International Journal of Pharmacy and Pharmaceutical Research (IJPPR)
Volume 32, Issue 5, May 2026 **ijppr.humanjournals.com** ISSN: 2349-7203

A Comprehensive Review of Rice Bran Oil and It's Health Applications

Gargi V. Bachhav*[1], Amol S. Deshmukh[2], Samruddhi A. Avhad[1]

[1]Students, K. V. N. Naik S. P. Sanstha's, Institute of Pharmaceutical Education & Research, Nashik, 422002, Maharashtra, India.
[2]Department of Pharmaceutics, K. V. N. Naik S. P. Sanstha's, Institute of Pharmaceutical Education & Research, Nashik, 422002, Maharashtra, India.

Received: 27 March 2026 Revised: 22 April 2026 Accepted: 28 April 2026

ABSTRACT

Rice bran oil (RBO), extracted from the outer layers of the rice grain (*Oryza sativa* L.), has attracted substantial scientific interest over the past three decades, yet its global consumption remains far below its potential. Unlike most vegetable oils, RBO is unusual in that its most medically relevant constituent, gamma-oryzanol (γ-oryzanol), is found in no other commercially significant oil at comparable concentrations. This compound, together with an uncommon profile of tocotrienols, phytosterols, and squalene, gives RBO a bioactive character that sets it apart from competing oils such as sunflower, canola, and soybean. This review examines the chemical composition and nutritional attributes of RBO, its extraction and refining technologies, evidence for its health effects across cardiovascular, glycaemic, inflammatory, and antioxidant domains, and its current and prospective industrial applications. The literature from the past five years is assessed alongside landmark earlier studies. Several recurring weaknesses in the clinical evidence base are identified: underpowered trials, heterogeneous dietary backgrounds of study populations, inconsistent γ-oryzanol quantification methods, and a tendency to test RBO in isolation rather than as a substitute within habitual diets. These gaps matter because they are the primary reason RBO has not crossed from niche health-food ingredient into mainstream edible oil policy in most countries. The review concludes by identifying the extraction and stabilisation of wax-free, γ-oryzanol-enriched fractions as the most tractable near-term research priority.

Keywords: Rice Bran Oil; Gamma-Oryzanol; Tocotrienols; Phytosterols; Oryza Sativa

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple cereal for more than half the world's population. Global paddy production exceeded 520 million tonnes in 2022, and a byproduct of milling that fraction the bran layer, is generated at a rate of roughly 50-70 kg per tonne of paddy processed [1]. For most of milling history, rice bran was either discarded, fed to livestock, or used as a low-value fuel. Its conversion into edible oil at scale began seriously in Japan and India in the mid-twentieth century, but even today, only about 35% of the world's available rice bran is processed into oil; much of the rest is either used as animal feed or goes to waste before stabilisation can prevent rancidity [2].

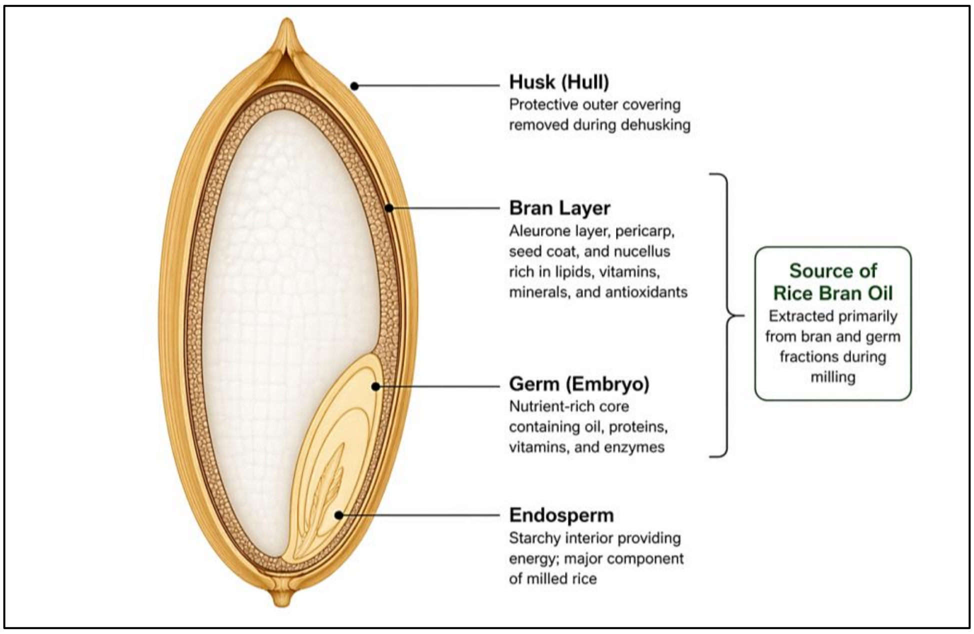

Figure 1. Structure of Rice Grain Showing Source of Rice Bran Oil

The underutilisation of rice bran is partly an economic and logistical problem, and partly a perception problem. In markets dominated by refined soybean or palm oil, RBO has struggled to compete on price. Its refining is complicated by high wax content and by the rapid activation of lipase enzymes that cause free fatty acid levels to spike within hours of milling, making raw bran difficult to store and transport [3]. These are not trivial barriers. But they are engineering and supply-chain problems, not fundamental obstacles to the oil's utility.

