demonstrated the most effective selective anti-proliferation against Jurkat cells. Thirty lines of rice variety in Indonesia were ethanol extracted, and the extracts showed the potential ability to cause cytotoxicity in the presence of the cancer cell lines MCF-7, HeLa, and OVK-18 [41]. For the *in vivo* study of Talib *et al*. [42], mice's food had added 10% and 20% rice bran, which provided by local mills in Al-Najaf (south of Iraq). For 2 weeks, mice were given rice bran-infused mouse food as a treatment. EMT6/P breast cancer cells were subcutaneously injected into the abdomen of each animal during the 3rd week of the experiment (10^6 cells/mL). Following a 14-day tumor inoculation period, the growing tumors' sizes were measured. This study reported that rice bran was found to be beneficial in boosting the immune system by stimulating the proliferation of lymphocytes and phagocytes, while also modulating cytokine levels. Three bacterial strains were utilized to test the antibacterial effectiveness of rice bran extracts using the microbroth dilution method. In ethanol and n-hexane extracts, the strongest anti-proliferative efficacy was seen. The most potent apoptosis-inducing and angiogenesis-inhibiting effects were seen in ethanol and methanol extracts. By stimulating lymphocyte and phagocyte proliferation and altering cytokine levels, both extracts were also effective at boosting immunity. When compared to the negative control, the addition of rice bran to mice's diet reduced tumor growth and development by 20%. According to this study, rice bran is a rich source of phytochemicals that are active and may help prevent cancer and boost the immune system. Multiple phytochemicals that work together synergistically in rice bran may be the cause of its biological effects. Black rice flour has recently been shown to be effective against the HCT116 and 3T3-L1 mouse embryo cell line by Thanuja *et al*. [43] Suantai *et al*. [44] studied on antiviral and anticancer potential of extract of red jasmine rice in Thailand. The study revealed that the ethanolic extract had a higher level of toxicity than the aqueous extract and had the potential to kill Caco-2 cells by intrinsic and extrinsic apoptotic routes, fragmenting their DNA. These results imply that red jasmine rice extract exhibits biological activity on herpes simplex virus, free radicals, and cancer cell inhibition in addition to nutritional value.

4.3. Anti-Diabetic Properties of Pigmented Rice

All health-care organizations are extremely concerned about the diabetes epidemic, which has become a global hazard. Both *in vitro* and *in vivo* studies were done to determine the ability of colored rice manages diabetes and the issues that come with these problems. According to Suwannasom *et al*. [45] research on black and red rice in Thailand, rats given these rice had considerably better glucose management, and the levels of triglycerides and cholesterol in the diabetic groups were also lowered. These rice resulted in lower concentrations of creatinine, blood urea nitrogen, aspartate aminotransferase, and malondialdehyde. In addition, diabetic rats treated with red rice or black rice had considerably higher glutathione concentrations in their serum and liver tissue [46]. Superhongmi rice in Korea found to have high rat small intestinal sucrase inhibitory activity and the anti-hyperglycemic effect using a Sprague-Dawley rat model [47]. Pigmented rice (*O. sativa* L., Superhongmi cultivar) has been shown to improve glucose and bone metabolism by changing the levels of insulin and adipokine in postmenopausal ovariectomized rats. According to a study in Thailand, eating rice bran extract lessened fat deposition and activated the genes for insulin signaling and glucose sensing in obese rodents that had been given high-fat diets, which in turn reduced pancreatic dysfunction [48]. With regard to its ability to treat type 2 diabetic mellitus (T2DM), black rice was regarded as a nutritious food. In rats, the levels of inflammatory cytokines, lipid metabolism, blood glucose, insulin resistance, and serum oxidative stress state were all considerably improved by black rice husk anthocyanin extracts, according to the Sun *et al*. [49] study, which also shown that liver damage was reduced. Black rice husk anthocyanin extracts altered the structure of the gut microbiota, increased the amount of short-chain fatty acids, activated activated protein kinase, PI3K, and AKT, suppressed the expression of HMGCR, G6pase, and phosphoenolpyruvate carboxykinase, and decreased hepatic gluconeogenesis. In T2DM rats, the levels of urea, deoxycytidine, L-citrulline, pseudouridine, and other blood metabolites were altered, which also resulted in a downregulation of the pyrimidine metabolism and arginine production pathways. The range of the red rice's *in vivo* glycemic index in Sri Lankra was between 52.5 and 64.0 [50]. Rice consumption and the glycemic index are typically viewed as diabetes risk factors. According to this study, consuming more colored grains may lower the chance of developing metabolic disease. Numerous studies have shown that eating colored brown rice instead of white rice has multiple health benefits since it contains larger concentrations of GABA and phenolic chemicals, which regulate the body's glycemic index, metabolic parameters, and endothelium activities.

