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Unmasking the Functional Food Potential of *Russula delica*: A Nutritional and Phytochemical Approach

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ABSTRACT

The present study investigates the nutritional composition, nutraceutical potential, and phytochemical constituents of the wild edible mushroom *Russula delica* Fr., collected from forest regions of Chhattisgarh, India. Although commonly consumed by indigenous communities, this species remains underexplored with respect to its scientific and nutritional significance. Proximate analysis of the dried fruiting bodies revealed a high carbohydrate content (66.21%) along with substantial protein levels (26.61%), indicating its value as an energy-rich and protein-dense food source. In addition, the mushroom contained appreciable amounts of dietary fiber (10.57%), ash (8.21%), and crude fat (3.62%), contributing to its overall nutritional profile. Nutraceutical evaluation revealed a total phenolic content of 10.16 mg/g and a flavonoid content of 1.37 mg/g, both of which are associated with strong antioxidant properties. Furthermore, trace amounts of carotenoids, including β-carotene (0.08 µg/g) and lycopene (0.11 µg/g), were detected. Gas chromatography–mass spectrometry (GC–MS) analysis of the methanolic extract revealed the presence of fatty acids, terpenoids, steroids, and hydrocarbons. These bioactive compounds are known to exhibit diverse pharmacological activities, such as antimicrobial, anti-inflammatory, and antioxidant effects. Overall, the study demonstrates the significant nutritional and medicinal value of *R. delica*, validating its traditional use and highlighting its potential as a functional food. The findings also emphasize its promise as a sustainable, nutrient-rich resource for future therapeutic and nutraceutical research.

Keywords: *Russula delica*, Wild edible mushrooms, Nutritional composition, Phytochemical analysis, Functional food

INTRODUCTION

Mushrooms have gained global recognition for their nutritional richness, unique organoleptic properties, and wide-ranging therapeutic potential. Owing to their low-fat content, high-quality protein, vitamins, minerals, and diverse bioactive compounds, edible mushrooms are increasingly being regarded as functional foods and valuable nutraceutical sources (Kalac, 2013). Among the vast diversity of mushrooms, wild edible mushrooms—naturally occurring and foraged rather than cultivated—play a particularly vital role in the diets and traditional medicinal systems of many indigenous and rural communities worldwide (Boa, 2004; Chang & Wasser, 2012).

India, with its rich forest ecosystems and diverse climatic conditions, supports a wide variety of wild mushrooms. The state of Chhattisgarh, located in central India, is especially rich in forest resources and biodiversity. Often referred to as the "Herbal State of India," Chhattisgarh is home to numerous tribal communities that have long relied on forest produce, including wild edible mushrooms, for food and medicinal purposes (Pati, 2005). Despite their cultural, nutritional, and economic importance, wild mushroom species from this region remain underexplored in scientific literature. Systematic research on their nutritional composition and bioactive properties is limited, thereby restricting their integration into mainstream food systems and functional food markets.

One such underutilized species is *Russula delica*. This mushroom is frequently consumed by tribal communities in Chhattisgarh but has not been extensively investigated. Taxonomically, *Russula delica* belongs to the genus *Russula*, family Russulaceae, and order Russulales. The species is widely distributed across tropical and subtropical regions of Asia and Africa (Joshi *et al*., 2012; Buyck *et al*., 2021; Corrales *et al*., 2022). Its macrofungal fruiting bodies are typically white, thick-fleshed, and occur in association with various forest tree species, particularly during the monsoon season.

Despite its widespread occurrence and culinary use, scientific information on the nutritional profile,

phytochemical composition, and therapeutic potential of *Russula delica* from the Indian subcontinent remains scarce. Comprehensive knowledge of its nutritional value and biochemical constituents is essential to validate its traditional uses and to assess its potential as a functional food. The incorporation of wild mushrooms such as *R. delica* into the human diet can enhance food diversity, improve nutritional security, and support sustainable forest-based livelihoods, particularly among forest-dependent rural populations.