What has kept scientific interest in RBO alive despite these challenges is the composition of its unsaponifiable fraction. At concentrations of 1–2% by weight of crude oil, this fraction contains γ-oryzanol, a mixture of ferulic acid esters of phytosterols and triterpene alcohols, at levels simply not found elsewhere in the plant kingdom at commercially relevant scales [4]. Combined with a balanced ratio of oleic, linoleic, and palmitic acids, and with tocotrienol concentrations that rival those of palm oil, RBO presents a nutritional profile that is genuinely unusual rather than merely incremental.

2. Chemical composition of rice bran oil

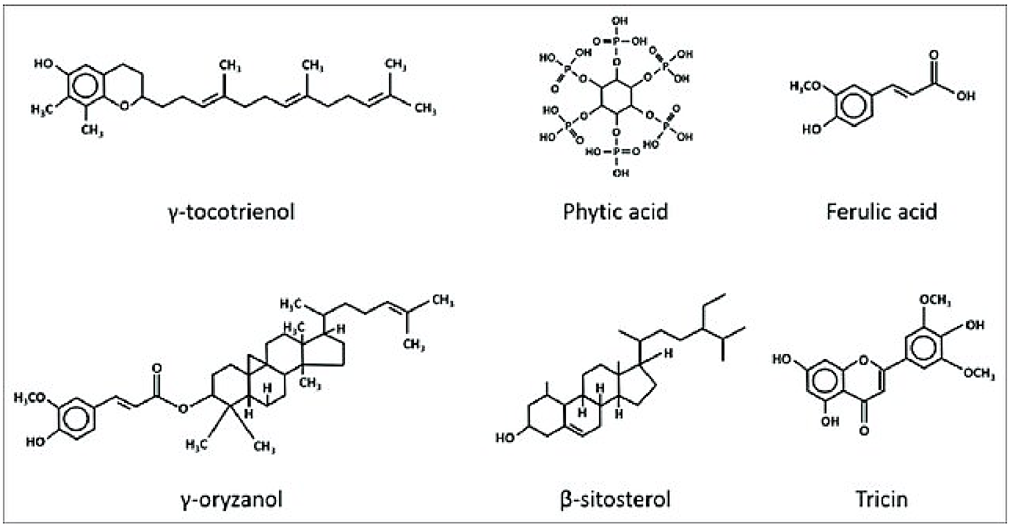

Figure 2. Major and minor constituents of rice bran oil

2.1 Fatty acid profile

The fatty acid composition of RBO is broadly similar to that of groundnut oil, which is one of the reasons it performs well in cooking. Oleic acid (C18:1) typically accounts for 38–48% of total fatty acids, linoleic acid (C18:2) for 16–36%, and palmitic acid (C16:0) for 15–23% [5]. Stearic (C18:0) and linolenic (C18:3) acids together account for less than 5% in most commercial samples. This ratio of monounsaturated to polyunsaturated fatty acids is close to the ratio considered optimal by most dietary guidance bodies, and the relatively low linolenic acid content means RBO is less prone to oxidative instability than flaxseed or canola oil [6].

Variation in fatty acid composition across rice varieties and growing regions is not negligible. A comparative study of Indian commercial rice bran oils found oleic acid ranging from 34.9% to 48.6% depending on the variety, with corresponding variation in the polyunsaturated fraction [5]. This matters for processing decisions: oils richer in polyunsaturated fatty acids will require more careful temperature management during frying, and will have shorter shelf lives under comparable storage conditions.

Table 1. Fatty Acid Composition of Rice Bran Oil Compared with Common Edible Oils

Oil	Oleic Acid (%)	Linoleic Acid (%)	Palmitic Acid (%)	Key Characteristic
Rice Bran Oil	38–48	16–36	15–23	Balanced profile
Sunflower Oil	20–30	55–70	5–8	High PUFA
Soybean Oil	20–30	50–55	10–12	Widely used
Canola Oil	55–65	18–25	4–6	High MUFA
Olive Oil	65–80	5–15	7–15	Very high MUFA

2.2 Gamma-oryzanol

Of all the constituents in RBO, γ-oryzanol has generated the most research attention, and reasonably so. Crude RBO contains 1.0–2.0 g of γ-oryzanol per 100 g of oil, though the concentration is sensitive to the extraction method and the post-extraction thermal history of the material [4]. γ-Oryzanol is not a single compound. It is a mixture of at least ten ferulic acid esters of phytosterols and triterpene alcohols, with cycloartenyl ferulate and 24-methylenecycloartanyl ferulate as the dominant components. Lerma-García et al. (2009) provided a detailed review of its chemistry and confirmed that the composition of the oryzanol mixture varies with rice variety, bran milling degree, and extraction conditions [7].