4.4. Potential of Anti-inflammatory

Rich antioxidant compound could provide many potentials to anti-inflammatory. In black rice, 9 anthocyanin compounds were discovered using the UPLC-LTQ-Orbitrap-MS/MS technique. Furthermore, these substances dramatically reduced the release of nitric oxide and prostaglandin E2 from LPS-stimulated W264.7 cells, demonstrating their anti-inflammatory effects. Black rice bran extract impacts the control of jun-amino-terminal kinase, extracellular signal-regulated kinase, p65, and IB phosphorylation and inhibits the activation of the mitogen-activated protein kinases and nuclear factor-kappa B pathways [51]. Jom*et al*. [52] studied on pairwise correlation was used to identify the phytosterols causing colored rice bran oil's anti-inflammatory effect, and showed a substantial association with the suppression of pro-inflammatory cytokine genes. Activating cytokines known as type I interferons (IFNs-I) are involved in the pathophysiology of autoimmune and inflammatory disorders. Production of IFNs-I is triggered by signaling through nucleic acid sensors. When interferon genes are activated, a DNA sensor called a stimulator of interferon genes (STING) transmits signals that trigger the synthesis of IFNs-I. Through the stimulation of STING signaling, the red rice bran extract (RRBE)'s anti-inflammatory actions on macrophages were discovered in the Onsa-Ard *et al*. [53]'s investigation. With and without RRBE, STING agonist (DMXAA) was used to activate RAW264.7 macrophage cells. Using quantitative polymerase chain reaction and enzyme-linked immunoassay, the production of inflammatory cytokines was examined, and the level of mRNA expression was assessed. As a result, STING, and interferon-stimulated genes transcription is found to be considerably reduced by RRBE.

Two mechanisms - oxidative stress and inflammation - have an impact on research on the etiology of celiac disease (CD) [7]. To evaluate the possible antioxidant and anti-inflammatory activities of extracts from several varieties of black rice within the context of CD, this study developed a particular cellular model based on the use of gliadin as a pro-inflammatory stimulus. Moreover, by using the K562(S) agglutination test, it was demonstrated how the extracts modulate the activation of epithelial cells in CD. In particular, the lymphocyte-attracting CXCL-10 both before and after digestion was shown to be inhibited by the black rice extracts in their ability to produce the oxidative and inflammatory mediators under consideration. The observed anti-inflammatory action during *in vitro* digestion may be explained by the presence of anthocyanins and their digestive byproducts. Using black rice as a nutritious food or component of food supplements for celiacs is supported by the preliminary data from this study.

One of the most popular functional meals in the world, black rice has many health advantages. Special rice varieties have been created that offer higher nutrient values and demonstrate consumer-beneficial biological activities in an effort to support the rising trend of consumer interest in foods that promote well health. Mapoung *et al*. [4] studied on eight selected black rice germ and bran extracts from four non-glutinous and four glutinous rice varieties were compared for their phytochemical content, antioxidant levels, and anti-inflammatory effects. In line with this, glutinous BR extracts had higher levels of C3G, P3G, antioxidant, and anti-inflammatory characteristics than non-glutinous black rice extracts. According to Pearson's correlation, there was a significant positive correlation between the antioxidant capabilities and the amount of C3G in the black rice extracts. While P3G showed a high correlation between its anti-inflammatory capabilities. Last but not least, the black rice varieties were divided into three groups based on the results of the principal component analysis: Group A had the highest concentration of C3G and the best antioxidant properties; Group B had the highest concentration of P3G and the strongest anti-inflammatory properties; and Group C had the lowest concentration of phytochemical contents and the weakest bioactivities. The results of this study could help the food industry choose the type of black rice for functional foods based on its anthocyanin concentration, which could assist consumers for a new normal healthy lifestyle.

4.5. Other Health Perspectives

First, colored rice could potential in metabolic disorders, cardiovascular diseases and obesity. In preclinical and clinical trials involving diabetic, hypercholesterolemic, obese, and healthy individuals, rice bran and rice bran oil shown strong cardiometabolic protective benefits [54,55]. The black rice bran's anthocyanin is regarded as a significant hepatoprotective compound [56,57]. Moreover, the potential of prebiotic also presented on the colored rice. Jia *et al*. [58] was examined the effect of three colored rice cultivars' phenolic compound extracts on the gastrointestinal microbiome. According to this study, the main metabolites produced by gut microbiota fermentation were protocatechuic acid, chlorogenic acid, caffeic acid, and p-coumaric acid. Phenolic compounds stimulated the growth of these organisms [59]. While the presence of Megamonas was favorably connected with catechin and caffeic acid, the concentrations of ferulic and syringic acids were positively correlated with Bifidobacterium [58].