Although the global market for edible and medicinal mushrooms is expanding rapidly, research in India has largely focused on commercially cultivated species such as *Agaricus bisporus*, *Pleurotus* spp., and *Lentinula edodes* (Sharma *et al*., 2017). In contrast, wild mushrooms like *Russula delica*, despite being widely consumed in rural and tribal regions, remain neglected in terms of systematic biochemical and nutritional analysis. Moreover, the absence of detailed compositional data limits their wider acceptance and potential commercialization.

Studies from other regions suggest that *Russula* species possess a variety of bioactive compounds, including phenolics, flavonoids, terpenoids, sterols, and fatty acids, which exhibit antioxidant, antimicrobial, and anti-inflammatory activities (Kostić *et al*., 2020; Balkrishna *et al*., 2024). However, species-specific and region-specific variations in chemical composition are influenced by factors such as soil type, climatic conditions, host tree associations, and ecological settings (Roncero-Ramos *et al*., 2017; Bellettini *et al*., 2019). Therefore, it is essential to characterize the nutritional and chemical profile of *R. delica* from the Chhattisgarh region, where it is traditionally consumed yet remains scientifically under-documented.

MATERIALS AND METHODS

Sample Collection

Fresh fruiting bodies of *Russula delica* (ABR-16) were collected from forested regions of Chhattisgarh during the monsoon season (Fig. 1). The specimens were authenticated based on morphological characteristics and preserved appropriately for further analysis.

Determination of Moisture Content

Moisture content was determined following the AOAC (19th Edition, 2012) method. Pre-weighed mushroom samples were placed in a hot air oven at 60 ± 2 °C for 48 h or until a constant weight was achieved. Moisture content was calculated using the following formula:

Moisture content (%) = [(Initial weight − Final weight) / Initial weight] × 100

Determination of Crude Fiber Content

Crude fiber content was determined according to the AOAC (2012) method. Two grams of finely ground sample were first defatted using petroleum ether. The defatted residue was then mixed with 200 ml of 1.25 % (w/v) H_2SO_4 and boiled for 30 min with the addition of boiling chips to prevent splashing. After acid digestion, the suspension was filtered through linen (muslin) cloth and washed thoroughly with distilled water until free from acid.

The residue was transferred to a clean flask, treated with 200 ml of 1.25 % (w/v) NaOH, and boiled for an additional 30 min. The mixture was again filtered through linen cloth and the residue was washed successively with 25 ml of boiling 1.25 % H_2SO_4, three portions of 50 ml hot distilled water, and finally with 25 ml ethanol.

The final residue was transferred to a pre-weighed ashing dish (W_1), dried at 130 ± 2 °C for 2 h, cooled in a desiccator, and weighed (W_2). The sample was then ignited in a muffle furnace at 600 ± 15 °C for 30 min. After cooling in a desiccator, the final weight (W_3) was recorded. Crude fiber content was calculated using the formula:

Crude fiber (%) = [(W_2 − W_3) / Weight of sample] × 100

Determination of Total Ash Content

Total ash content was determined by dry ashing approximately 2 g of oven-dried sample in a muffle furnace at 550 ± 5°C until a grey-white residue was obtained, following the AOAC (2012) method. Results were expressed as percentage ash on a dry weight basis.

Determination of Total Protein

Total protein content was determined using the Lowry method (Lowry *et al*., 1951). Bovine serum albumin (BSA) was used as the standard. Absorbance was measured at 660 nm using a UV–

Visible spectrophotometer. The reaction mixture was prepared by adding 2.5 ml of freshly prepared alkaline copper reagent (Reagent A: 2 % sodium carbonate in 0.1 N NaOH; Reagent B: 0.5 % $CuSO_4 \cdot 5H_2O$ in 1 % sodium potassium tartrate, mixed in a 50:1 ratio) to 0.5 ml of the sample.

The mixture was allowed to stand for 20 min, followed by the addition of 0.25 ml of Folin–Ciocalteu reagent. The contents were mixed thoroughly and incubated in the dark for 30 min for colour development. A blank was prepared using 0.5 ml of 1 N NaOH. Optical density of the developed blue colour was measured at 660 nm against the blank. Protein concentration was calculated using a standard curve prepared with known concentrations of BSA. All estimations were carried out in triplicate.