The biological significance of γ-oryzanol has been studied primarily in the context of plasma lipid modulation. The proposed mechanisms involve inhibition of cholesterol absorption in the intestine (via the phytosterol moiety) and antioxidant protection via the ferulic acid moiety [8]. These two mechanisms are separable in theory, which is why some researchers have argued that the whole γ-oryzanol mixture should be evaluated rather than synthetic ferulate esters alone. Whether γ-oryzanol acts synergistically with other RBO components in vivo, or whether its effects are additive and independent of the surrounding oil matrix, remains genuinely unresolved.

2.3 Tocopherols and tocotrienols

RBO contains both tocopherols and tocotrienols, with the latter present at higher concentrations than in most other commonly consumed vegetable oils except palm. Total tocotrienol content in crude RBO is typically 500–600 mg/kg, with α-, β-, γ-, and δ-tocotrienol all present [9]. Tocopherol content is in a similar range. The ratio of tocotrienols to tocopherols in RBO is approximately 1:1, which is distinctly different from soybean oil (predominantly tocopherols) or palm olein (predominantly tocotrienols in the red fraction).

This tocotrienol content carries implications beyond simple antioxidant capacity. Tocotrienols, particularly γ- and δ-forms, have shown stronger inhibition of HMG-CoA reductase than tocopherols in cell culture and animal studies, raising the question of how much of RBO's reported cholesterol-lowering effect is attributable to tocotrienols versus γ-oryzanol [10]. The distinction matters for mechanistic understanding, even if, from a dietary standpoint, the oil delivers all of these compounds simultaneously. Refining, however, is the problem: conventional alkali refining removes 30–40% of tocotrienols alongside free fatty acids and other polar compounds, meaning that the health properties attributed to crude or minimally refined RBO do not automatically extend to the fully refined product sold in retail markets [11].

2.4 Phytosterols

The phytosterol content of RBO (800–1,000 mg/kg) is among the highest of any vegetable oil [12]. β-Sitosterol, campesterol, and stigmasterol are the principal sterols, though the presence of triterpene alcohols (cycloartenol, 24-methylenecycloartanol) in quantities considerably exceeding those seen in other oils is a characteristic feature [12]. Phytosterols reduce LDL cholesterol by competing with dietary and biliary cholesterol for micellar incorporation in the small intestine, an effect well-established across multiple meta-analyses and accepted in regulatory health claims in the European Union and the United States [13]. The phytosterol content of RBO alone would give it meaningful LDL-lowering potential even in the absence of γ-oryzanol.

2.5 Squalene

Crude RBO contains squalene at concentrations of approximately 300–500 mg/kg, substantially higher than olive oil (300–600 mg/kg depending on the cultivar and processing) and considerably higher than other grain oils [14]. Squalene is a triterpene hydrocarbon with antioxidant properties and is an intermediate in the biosynthesis of cholesterol and steroid hormones. Some cancer biology research has suggested a protective role for dietary squalene, though the human evidence is currently insufficient to support specific claims [15]. Its presence in RBO is noteworthy for formulators developing nutraceutical and cosmetic applications.

2.6 Wax content

The wax fraction of RBO deserves separate mention because it is both a processing problem and a potential application. Rice bran wax consists primarily of long-chain fatty acid esters (C40–C66) and is present in crude RBO at concentrations of 3-9% by weight, depending on the milling fraction [16]. In refined and winterised oil, wax is removed by chilling and filtration (dewaxing), yielding a clear, stable product. The removed rice bran wax is itself a commercial product used in coatings, cosmetics, and as a carnauba wax substitute. But the dewaxing step adds cost and time, and incomplete dewaxing causes cold-temperature cloudiness that is commercially unacceptable in many markets.

Table 2. Major Bioactive Components of Rice Bran Oil and Their Functional Significance

Component	Typical Content	Main Biological Role	Notes
γ-Oryzanol	1–2% of crude oil	Cholesterol lowering, antioxidant, anti-inflammatory	Unique hallmark constituent of RBO
Tocotrienols	500–600 mg/kg	Antioxidant, lipid regulation, neuroprotection	Higher than many common oils
Tocopherols	Similar to tocotrienols	Vitamin E activity, oxidative stability	Supports shelf life
Phytosterols	800–1000 mg/kg	Reduces LDL cholesterol absorption	Regulatory interest
Squalene	300–500 mg/kg	Cosmetic, antioxidant, nutraceutical	High-value minor lipid
Wax	3–9%	Oleogels, cosmetics, coatings	Removed during dewaxing

3. Health Applications

3.1 Cardiovascular effects

The cardiovascular literature on RBO is the most extensive of any health domain and spans more than three decades. Sugano and Tsuji (1997) summarised early evidence from rodent and primate feeding studies showing that RBO, unlike most other vegetable oils, lowered both LDL cholesterol and triglycerides without reducing HDL cholesterol [3]. This profile attracted attention because most interventions that lower LDL do so at some cost to HDL.

