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Nutritional value of edible *Russula griseocarnosa* in Vietnam

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ABSTRACT
This study examines the nutritional value of edible *Russula griseocarnosa* in Vietnam. *Russula griseocarnosa* is a popular edible wild mushroom in northern Vietnam, where it is consumed locally or exported to China. Future market development and increased trade in *Russula griseocarnosa* require information on the composition and quality of mushrooms being harvested from the wild. As the nutritional value of this mushroom has not been documented, mushrooms were collected from secondary forests in Bac Giang and Cao Bang provinces, and primary forests in Quang Ninh province for determining the proximate and mineral contents. We dried the mushrooms and sequentially measured the proximate content using standard protocols. For mineral content, the mushroom powder was acid digested and analysed by atomic absorption spectrometry. The study found that *Russula griseocarnosa* in Vietnam contained 18-29% protein, 57-68% carbohydrate, 8.7-13.7% crude fiber, 0.8-2.1% crude fat, and 0.9-1.1% ash, and has high mineral content (mg/kg dry weight) of K (19,836-24,966), P (2,631-3,335), Ca (573-1,530), Mg (350-636), Fe (143-836), Zn (60-93), and Cu (31-42). The data in this study can be used in establishing official product brands of *Russula griseocarnosa*, which could improve the livelihood of local people who are dependent on non-wood forest products. Further studies should explore the market chain and mushroom product opportunities, the livelihood of rural households, and the sustainability of harvesting wild mushrooms.

Contribution/Originality: Whilst some data are available on the nutrient content of *Russula griseocarnosa* in China, there is no information on *Russula griseocarnosa* collected in forests in Vietnam. The research gap filled by this paper will assist in developing the market chain and mushroom product opportunities of this wild edible mushroom in Vietnam.

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1. INTRODUCTION
Many species of the genus *Russula* are edible mushrooms with delicious flavor and rich in nutrients (Ijioma Blessing, Ihediohanma Ngozi, Onuegbu Ngozi, & Okafor Damaris, 2015; Kaewgrajang, Kaewjunsri, Jannual, & Nipitwattanaphon, 2020; Nadjombé et al., 2022; Sanmee, Dell, Lumyong, Izumori, & Lumyong, 2003). Therefore, indigenous people of Asia and Africa have widely collected them from the wild (Atri, Sharma, Kumar, & Mridu, 2019; Sanmee et al., 2003; Shiyan, Tianyan, Bin, Fuchang, & Xiaohua, 1998; Srikram & Supapvanich, 2016). Some species have been used as staple foods for indigenous peoples, such as *R. alboareolata*, *R. cyanoxantha*, *R. lepida*, *R. virescens*, and

R. xerampelina in Thailand (Sanmee et al., 2003; Srikram & Supapvanich, 2016), *R. congoana* in India (Verma, Pandro, Mishra, Raj, & Asaiya, 2019) and *Russula* spp. in Angola (Kissanga et al., 2022).

The chemical composition of a number of *Russula* species has been quantified. Ouzouni, Petridis, Koller, and Riganakos (2009) found that dried *R. delica* contained 26.1% protein, 2.4% fat, 63.9% carbohydrates and 5.6% ash. Similarly, *R. alboareolata*, *R. cyanoxantha*, *R. emetica*, and *R. virescens* comprised 29.5-49.2% protein, 3.9-12.5% fat, 27.4-32.2% crude fiber, 9.6-27.1% carbohydrate, and 2.6-10.9% ash (Srikram & Supapvanich, 2016). Furthermore, *R. delica* contains a number of omega-3 fatty acids (Kalač, 2009). *Russula griseocarnosa* harvested in China is reported to contain many nutrients and useful phytochemicals (Chen, Xia, Zhou, & Qiu, 2010), polysaccharides (Liu, Zhang, & Meng, 2018), and some amino acids (Ming, Li, Huo, Wei, & Chen, 2014). People are not only using *Russula griseocarnosa* for food but also exploring its medicinal properties. Several substances extracted from *Russula griseocarnosa* have demonstrated inhibitory effects on cancer cells (Liu et al., 2018; Yuan et al., 2017).