Table 1: Current application of pigmented rice in food industry.

Country	Color of rice/variety	Product	References
Vietnam	Purple "Cẩm" rice	Instant rice	[12]
	Purple "Cẩm" rice	Germinated rice four	[62]
	Purple "Cẩm" rice	Rice bread	[12]
	ST 25 (purple rice)	Rice milk	[67]
Thailand	Hom nil rice (black rice)	Vinegar	[64]
	Purple riceberry rice	Drinking beverage	[65]
	Riceberry and hom nil rice	Rice noodle	[68]
Taiwan	Purple rice	Wine	[66]
China	Black rice	Steamed bread	[69]

5. CURRRENT APPLICATION STATUS OF PIGMENTED RICE

Colored rice cultivars have garnered significant attention in exploratory research due to their possible applications and processing technologies that might enhance quality features and offer advantageous health properties. This is mostly attributed to the various health-promoting and chronic-disease-preventing effects associated with these cultivars. According to Surh and Koh [60], pigmented rice serves as a significant or subordinate component in several culinary preparations such as paella, rice cakes, fried rice, pancakes, risotto, and cereal [Table 1]. For example, the black rice was applied to pasta production, which is not only create the color for pasta but also provide the antioxidant sources [61]. Purple rice in Tien Giang (Vietnam) was also used for making instant rice with high content of antioxidant and potential to low glycemic index food [12]. The germinated flour from purple rice was also potential the functional ingredients in gluten-free bread production [62,63]. A high antioxidant vinegar was produced by Thai pigmented rice, which shown the highest efficacy in suppressing the growth of harmful bacteria, encompassing both Gram-negative and Gram-positive strains, was glutinous rice vinegar [64]. A functional product from Riceberry, a purple rice in Thailand, was used in beverage, which shown acceptance by consumers and high antioxidant compound [65]. A wine from Taiwanese purple rice was produced with aid of sonication process, which indicated the high antioxidant releasing and antioxidant activities [66]. As a result of its distinctive functions, this ingredient has gained significance as a key component in several innovative culinary products, including beverages, puddings, children's meals, porridge, desserts, traditional rice cake, bread, and pasta. However, the clinical test should be considered for acquiring the potential health benefits of these products.

6. CONCLUSION AND FUTURE PROSPECTS

Rice is one of the most widely used and healthiest cereal components worldwide. In addition to providing good nutrients, rice may also have helpful secondary metabolites. Pharmacological and phytochemical research on rice has received a lot of attention since rice bran includes bioactive compounds such γ-oryzanol, phytosterols, tocopherol, phenolic components, anthocyanin, and proanthocyanin. A wide range of pharmacological properties, including antioxidant, anti-inflammatory, anticancer, immunomodulatory, anti-diabetic, anti-hyperlipidemic, cardiovascular protective, antimicrobial, hepatoprotective, and nephroprotective properties, have been linked to rice bran or rice constituents through a number of mechanisms. The rice plant's many antioxidant compounds demonstrated strong advantages for health. Because rice plants provide the food industry with a wide range of raw materials and significant nutraceuticals, several food supplements have been produced. In the food business, rice by-products such rice bran, rice hull, rice bran oil, broken rice, and rice straw are the main raw materials utilized to make functional foods and supplements, particularly from rice that is rich in polyphenols. Colored rice bran has just lately been discovered to be a significant source of therapeutic chemicals. Rice starch is increasingly regarded as a key ingredient in nanofilms, mucoadhesives, and pharmacological adjuvants. There are many different medical and pharmacological applications for rice bran and its bioactive components, according to the literature that is currently available. Consuming whole-colored rice grains could be a future technique of illness prevention or treatment for conditions brought on by oxidative stress. Pharmaceuticals to prevent and treat a range of human diseases, such as metabolic disorders, inflammatory conditions, oxidative stress-related pathogenesis, and cancer, may soon be made using colored rice and its biomolecules. Due to rice's multiple applications in the production of complex formulations, its use and significance are expanding in the pharmaceutical business. Amylose is highly concentrated in both whole rice components and dietary supplements. Colored rice cultivars with high amylose bundle concentrations are required for the production of a variety of rice products, including noodles, cakes, desserts, alternative lipids, and nutritional supplements in powder form for immune system support.

7. AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, and analysis and interpretation of data. Ngo Van Tai took part in drafting the article; Ngo Van Tai, Le Thi Kim Loan and Bui The Vinh took part in revising the drafting of manuscript and providing valuable suggestions. All authors agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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9. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

10. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

11. DATA AVAILABILITY

All data generated and analyzed are included within this review article.

12. PUBLISHER'S NOTE

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