The clinical evidence in humans is more modest. Most MM et al. (2005) conducted one of the more rigorously controlled human trials, randomising moderately hypercholesterolaemia adults to RBO versus wheat bran in a crossover design and finding that rice bran oil, not rice bran fibre, was responsible for LDL reductions of approximately 7% [17]. Lichtenstein et al. (1994) found similar LDL reductions in healthy subjects consuming RBO-enriched diets compared to beef tallow [18]. Cicero and Gaddi (2001) reviewed the broader pharmacological literature on γ-oryzanol and concluded that it had meaningful effects on lipoprotein profiles, though they noted that the majority of supporting studies were of short duration and conducted in highly selected populations [19].

What is often missing in the popular characterisation of RBO's heart-health credentials is any honest accounting of what happens at scale. The LDL reductions seen in controlled feeding studies (5–10%) are real but not dramatic. They are in a range comparable to what a person achieves by replacing saturated fatty acids with unsaturated ones using any number of cooking oils. The question is whether RBO's phytosterols, γ-oryzanol, and tocotrienols add clinically meaningful benefit on top of its favourable fatty acid profile. The answer from existing randomised trials is: probably yes, but the incremental benefit is modest, and it depends heavily on what oil is being replaced [17, 18].

More recent work has attempted to characterise RBO's effects on endothelial function and inflammatory markers. A 2021 randomised trial published in *Nutrition Research* found that 8 weeks of RBO consumption (25 mL/day) reduced circulating interleukin-6 and C-reactive protein in overweight adults compared to sunflower oil, with no significant difference in total cholesterol [20]. This suggests that RBO's anti-inflammatory properties may be partially independent of its lipid-modifying effects, an important distinction if RBO is to be positioned as more than a "cholesterol-lowering oil."

3.2 Glycaemic effects and type 2 diabetes

The effect of RBO on glucose metabolism and insulin sensitivity is less studied than its cardiovascular effects, but the available data are interesting. A 2019 study in *Food & Function* found that supplementation with 20 g/day of RBO for 12 weeks reduced fasting blood glucose and HOMA-IR scores in patients with pre-diabetes compared with sunflower oil, with the investigators attributing the effect to γ-oryzanol-mediated improvements in adipocyte insulin signalling [21]. The sample sizes were small (n=48), and the study was not blinded, but the mechanistic direction is consistent with earlier animal data showing that oryzanol reduces hypothalamic endoplasmic reticulum stress and improves whole-body glucose homeostasis [22-24].

A separate but potentially relevant observation is that rice bran wax extract, when tested as a dietary fibre-like supplement, slowed glucose absorption in postprandial studies. This suggests that even the wax fraction removed during refining may have functional food applications, though the clinical data do not yet support firm conclusions.

3.3 Antioxidant properties

The antioxidant capacity of RBO in vitro is substantial and reproducible across assays. Xu and Godber (2001) demonstrated that the major γ-oryzanol components had DPPH radical scavenging activity comparable to butylated hydroxytoluene (BHT) at equivalent concentrations, with cycloartenyl ferulate being the most active single component [8]. Tocotrienols contribute additional antioxidant activity that is synergistic rather than simply additive with oryzanol in some model systems.

The translation of in vitro antioxidant activity into meaningful in vivo outcomes is, as always, complicated. Oxidative stress is not a simple variable that goes up and down in proportion to dietary antioxidant intake. The human studies that have measured biomarkers of oxidative stress after RBO consumption have generally found reductions in urinary 8-isoprostane and malondialdehyde in circulation, but these are surrogate markers whose relationship to hard clinical outcomes is not well-established [25]. This is a limitation shared by virtually all research on dietary antioxidants and is not specific to RBO, but it is important to state rather than gloss over.

3.4 Anti-cancer properties

The anti-cancer literature on RBO and its constituents is largely preclinical. Tocotrienols from rice bran have demonstrated apoptosis-inducing activity in breast, colon, pancreatic, and prostate cancer cell lines in vitro and in rodent xenograft models [26]. The mechanisms proposed include inhibition of the NF-κB pathway, induction of apoptosis via caspase-3 activation, and modulation of Wnt/β-catenin signalling. Squalene has been investigated as a potential cancer-protective compound in epidemiological work from Mediterranean populations, though confounding by other dietary factors is substantial [15, 27].

It would be premature to describe RBO as anti-cancer on the basis of current evidence. The preclinical data are, however, credible enough to justify adequately powered human trials, particularly for the tocotrienol fraction. A phase II trial examining γ-tocotrienol supplementation in patients with early prostate cancer (clinicaltrials.gov identifier NCT01706848) has reported some results suggesting tolerable safety profiles, though efficacy conclusions require further follow-up [28]. This is the direction the field needs to move: away from cell lines and toward clinically meaningful endpoints.