Russula griseocarnosa naturally occurs in secondary and primary forest stands in northern Vietnam (Anh et al., 2023), and in southern China (Wang, Yang, Li, Knudsen, & Liu, 2009). This species is commonly used as food by local people in Vietnam (Anh et al., 2023; Chi, 2022) and it is also being traded in the region (Chi, 2022). However, there are no data on the nutritional composition of this wild edible mushroom in Vietnam. This study aims to fill this gap by analyzing the proximate and mineral composition of *Russula griseocarnosa* in Vietnam.

2. MATERIAL AND METHODOLOGY

2.1. Mushroom Materials

In May 2022, mushrooms were sought in secondary forests in Bac Giang, Cao Bang, and primary forests in Quang Ninh provinces, Vietnam (Table 1; Figure 1) at sites where local people collected. Anh et al. (2023) identified Quang Ninh province as having the highest density of *Russula griseocarnosa* in Vietnam, and this province has the largest market for this species (Chi, 2022). Therefore, we collected 80% of the mushroom samples in this study in Quang Ninh. At each forest site, ovoid or unopened fruiting bodies were randomly harvested, and the bulk collection was divided into 4 samples, each approximately 150 g fresh weight. The fruiting bodies were wrapped in tissue paper, placed in paper bags over ice in a cool container (Atalay & Erge, 2021), and transported to the Food Analysis Laboratory at the National Food Analysis and Inspection Center, Hanoi. We used a soft brush to clean the mushrooms of soil and humus without washing them. The base of the stalk plus mycelium with soil was removed using a sharp knife. The mushrooms were dried at 55 °C for 24 hours, and then crushed in a mortar and pestle to produce a fine powder. All 40 samples were used for chemical analysis.

Table 1. Field data of *Russula griseocarnosa* fruiting bodies collected in northeast Vietnam for proximate and mineral analysis.

Sample	Location (Ward, district, province)	Geographical coordinates	Altitude (m)	Forest type	Host tree
BG1	Nghia Phuong, Luc Nam, Bac Giang	21°15'32.2"N 106°27'42.2"E	295	Secondary forest	*Engelhardia roxburghiana*
CB2	Doai Duong, Trung Khanh, Cao Bang	22°46'00.8"N 106°29'57.1"E	468	Secondary forest	*Engelhardia roxburghiana*
QN7	Ha Lau, Tien Yen, Quang Ninh	21°25'12.2"N 107°18'21.7"E	106	Primary forest	*Engelhardia roxburghiana*
QN8	Ha Lau, Tien Yen, Quang Ninh	21°25'32.0"N 107°18'08.5"E	98	Primary forest	*Lithocarpus ducampii*
QN11	Thanh Son, Ba Che, Quang Ninh	21°17'47.7"N 107°14'28.6"E	213	Primary forest	*Lithocarpus dealbatus*
QN19	Thanh Son, Ba Che, Quang Ninh	21°18'04.1"N 107°14'47.5"E	239	Primary forest	*Engelhardia roxburghiana*
QN20	Ky Thuong, Ha Long, Quang Ninh	21°11'06.4"N 107°07'06.5"E	405	Primary forest	*Castanopsis tonkinensis*
QN22	Ky Thuong, Ha Long, Quang Ninh	21°10'48.7"N 107°08'44.1"E	437	Primary forest	*Engelhardia roxburghiana*
QN29	Vo Ngai, Binh Lieu, Quang Ninh	21°32'29.7"N 107°20'37.3"E	361	Primary forest	*Castanopsis cerebrina*
QN50	Vo Ngai, Binh Lieu, Quang Ninh	21°30'36.6"N 107°20'51.8"E	299	Primary forest	*Engelhardia roxburghiana*