Determination of Total Carbohydrate

Total carbohydrate content was determined using the Anthrone method as described by Sharma *et al*. (2015) and Sukifto *et al*. (2020), with minor modifications. A glucose stock solution (200 µg/ml) was used to prepare working standards ranging from 10 to 200 µg/ml. One gram of dried mushroom powder was homogenized in phosphate buffer using a mortar and pestle, followed by centrifugation at 3,000 rpm for 3 min at 4 °C.

To 0.1 ml of sample or standard, 5 ml of freshly prepared Anthrone reagent was added. The reaction mixture was incubated in a water bath at 90 °C for 10 min and then immediately cooled in an ice bath to terminate the reaction. Absorbance was measured at 620 nm using a spectrophotometer. Carbohydrate content was calculated using a linear regression equation obtained from the glucose standard curve and expressed as percentage (%) on a dry weight basis.

Determination of Total Lipid

Crude fat content was estimated following the AOAC (2012) method. One gram of dried mushroom powder was accurately weighed and transferred into a Soxhlet extraction thimble, which was sealed with cotton. Seventy-five millilitres of anhydrous ether was added, and the sample was subjected to orbital shaking. Fat extraction was carried out using a water bath, allowing partial evaporation of the ether. After reduction of the solvent volume, the extract was transferred to a clean, dry, pre-weighed beaker. Residual ether was completely evaporated using a steam bath under low heat, followed by drying in a hot-air oven at 100 °C for 1 h. The beaker was then cooled in a desiccator and weighed. Crude fat content was calculated using the following formula:

Crude fat (%) = [(Final weight − Initial weight) / Sample weight] × 100

Determination of Total Phenolic Content

Total phenolic content was determined using the Folin–Ciocalteu method as described by Singleton and Rossi (1965) and modified by Olajire and Azeez (2011). Briefly, 1 ml of mushroom extract was mixed with 1 ml of Folin–Ciocalteu phenol reagent. After 3 min, 1 ml of saturated sodium carbonate solution was added, and the total volume was adjusted to 10 ml with distilled water. The reaction mixture was incubated in the dark for 90 min at room temperature. Absorbance was measured at 725 nm using a UV–Visible spectrophotometer. A standard calibration curve was prepared using gallic acid in the concentration range of 0.01–0.4 mM. Results were expressed as milligrams of gallic acid equivalents (mg GAE/g) of extract.

Determination of Total Flavonoid Content

Total flavonoid content was estimated following the method described by Yoo *et al*. (2008). In this assay, 250 µl of methanolic mushroom extract was mixed with 1.25 ml of distilled water and 75 µl of 5 % sodium nitrite solution. After standing for 5 min, 150 µl of 10 % aluminium chloride solution was added, followed by a 6-min incubation. Subsequently, 500 µl of 1 M sodium hydroxide (NaOH) and 275 µl of distilled water were added. The mixture was thoroughly mixed, and absorbance was measured at 510 nm using a UV–Visible spectrophotometer. Catechin was used as the reference standard. Flavonoid content was calculated from the standard curve and expressed as milligrams of catechin equivalents (mg CE/g) of extract.

Determination of Carotenoids

The contents of Carotenoids (β-Carotene and Lycopene) were determined using the method described by Barros *et al*. (2007). For extraction, 100 mg of dried methanolic mushroom extract was vigorously mixed with 10 ml of an acetone–hexane mixture (4:6, v/v) for 1 min. The mixture was filtered through Whatman No. 4 filter paper, and the absorbance of the filtrate was recorded at 453

nm, 505 nm, 645 nm, and 663 nm. The concentrations of β-carotene and lycopene were calculated using the following equations:

β-Carotene (mg/100 ml) = $0.216A_{663} - 0.304A_{505} + 0.452A_{453}$

Lycopene (mg/100 ml) = $-0.0458A_{663} + 0.372A_{505} - 0.0806A_{453}$

GC–MS Analysis

Methanolic extracts of *Russula delica* were subjected to gas chromatography–mass spectrometry (GC–MS) analysis for phytochemical profiling. The analysis was performed to identify volatile and semi-volatile bioactive compounds present in the extract. Separation of components was based on their retention times, and compound identification was achieved by comparing the obtained mass spectra with those available in the NIST (National Institute of Standards and Technology) mass spectral library.