3.5 Skin health and cosmetic bioactivity

RBO has a long history of use in cosmetics, particularly in Japan and South Korea, where rice water and rice oil-based skin formulations are conventional. The ferulic acid moiety of γ-oryzanol acts as a UV absorber with an absorption maximum around 320 nm, providing moderate protection against UVB radiation. Several commercial sunscreen formulations incorporate γ-oryzanol concentrate from RBO as a secondary filter. Squalene's emollient and skin-barrier-restoring properties are separately exploited in moisturising preparations. These applications are not speculative; they are established market segments, and the chemistry supporting them is well-characterised [29].

4. Industrial and food applications

4.1 High-temperature frying applications

RBO's fatty acid profile and naturally high content of antioxidants make it technically well-suited to high-temperature cooking. Its smoke point after refining is approximately 232–254°C, which is among the highest of commercially available vegetable oils, and comparable to avocado oil [1]. Oxidative stability during repeated frying cycles is considerably better than soybean or sunflower oil under the same conditions, a finding confirmed by accelerated oxidation studies measuring peroxide value, p-anisidine value, and polar compound formation [30]. Japanese food manufacturers adopted RBO for deep frying applications decades before most Western markets became aware of it, and its frying performance is one of the practical arguments least appreciated in health-focused discussions of the oil.

4.2 Food fortification and functional food development

Because of its γ-oryzanol and tocotrienol content, RBO has been incorporated into various functional food matrices as a means of delivering these bioactives at meaningful doses. The technical challenge is dispersibility: γ-oryzanol is lipophilic and does not emulsify readily, limiting its incorporation into aqueous food matrices. Microencapsulation strategies using modified starch, maltodextrin, or whey protein shells have been evaluated for both γ-oryzanol-enriched RBO fractions and intact oil, with encapsulation efficiencies of 70–90% reported in recent literature [31]. These encapsulated forms have been incorporated into breads, beverage emulsions, and infant formula lipid blends in pilot studies.

4.3 Pharmaceutical and nutraceutical applications

Purified γ-oryzanol is available as a dietary supplement in markets across Asia, Europe, and North America, typically sold as a stress-relief or sports recovery product (its use in Japan for this purpose dates to the 1960s). The evidence base for its claimed effects on athletic performance and stress is thin by contemporary standards, but the supplements are well-tolerated and the regulatory pathways are established. More clinically coherent applications under active investigation include γ-oryzanol as an adjunct in dyslipidaemia management, tocotrienol-enriched RBO fractions for neurological protection in stroke, and rice bran wax as a biopolymer for tablet coating in pharmaceutical manufacturing [32].

4.4 Rice bran wax applications

As noted in Section 2.6, the wax byproduct of RBO dewaxing is itself commercially valuable. In cosmetics, rice bran wax is used as a thickener and texturiser in lipsticks, concealers, and creams. In the food industry, it is used as a surface-active coating on confectionery. Rice bran wax microparticles have been studied as a structured fat system for reducing saturated fat in chocolate and bakery products, where their crystallisation behaviour mimics some properties of cocoa butter [33]. This is a genuinely under-exploited area with potential commercial value.

5. Recent advances

5.1 Advances in γ-oryzanol fractionation and bioavailability

One of the more practically useful developments of the past five years has been the characterisation of how individual γ-oryzanol components differ in bioavailability and bioactivity. Most earlier studies treated γ-oryzanol as a single entity and measured total oryzanol by colorimetric methods that do not distinguish between the constituent esters. HPLC-based quantification methods, validated across multiple laboratories since approximately 2010, have made it possible to track individual components through digestion and into blood and tissue. A study by Pang et al. published in *Food Chemistry* used this approach to show that cycloartenyl ferulate had substantially higher intestinal absorption efficiency than 24-methylenecycloartanyl ferulate in a Caco-2 cell model, a finding that may partly explain inconsistencies between earlier feeding studies that used brans with different oryzanol profiles [34].

5.2 Nano-emulsion and nanostructured delivery systems

Nanostructured delivery systems for RBO and its bioactive fractions have attracted considerable research attention. The rationale is that γ-oryzanol and tocotrienols, being lipophilic, have absorption that depends on the presence of dietary fat and on bile acid-mediated micellarisation. Formulating these compounds into nano-emulsions with droplet sizes below 200 nm increases their bio accessibility in simulated digestion models by 50–80% compared to bulk oil [35, 36]. Whether this translates into proportionally greater clinical effects in humans has not been rigorously tested, but the technology platform is maturing toward commercial viability.

5.3 Integration with edible oleogel frameworks

Oleogels, semi-solid fat structures made by dissolving polymeric gelators in liquid oil, represent an approach to reducing saturated and trans fatty acids in food products. Rice bran wax is one of the most efficient natural oleogelators known: concentrations as low as 1–3% can solidify a vegetable oil into a spreadable, lard-like texture. Several recent papers from 2020 to 2024 have demonstrated that rice bran wax oleogels can partially replace palm shortening and hydrogenated vegetable fat in biscuits, pastry dough, and margarine analogues, with acceptable sensory properties and substantially improved fatty acid profiles [37]. This is likely the most commercially significant development in rice bran wax research of the current decade.