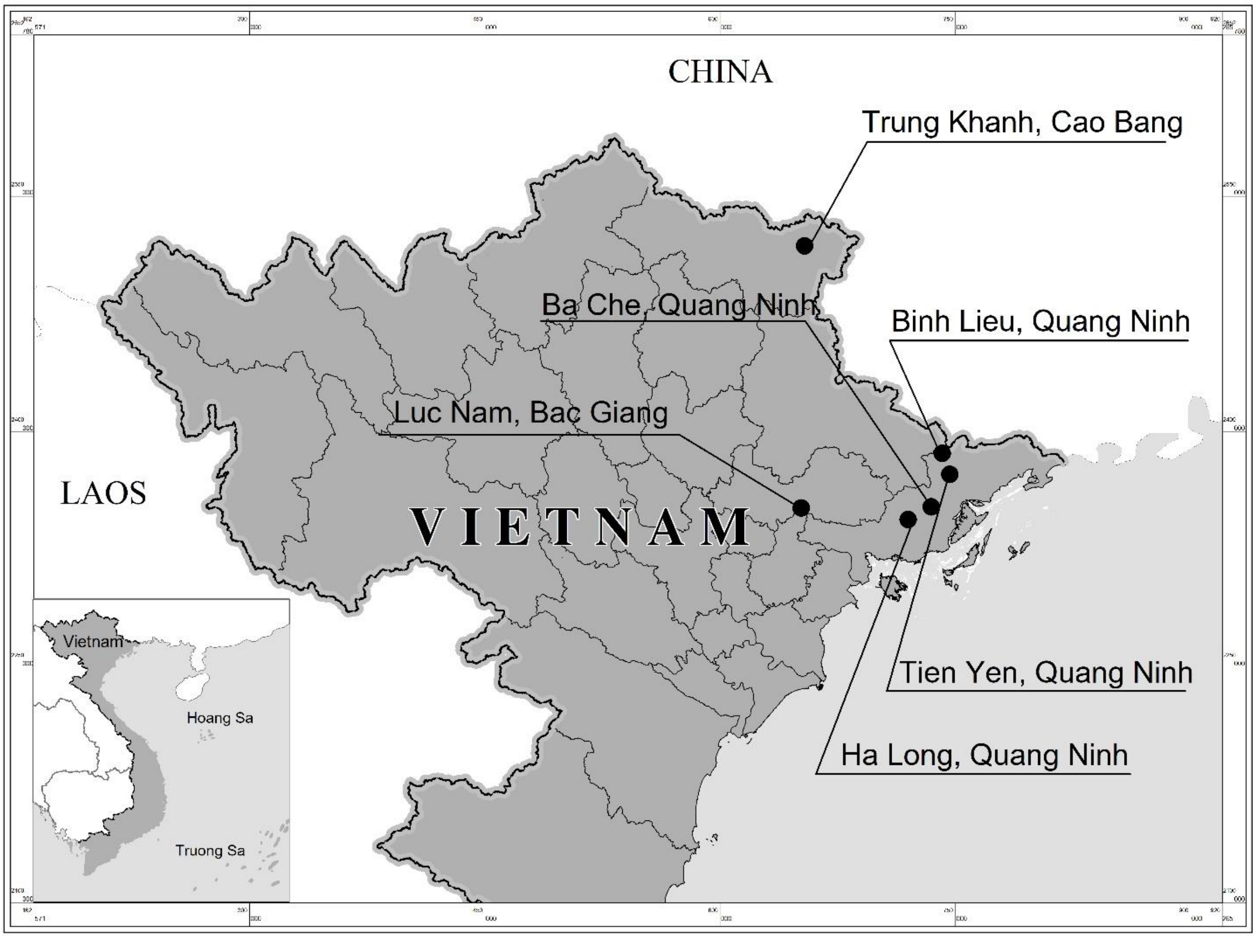

Figure 1. Location of the *Russula griseocarnosa* samples that were collected in Northeast Vietnam.

2.2. Methods

2.2.1. Ash, Crude Protein, Crude Fat, Crude Fiber, and Carbohydrate

Aliquots of the dried fungal powder were taken, and the proximate components were sequentially measured using standard protocols (AOAC, 2000). Briefly, the methods were as follows: crude nitrogen; crude fat by Soxhlet extraction in petroleum ether; crude fiber using 1.25% H_2SO_4 and 1.25% NaOH; and ash by combustion. The carbohydrate content was calculated as the difference between 100% and the combined percentages of crude protein + ash + fat + crude fiber. A conversion factor of 4.38 was used for crude protein as fungi contain non-protein nitrogen (Kalač, 2009). The results were expressed as % dry weight.

2.2.2. Mineral Elements

Aliquots wet digested (HNO_3 + H_2SO_4 + H_2O_2) (AOAC, 2000) and the concentrations of Ca, Cu, Fe, K, Mg, Mn, Na, P and Zn were determined by Atomic Absorption Spectrometry (PerkinElmer AAnalyst™ 700, Waltham, MA, USA), using a deuterium background correction.