RESULTS AND DISCUSSION

Nutritional profiling

The proximate composition of *Russula delica* obtained in the present investigation confirms that this wild edible mushroom is nutritionally dense while remaining low in fat (Table 1). Moisture content accounted for 84.51 % of the fresh basidiocarp. This value falls within the broad moisture range (75–90 %) generally reported for wild mushrooms and reflects the strong influence of harvest stage, ambient temperature, and relative humidity on water retention in fungal tissues (Xinwen and Baojun, 2025).

When expressed on a dry weight (DW) basis, carbohydrates (66.02 %) were the most abundant macronutrient, followed by protein (26.61 %). Such carbohydrate-rich and moderately proteinaceous profiles are typical of ectomycorrhizal *Russula* species and are largely attributable to the presence of structural polysaccharides (chitin and β-glucans) and storage glycogen (Xinwen and Baojun, 2025). The observed protein content is consistent with the 26–29 % DW range reported for other Asian collections of *R. delica*, *R. brevipes*, and *R. griseocarnosa* (Sharma *et al*., 2023; Anh *et al*., 2024). However, it is slightly lower than the exceptionally high protein levels (38.08–38.52 % DW) reported for specimens from Côte d'Ivoire collected at a later stage of maturity (Kouassi *et al*., 2016; Jaures *et al*., 2019; Gbotognon *et al*., 2022).

Variations in nutritional composition among studies may arise from differences in developmental stage, soil nitrogen availability, host tree associations, and analytical methodologies employed (Khatua *et al*., 2015; Appolinaire *et al*., 2016; Jaures *et al*., 2019; Saithong *et al*., 2024; Yang *et al*., 2025).

Table 1: Proximate nutritional composition of *Russula delica* fruiting bodies

Component	*Russula delica* (% dry weight basis) (mean±SD)
Moisture	84.51±1.89
Carbohydrate	66.21±1.02
Protein	26.61±1.04
Ash	8.21±0.04
Fiber	10.57±0.36
Crude Fat	3.62±0.33

Dietary fiber, quantified as crude fiber, reached 10.57 % DW, supporting earlier assertions that *Russula* mushrooms are valuable sources of non-starch polysaccharides with prebiotic potential. The ash fraction (8.21 % DW) indicates a substantial mineral content, particularly potassium (K), phosphorus (P), calcium (Ca), and magnesium (Mg), although this value is slightly lower than the 12.7–13.8 % range reported for West African specimens. Such variation is expected, as ash content reflects edaphic chemistry and the depth of mycelial foraging within the soil profile (Kouassi *et al*., 2016; Jaures *et al*., 2019; Xinwen and Baojun, 2025).

Consistent with the reputation of mushrooms as low-calorie foods, the analyzed sample contained only 3.62 % DW crude fat. Previous studies have reported lipid contents of *R. delica* ranging from 4.1 % to 5.7 % DW, composed predominantly of unsaturated fatty acids (Kouassi *et al*., 2016). The

slightly lower lipid content observed in the present study may be attributed to an earlier harvest stage (pre-sporulation) or regional climatic conditions that influence lipid biosynthesis.

A synthesis of published datasets reveals a nutritionally robust yet variable profile for *R. delica*. West African collections (Appolinaire *et al*., 2016) generally exhibit higher protein and mineral (ash) contents, whereas reports from Southeast Asia and India (Khatua *et al*., 2015; Saithong *et al*., 2024) align more closely with the carbohydrate-dominant pattern observed in the present study. These inter-study variations underscore the influence of species-specific ecophysiology, as even within a single taxon, genotypic variation can significantly alter nutrient partitioning. Additionally, maturation effects are evident, with protein and ash contents typically increasing and moisture decreasing as sporocarps expand. Environmental factors such as substrate chemistry, rainfall, and temperature regimes further modulate nutrient uptake and metabolic processes.

Taken together, the proximate profile—characterized by high carbohydrate content, moderate protein levels, appreciable dietary fiber and mineral fractions, and low lipid content—supports the classification of *R. delica* as a nutritious and energy-lean food source. Its macronutrient balance compares favourably with many cultivated mushrooms and meets key criteria for inclusion in low-fat, high-fiber dietary formulations. Future investigations should integrate proximate analysis with amino acid profiling and mineral speciation to further refine the nutritional valuation of this species across different biogeographic regions.