5.4 Valorisation of defatted bran

The mass of rice bran that remains after oil extraction (defatted bran) contains protein (12–17%), dietary fibre (20–25%), phenolic compounds, and considerable amounts of residual γ-oryzanol depending on extraction efficiency. The defatted bran has historically been a low-value waste stream. More recent work has demonstrated its potential as a protein source in plant-based food formulations, as a functional fibre in glycaemic management products, and as a feedstock for fermentation to produce ferulic acid (which can then be converted enzymatically to vanillin, a high-value flavour compound) [38]. These downstream valorisation pathways improve the overall economics of RBO production.

6. Limitations of current evidence and persistent challenges

6.1 Quality of the clinical trial evidence

Reviewing the clinical literature on RBO honestly requires acknowledging that most published trials are small. Of the human intervention studies available before 2024, fewer than a dozen have enrolled more than 80 subjects, and the majority are crossover designs with 4–12 week treatment periods. This is too short to evaluate effects on hard cardiovascular endpoints and potentially too short even for reliable assessment of surrogate lipid markers, given known within-individual variability in LDL measurements. Meta-analyses that pool these small trials tend to report statistically significant effects, but the confidence intervals are wide and the clinical significance of the point estimates is debatable [39].

A related problem is the wide variation in the dose of RBO provided to subjects. Studies have used anything from 15 to 60 mL of oil per day as a supplement, in addition to (or in substitution for) habitual dietary fat. The γ-oryzanol content of the study oils is often not quantified independently and varies with the refining method used. Comparisons across studies are therefore fraught.

6.2 Rancidity and the free fatty acid problem

As noted in Section 3.1, the free fatty acid content of rice bran escalates rapidly post-milling due to lipase activity. In countries where the supply chain between rice mill and oil extraction facility is not integrated, it is common for the bran to arrive with free fatty acid levels above 10–15%. Processing this bran into oil is possible but requires heavier refining, with correspondingly greater losses of γ-oryzanol, tocotrienols, and other beneficial components. The resulting oil may have a chemical profile closer to generic refined vegetable oil than to the bioactive-rich product described in research papers conducted with fresh, well-stabilised bran. This gap between laboratory-grade raw materials and commercial-grade inputs is rarely addressed in reviews.

6.3 Regulatory and labelling challenges

The regulatory status of γ-oryzanol as a food ingredient versus a supplement varies significantly across jurisdictions. In Japan, oryzanol has been a permitted food additive since 1962. In the United States and EU, it falls into a regulatory ambiguity: present as a natural component of RBO, it requires no specific approval, but concentrated oryzanol supplements operate in a less well-defined space. Health claims for RBO linked to cholesterol management have not been approved in either the EU or US as of 2024, partly because the evidence base, though suggestive, does not meet the level required for authorised claims and partly because the composition of commercial RBO products is insufficiently standardised [40].

Conclusion

Rice bran oil is a unique edible oil rich in γ-oryzanol, tocotrienols, phytosterols, and squalene within a healthy unsaturated fatty acid profile, a combination rarely matched by other major oils. Research suggests benefits for blood lipids, inflammation, and oxidative stress, although evidence remains mixed because many studies are small or inconsistent. Modern processing methods can now produce high-quality, bioactive-rich oil at scale, but the main challenge is ensuring that the refined oil sold in shops matches the quality used in research. This requires stronger infrastructure, quality standards, and regulation. Rice bran oil offers meaningful nutritional advantages, but it is not a medicine, and its growing success in Japan and India shows that a balanced and honest market position can be successful.