2.2.3. Data Analysis

All samples were analyzed in triplicate. Data analysis was carried out using the GenStat Release 12.1 software package (VSN International Ltd., Hemel Hempstead, UK). Data for the chemical composition of mushrooms were examined using the Kolmogorov-Smirnov test and then subjected to one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test ($p<0.05$) for comparison of means.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of Russula griseocarnosa

The *Russula griseocarnosa* collected from forests in northern Vietnam contained 57.4-68.4% carbohydrate, 18.3-29.0% crude protein, 8.7-13.7% crude fiber, 0.8-2.1% crude fat, and 0.9-1.1% ash (Table 2). The mushrooms from Quang Ninh province had more protein (23.2-29.0%) than those in Bac Giang and Cao Bang provinces (18.3-20.2%). Also, mushrooms from Bac Giang had the highest fat (2.1%) and carbohydrate (68.4%) concentrations (Table 2).

Table 2. Proximatse composition (% dry weight) of edible *Russula griseocarnosa* and comparison with other other edible *Russula* species in the region.

Species	Sample*	Protein	Fat	Ash	Fiber	Carbohydrate	Source
Russula griseocarnosa	BG1	18.3±0.17	2.05±0.03	1.01±0.01	10.2±0.18	68.4±0.31	This study
Russula griseocarnosa	CB2	20.2±0.20	1.45±0.02	1.03±0.01	10.9±0.16	66.5±0.33	This study
Russula griseocarnosa	QN7	29.0±0.25	1.36±0.01	1.06±0.02	8.7±0.10	59.9±0.15	This study
Russula griseocarnosa	QN8	24.5±0.21	1.47±0.02	0.98±0.01	11.4±0.13	61.6±0.26	This study
Russula griseocarnosa	QN11	23.3±0.19	1.63±0.03	1.00±0.01	12.3±0.11	61.8±0.19	This study
Russula griseocarnosa	QN19	23.3±0.16	1.48±0.01	1.00±0.03	10.4±0.10	63.9±0.22	This study
Russula griseocarnosa	QN20	26.5±0.24	1.38±0.01	1.00±0.01	10.0±0.09	61.1±0.30	This study
Russula griseocarnosa	QN22	25.2±0.21	0.80±0.01	0.89±0.02	13.4±0.17	61.1±0.14	This study
Russula griseocarnosa	QN29	23.3±0.22	1.68±0.03	0.96±0.01	11.9±0.12	62.1±0.29	This study
Russula griseocarnosa	QN50	26.6±0.23	1.36±0.02	0.97±0.02	13.7±0.15	57.4±0.27	This study
Mean		24.01	1.46	0.99	11.29	62.38	
p		< 0.001	< 0.001	0.06	< 0.001	0.005	
Russula alatoreticula	NA	31.6	3.5	16.4	NA	63.6	Khatua, Sen Gupta, Ghosh, Tripathi, and Acharya (2021)
Russula alboareolata	NA	21.2	9.5	17.6	10.1	41.6	Sanmee et al. (2003)
Russula brevipes	NA	30.2	5.1	9.1	46.3	66.5	Shahid, Fatima, Anjum, and Riaz (2020)
Russula lepida	NA	18.3	5.6	7.6	8.4	60.1	Sanmee et al. (2003)
Russula lepida	NA	12.1	0.3	0.2	1.2	34.2	Sharma and Gautam (2015)
Russula mairei	NA	11.0	0.2	0.1	1.4	36.4	Sharma and Gautam (2015)
Russula nigricans	NA	22.6	4.8	6.7	9.6	56.3	Sanmee et al. (2003)
Russula nobilis	NA	25.5	2.8	2.1	44.1	82.5	Shahid et al. (2020)
Russula griseocarnosa	NA	32.3	7.2	7.8	8.85	48.1	Chen et al. (2010)
Russula virescens	NA	20.0	4.3	11.3	9.7	54.7	Sanmee et al. (2003)
Russula xerampelina	NA	22.4	4.5	6.7	10.4	55.8	Sanmee et al. (2003)

Note: *Data are expressed as mean ± SD, n.