Metabolite Profiling

The concentrations of major bioactive compounds, including phenolics, flavonoids, β-carotene, and lycopene, in the analyzed wild edible mushroom *R. delica* are presented in Table 2. Mushrooms are recognized as rich sources of secondary metabolites that contribute to diverse biological activities. In the present study, total phenolic content (TPC) was the most abundant class of bioactive compounds, measuring 10.16 mg GAE/g extract. Total flavonoid content was comparatively lower at 1.37 mg/g, while carotenoids were detected only in trace amounts (β-carotene: 0.08 µg/g; lycopene: 0.11 µg/g).

These findings are broadly consistent with earlier reports identifying phenolic compounds as the dominant antioxidant constituents in *R. delica*. For instance, Yaltırak *et al*. (2009) reported a TPC of 6.23 mg/g in ethanolic extracts and detected β-carotene (0.11 mg/g) and lycopene (0.03 mg/g). Their HPLC analysis further identified catechin (5.33 mg/L) as the major phenolic compound. Moreover, the authors demonstrated significant DPPH radical-scavenging and Fe^{2+}-chelating activities, supporting the functional relevance of these bioactive constituents.

Table 2: Nutraceutical profile (bioactive compound content) of *Russula delica* fruiting bodies

Bioactive compounds	***Russula delica* (dry weight basis) (mean±SD)**
Phenolic compounds (mg/g)	10.16±0.50
Flavonoids (mg/g)	1.37±0.06
β-carotene (µg/g)	0.08±0.03
Lycopene (µg/g)	0.11±0.01

Further, a phenol-rich fraction of *R. delica* from India exhibited strong antioxidant activities, including superoxide, hydroxyl radical, DPPH, and β-carotene bleaching assays. In this fraction, phenolic compounds (14.32 µg/mg) constituted the major bioactive component, while flavonoids were not detected. β-Carotene (0.48 µg/mg) and lycopene (0.34 µg/mg) were present only in minor quantities. Collectively, available literature concurs that *R. delica* contains appreciable levels of phenolic compounds, accompanied by comparatively modest carotenoid concentrations.

GC–MS profiling

GC–MS profiling of the methanolic extract revealed a diverse set of sixteen chemical constituents, including fatty acids, terpenoids, steroids, and hydrocarbons. The prominent compounds identified were tetradecane, pentadecane, 7,8-epoxylanostan-11-ol, and 2,4,6,8,10-tetradecapentaenoic acid (Table 3). In

contrast, several compounds, such as milbemycin B, pregnane, and 9-desoxo-9-α-acetoxy-3,8,12-tri-O-acetylingol, each representing 0.55 % of the total peak area, were detected in the lowest proportions (Fig. 2).

The repeated detection of 2,4,6,8,10-tetradecapentaenoic acid at multiple retention times highlights its relative abundance and potential biological significance, including reported antioxidant, anticancer, and anti-inflammatory activities. Compounds such as 7,8-epoxylanostan-11-ol, 3-acetoxy, and decanoic acid (1.3 %) are known for their pharmaceutical relevance, particularly antimicrobial, anti-inflammatory, and anticancer properties. Nevertheless, further investigations are required to elucidate the specific pharmacological and nutraceutical applications of these compounds in greater detail.

Table 3: GC–MS identified phytochemical constituents of the methanolic extract of *Russula delica*