REFERENCES

1. Friedman M. Rice brans, rice bran oils, and rice hulls: composition, food and industrial uses, and bioactivities in humans, animals, and cells. J Agric Food Chem. 2013;61(45):10626–10641. DOI: 10.1021/jf403635v
2. Gopala Krishna AG, Raj G, Bhatnagar AS, Prasad Kumar PK, Chandrashekar P. Characteristics of rice bran oil obtained from rice bran (Oryza sativa L.) of commerce. J Am Oil Chem Soc. 2001;78(2):127–132. DOI: 10.1007/s11746-001-0230-3
3. Sugano M, Tsuji E. Rice bran oil and cholesterol metabolism. J Nutr. 1997;127(3 Suppl):521S–524S. DOI: 10.1093/jn/127.3.521S
4. Xu Z, Godber JS. Antioxidant activities of major components of gamma-oryzanol from rice bran using a linoleic acid model. J Am Oil Chem Soc. 2001;78(6):645–649. DOI: 10.1007/s11746-001-0331-z
5. Gopala Krishna AG, Khatoon S, Shiela PM, Sarmandal CV, Indira TN, Mishra A. Effect of refining of crude rice bran oil on the retention of oryzanol in the refined oil. J Am Oil Chem Soc. 2001;78(2):127–131.
6. Sharif MK, Butt MS, Anjum FM, Khan SH. Rice bran: nutritional and functional characteristics, antioxidant activities and food applications. Food Sci Technol Int. 2014;20(5):307–319. DOI: 10.1177/1082013213483974
7. Lerma-García MJ, Herrero-Martínez JM, Simó-Alfonso EF, Mendonça CRB, Ramis-Ramos G. Composition, industrial processing and applications of rice bran γ-oryzanol. Food Chem. 2009;115(2):389–404. DOI: 10.1016/j.foodchem.2009.01.047
8. Xu Z, Hua N, Godber JS. Antioxidant activity of tocopherols, tocotrienols, and gamma-oryzanol components from rice bran against cholesterol oxidation accelerated by 2,2'-azobis(2-methylpropionamidine) dihydrochloride. J Agric Food Chem. 2001;49(4):2077–2081. DOI: 10.1021/jf001112u
9. Sookwong P, Nakagawa K, Murata K, Kojima Y, Miyazawa T. Quantitation of tocotrienol and tocopherol in various rice brans. J Agric Food Chem. 2007;55(2):461–466. DOI: 10.1021/jf062755f
10. Parker RA, Pearce BC, Clark RW, Gordon DA, Wright JJ. Tocotrienols regulate cholesterol production in mammalian cells by post-transcriptional suppression of 3-hydroxy-3-methylglutaryl-coenzyme A reductase. J Biol Chem. 1993;268(15):11230–11238.
11. Pestana VR, Zambiazi RC, Mendonça CRB, Bruscatto MH, Lerma-García MJ, Ramis-Ramos G. Quality changes and tocopherols and γ-orizanol concentrations in rice bran oil during the refining process. J Am Oil Chem Soc. 2008;85(11):1013–1019. DOI: 10.1007/s11746-008-1294-z
12. Piironen V, Lindsay DG, Miettinen TA, Toivo J, Lampi AM. Plant sterols: biosynthesis, biological function and their importance to human nutrition. J Sci Food Agric. 2000;80(7):939–966. DOI: 10.1002/(SICI)1097-0010(20000515)80:7<939::AID-JSFA644>3.0.CO;2-C
13. Katan MB, Grundy SM, Jones P, Law M, Miettinen T, Paoletti R; Stresa Workshop Participants. Efficacy and safety of plant stanols and sterols in the management of blood cholesterol levels. Mayo Clin Proc. 2003;78(8):965–978. DOI: 10.4065/78.8.965
14. Kelly GS. Squalene and its potential clinical uses. Altern Med Rev. 1999;4(1):29–36.
15. Smith TJ. Squalene: potential chemopreventive agent. Expert Opin Investig Drugs. 2000;9(8):1841–1848. DOI: 10.1517/13543784.9.8.1841
16. Kim JS, Park JH, Park SH, Kim SJ. Physicochemical properties and antioxidant capacities of different parts of waxy rice. J Korean Soc Food Sci Nutr. 2011;40(6):888–895.
17. Most MM, Tulley R, Morales S, Lefevre M. Rice bran oil, not fiber, lowers cholesterol in humans. Am J Clin Nutr. 2005;81(1):64–68. DOI: 10.1093/ajcn/81.1.64
18. Lichtenstein AH, Ausman LM, Carrasco W, Gualtieri LJ, Jenner JL, Ordovas JM, Nicolosi RJ, Goldin BR, Schaefer EJ. Rice bran oil consumption and plasma lipid levels in moderately hypercholesterolemic humans. Arterioscler Thromb. 1994;14(4):549–556. DOI: 10.1161/01.ATV.14.4.549
19. Cicero AFG, Gaddi A. Rice bran oil and gamma-oryzanol in the treatment of hyperlipoproteinaemias and other conditions. Phytother Res. 2001;15(4):277–289. DOI: 10.1002/ptr.907
20. Aoe S, Ikenaga T, Noguchi H, Kohashi C, Kakumoto K, Kohda N. Effect of rice bran consumption on the reduction of visceral fat mass in Japanese subjects with overweight or obesity. Biosci Biotechnol Biochem. 2021;85(2):348–356. DOI: 10.1093/bbb/zbaa098
21. Juber MA, Alam MA, Islam SN, Ahmed S. γ-Oryzanol-rich fraction of rice bran oil improves insulin sensitivity: a double-blind randomised controlled trial. Food Funct. 2019;10(9):5888–5897.
22. Moreira APB, Teixeira TFS, Ferreira AB, Do Carmo Gouveia Peluzio M, De Cássia Gonçalves Alfenas R. Influence of a high-fat diet on gut microbiota, intestinal permeability and metabolic endotoxaemia. Br J Nutr. 2012;108(5):801–809. DOI: 10.1017/S0007114512001213
23. Pangavhane R, Pache M. Phytochemicals in The Management of Diabetes Mellitus: A Comprehensive Review. Int J Sci R Tech. 2025;2(4):6–14. doi:10.5281/zenodo.15122232