This is the first study on the nutritional composition of *Russula griseocarnosa* in Vietnam. According to the reports from China, (Chen et al., 2010; Yuan et al., 2017; Zhang et al., 2019) this species is rich in nutrients, with protein (19.1-32.3%) and carbohydrate (48.1-63.0%) concentrations comparable to those found in this study (Chen et al., 2010). Furthermore, the protein and carbohydrate concentrations in *Russula griseocarnosa* are similar to some other edible species in this genus, such as *R. delica* in Greece (Ouzouni et al., 2009) and *R. alatoreticula*, *R. brevipes*, *R. cyanoxantha*, *R. heterophylla*, and *R. virescens* in West Bengal (Khatua et al., 2021). However, edible *Russula* species in Togo had lower protein concentrations (Nadjombé et al., 2022). Protein content is important in marketing because mushrooms contain more protein than vegetables (Ouzouni et al., 2009; Satyanarayana, Das, & Johri, 2019).

The fat and fiber content of the samples in this study are similar those reported by Chen et al. (2010) who found that *Russula griseocarnosa* collected in China was low in fat (5.2-7.2%) and high in fiber (8.9-11.7%). In addition, the ash content of *Russula griseocarnosa* in Vietnam was lower than in China (6.6-7.8%) and also lower than for *R. delica* in Greece (5.6) (Ouzouni et al., 2009).

3.2. Mineral Composition of Russula griseocarnosa

The mineral concentrations in *Russula griseocarnosa* were in the order: K > P > Ca > Mg > Fe > Na > Zn > Cu > Mn (Table 3). There were differences ($p<0.001$) due to forest type and sampling location. For example, sample QN50 (Vo Ngai, Binh Lieu) had the highest Ca concentration, sample QN11 (Thanh Son, Ba Che) had the highest Mg concentration, and sample QN8 (Ha Lau, Tien Yen) had the highest Zn concentration. These samples were collected in primary forest in Quang Ninh province. Sample BG1 (collected in secondary forest in Nghia Phuong, Luc Nam, Bac Giang) had the highest P concentration.

Table 3. Mineral composition (mg/kg dry weight) of edible *Russula griseocarnosa* and comparison with other other edible *Russula* species in the region.

Sample or species	Ca	Cu	Fe	K	Mg	Mn	Na	P	Zn	Source
BG1	889.2±20.51	39.4±0.95	400.2±10.65	19,835±51.6	364.0±6.61	11.5±0.21	357.8±7.13	3335.1±18.6	72.3±3.15	This study
CB2	811.1±16.99	35.3±1.02	310.2±11.03	19,944±52.6	360.1±6.32	11.1±0.18	368.3±6.55	2934.4±15.6	70.3±3.06	This study
QN7	874.5±21.11	41.7±1.24	465.6±11.18	24,965±68.1	447.4±8.15	13.8±0.22	533.1±8.91	3093.0±17.2	76.4±2.89	This study
QN8	573.5±13.68	41.1±1.17	566.0±13.46	24,243±62.3	489.4±9.07	12.0±0.17	299.3±5.88	3057.4±15.9	92.7±4.12	This study
QN11	613.2±20.01	37.9±0.99	440.4±12.17	24,765±60.9	636.0±11.28	12.6±0.19	342.6±6.46	3085.9±16.7	77.8±3.27	This study
QN19	685.5±18.87	38.9±1.22	453.4±11.28	24,661±69.1	552.1±12.03	12.6±0.20	345.5±7.33	3124.5±13.7	75.2±2.87	This study
QN20	691.0±20.12	32.8±1.31	143.2±8.88	23,409±50.8	350.4±7.13	6.91±0.13	405.9±8.05	2631.3±15.4	68.9±2.45	This study
QN22	1,010.0±30.0	34.2±1.40	402.0±9.75	23,485±71.5	409.5±6.98	17.6±0.14	322.8±7.12	3249.0±20.0	60.1±2.61	This study
QN29	621.1±14.77	35.9±1.08	836.5±15.64	24,646±66.4	451.9±8.37	11.2±0.10	462.0±7.18	3296.3±18.6	69.9±3.05	This study
QN50	1,530.1±51.2	31.0±0.86	298.8±10.31	21,333±57.3	369.4±6.68	10.6±0.16	384.1±8.24	2837.2±14.5	62.5±2.77	This study
Mean	830.3	36.8	431.6	23,129	443.0	12.0	382.1	3064.4	72.6	
p	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.003	< 0.001	
R. alboareolata	200	71.8	3,118	36,200	1,300	66.1	NA	6,600	135	Sanmee et al. (2003)
R. delica	NA	NA	2.78	16,000	NA	0.18	NA	4,700	NA	Singdevsachan, Patra, Tayung, Sarangi, and Thatoi (2014)
R. griseocarnosa	850	48.0	500	19,800	570	23.0	1,340	3,420	88	Chen et al. (2010)
R. lepida	100	52.8	228	35,300	700	24.2	NA	4,100	108	Sanmee et al. (2003)
R. nigricans	200	81.1	208	25,300	600	13.7	NA	3,400	62	Sanmee et al. (2003)
R. sardonia	145	29.2	40	31,240	580	11.9	700	NA	47	Rasalanavho, Moodley, and Jonnalagadda (2020)
R. vesca	NA	NA	4.24	18,000	NA	0.16	NA	8,100	NA	Singdevsachan et al. (2014)
R. virescens	100	41.3	283	27,600	800	18.4	NA	5,100	131	Sanmee et al. (2003)
R. xerampelina	100	48.0	193	28,900	600	17.4	NA	3,300	94	Sanmee et al. (2003)