S. No.	Phytochemical constituents	R.T.	Area %
1.	Calconcarboxylic acid	2.18	0.57
2.	2,4,6,8,10-Tetradecapentaenoic acid	2.18	0.57
3.	Acetic acid	2.5	0.82
4.	7,8-Epoxylanostan-11-ol, 3-acetoxy	2.93	0.93
5.	2,4,6,8,10-Tetradecapentaenoic acid	2.93	0.93
6.	(Unnamed)	2.97	0.83
7.	Pregn-4-ene-3,20-dione	2.97	0.83
8.	Acetic acid	2.97	0.83
9.	2,4,6,8,10-Tetradecapentaenoic acid	3.37	0.58
10.	Decanoic acid	3.58	1.3
11.	Milbemycin B	3.65	0.74
12.	7,8-Epoxylanostan-11-ol, 3-acetoxy	3.65	0.74
13.	2,4,6,8,10-Tetradecapentaenoic acid	3.65	0.74
14.	7,8-Epoxylanostan-11-ol, 3-acetoxy	3.69	0.85
15.	Milbemycin B	4.37	0.55
16.	2,4,6,8,10-Tetradecapentaenoic acid	4.37	0.55
17.	Pregnane	6.7	0.55
18.	9-Desoxo-9-x-acetoxy-3,8,12-tri-O-acetylingol	6.7	0.55
19.	1',1'-Dicarboethoxy-1á,2á-dihydro-3'H-cyclopro	6.7	0.55
20.	3-Pyridinecarboxylic acid	7.69	0.53
21.	2,4,6,8,10-Tetradecapentaenoic acid	7.69	0.53
22.	Tetradecane	10.13	4.08
23.	Pentadecane	10.13	4.08
24.	Hydroxylamine, O-decyl-	10.13	4.08
25.	2,4,6,8,10-Tetradecapentaenoic acid	11.05	0.7
26.	7,8-Epoxylanostan-11-ol	11.05	0.7
27.	3-Pyridinecarboxylic acid	11.05	0.7
28.	2,4,6,8,10-Tetradecapentaenoic acid	11.45	0.61

CONCLUSIONS

The present study underscores the nutritional and nutraceutical potential of *Russula delica*, a wild edible mushroom collected from the forest ecosystems of Chhattisgarh, India. Proximate analysis revealed that *R. delica* is a valuable source of key macronutrients, particularly carbohydrates (66.02 % DW), protein (26.61 % DW), and dietary fiber (10.57 % DW), along with appreciable mineral content (ash: 8.21 % DW) and a low fat level (3.62 % DW). These attributes establish its suitability as a low-fat, high-fiber dietary component for health-conscious consumers.

Beyond its macronutrient richness, the presence of bioactive compounds such as phenolics and flavonoids suggests notable antioxidant potential, which may contribute to the mitigation of oxidative stress-related disorders. Furthermore, GC–MS

profiling of the methanolic extract revealed a complex array of bioactive constituents, including fatty acids, terpenoids, and hydrocarbons, reinforcing the mushroom's promise for pharmaceutical, nutraceutical, and functional food applications.



Figure 1: *Russula delica* fruiting bodies in their natural habitat

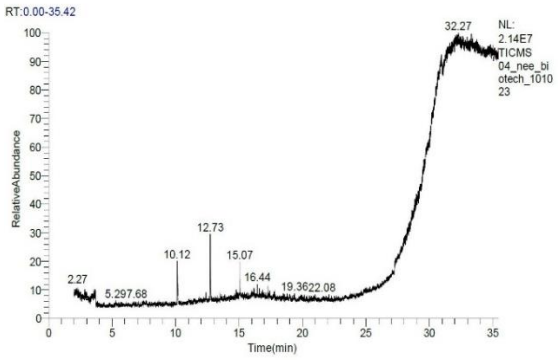


Figure 2: GC–MS chromatogram of the methanolic extract of *Russula delica*

The nutritional characteristics of *R. delica* are particularly relevant for improving nutritional security among indigenous and rural communities that rely on forest-derived foods. Its inclusion in traditional diets may enhance protein and micronutrient intake while simultaneously providing natural antioxidant benefits. Future research should focus on standardizing extraction protocols, validating antioxidant capacity using advanced assays (e.g., DPPH, ABTS, and FRAP), and exploring therapeutic properties such as antimicrobial, anti-inflammatory, and immunomodulatory activities. In addition, comparative evaluations with cultivated mushroom species and assessments of seasonal variation will be essential for establishing *R. delica* as a reliable and sustainable wild food resource.

In conclusion, *Russula delica* represents a promising functional mushroom with significant dietary and medicinal value, warranting further investigation within ethnonutritional, nutraceutical, and functional food research frameworks.

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CONFLICT OF INTEREST

There is no conflict of interest.

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