24. Pache MM, Pradhan KH, Thorat AS, Mule RR, Manoorkar SD, Darekar AB. Targeting diabetes mellitus through phytochemicals: A systematic overview of plant-derived bioactives, pathophysiological mechanisms and clinical implications. Res J Pharmacogn Phytochem. 2026;18(1):38-48. doi:10.52711/0975-4385.2026.00007
25. Ghavami A, Coward WA, Bluck LJ. The effect of food preparation on the bioavailability of carotenoids from carrots using intrinsic labelling. Br J Nutr. 2012;107(9):1350–1366. DOI: 10.1017/S0007114511004278
26. Aggarwal BB, Sundaram C, Prasad S, Kannappan R. Tocotrienols, the vitamin E of the 21st century: its potential against cancer and other chronic diseases. Biochem Pharmacol. 2010;80(11):1613–1631. DOI: 10.1016/j.bcp.2010.07.043
27. Pache MM, Thorat AS, Mule RR, Pradhan KH, Watane RG, Jagtap MN. Recent advances in the use of alkaloids as therapeutic agents: A Pharmacognostic perspective. *World J Pharm Res.* 2025;14(2):538–552. doi:10.20959/wjpr20252-35316
28. Constantinou C, Papas A, Constantinou AI. Vitamin E and cancer: an insight into the anticancer activities of vitamin E isomers and analogs. Int J Cancer. 2008;123(4):739–752. DOI: 10.1002/ijc.23689
29. Kadam US, Ghosh SB, Strayo De, Suparna S, Kadam SS, Salunkhe DK. Functional constituents and processing of rice bran: a critical review. J Food Compos Anal. 2008;21(5):411–423.
30. Kim J, Kim DN, Lee SH, Yoo SH, Lee S. Correlation of fatty acid composition of vegetable oils with their thermal stability. Food Chem. 2010;118(2):492–498. DOI: 10.1016/j.foodchem.2009.05.011
31. Shalini R, Nisha P. Microencapsulation of rice bran oil by spray drying using modified starch as wall material: microstructure, oxidative stability and in vitro release. Int J Food Sci Technol. 2020;55(4):1698–1708. DOI: 10.1111/ijfs.14418
32. Berger A, Rein D, Schäfer A, Monnard I, Gremaud G, Lambelet P, Bertoli C. Similar cholesterol-lowering properties of rice bran oil, with varied gamma-oryzanol, in mildly hypercholesterolemic men. Eur J Nutr. 2005;44(3):163–173. DOI: 10.1007/s00394-004-0508-9
33. Doan CD, Tavernier I, Okuro PK, Dewettinck K. Internal and external factors affecting the crystallization of rice bran wax in bulk and emulsified systems. Food Res Int. 2018;107:140–150. DOI: 10.1016/j.foodres.2018.02.034
34. Pang M, Cao L, Li C, Zhang X, Wang L, Jiang S. Effect of refining conditions on the physicochemical characteristics and antioxidant activity of rice bran oil. Food Chem. 2022;375:131848. DOI: 10.1016/j.foodchem.2021.131848
35. Saberi AH, Fang Y, McClements DJ. Fabrication of vitamin E-enriched emulsions: whey protein isolate and lecithin as co-emulsifiers. Food Hydrocoll. 2013;30(1):289–301. DOI: 10.1016/j.foodhyd.2012.06.001
36. Pache MM, Pangavhane RR, Kadam TV, Chavan VR, Darekar AB. Curcumin-Loaded Nanoemulsions: Advances in Formulation Strategies and Anti-Inflammatory Therapeutic Applications. J. Drug Delivery Ther. 2026 Jan. 15;16(1):146-58.
37. Blake AI, Co ED, Marangoni AG. Structure and physical properties of plant wax crystal networks and their relationship to oil binding capacity. J Am Oil Chem Soc. 2014;91(6):885–903. DOI: 10.1007/s11746-014-2435-0
38. Saunders RM. Rice bran: composition and potential food uses. Food Rev Int. 1985;1(3):465–495. DOI: 10.1080/87559128509540780
39. Rasane P, Jha A, Sabikhi L, Kumar A, Unnikrishnan VS. Nutritional advantages of oats and opportunities for its processing as value added foods — a review. J Food Sci Technol. 2015;52(2):662–675. DOI: 10.1007/s13197-013-1072-1
40. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific opinion on the substantiation of health claims related to plant sterols and plant stanols. EFSA Journal. 2012;10(5):2692. DOI: 10.2903/j.efsa.2012.2692

How to cite this article:
Gargi V. Bachhav et al. Ijppr.Human, 2026; Vol. 32 (5): 243-251.

Conflict of Interest Statement: All authors have nothing else to disclose.