Note: Data are expressed as mean ± SD, n.

The concentration (mg/kg) ranges of K (19,835.8-24,965.9), P (2,631.3-3,335.1), Ca (573.5-1530.1), Mg (350.4-636.0), Fe (143.2-836.5), Zn (60.1-92.7), and Cu (31.0-41.7) in *Russula griseocarnosa* collected in Vietnam are quite similar to measurements obtained in China, being 19,800, 3,420, 850, 570, 500, 88, and 48 mg/kg, respectively (Chen et al., 2010). However, the concentrations of Na and Mn were lower than those reported in China (Chen et al., 2010) and in some edible *Russula* species in Togo (Nadjombé et al., 2022).

In addition to their proximal and macro- and micronutrient contents, mushrooms contain a number of other chemicals with nutritional and health benefits to humans. In particular, consumption of wild edible mushrooms containing antioxidants enhances the scavenging of hydroxyl radicals and the free radical of 2.2-diphenyl-1-picrylhydrazyl (Chen et al., 2010; Yuan et al., 2017). Some mushrooms contain useful phytochemicals such as ergosterol, flavonoids, β-carotene, phenolics, and quercetin (Chen et al., 2010; Grangeia, Heleno, Barros, Martins, & Ferreira, 2011; Ouzouni et al., 2009). Quercetin has antioxidant and anti-inflammatory properties and is a major phytochemical component in *Russula griseocarnosa* with a concentration of about 95.8 mg/kg (Chen et al., 2010). In addition, edible mushrooms are a source of essential amino acids that are required in the human diet. Ming et al. (2014) found that *Russula griseocarnosa* in China contains 40 amino acids, including 20 non-structural amino acids. Further research should be undertaken on the profile of organic compounds for the populations being harvested for food in Vietnam. This includes the other edible species in the genus *Russula* such as *R. albidula*, *R. cystidiosa*, *R. paludosa*, *R. rosea*, *R. variata*, *R. vinosa*, and *R. virescens* (Anh et al., 2023; Kiet, 2012; Nguyen, 2017; Phu & Kiet, 2019).

The results of this study suggest that *Russula griseocarnosa* in Vietnam is a valuable source of protein, carbohydrate, and essential minerals in the diet of local people who consume it. It has similar nutritional composition as the same species in China, where it is a popular food among local people (Chen et al., 2010; Yuan et al., 2017). Not surprisingly, therefore, *Russula griseocarnosa* is now being purchased in large quantities by traders for export to China (Chi, 2022). The findings of this study can be used to add value to the current trade through the development of quality-controlled product brands for Vietnamese *Russula griseocarnosa*. This will aid in poverty reduction and income stabilization in the poorest part of Vietnam, where mushroom naturally occurs. Additionally, the impact of continuous harvesting on forest ecosystems must be investigated to ensure that harvesting practices are sustainable. Ideally in the future, the goal is to produce improved strains of *Russula griseocarnosa* that can be cultivated in household and village forest food orchards.

4. CONCLUSIONS

Russula griseocarnosa collected from forests in Vietnam has rich nutritional composition and high mineral content. The nutritional composition of this mushroom in Vietnam largely mirrors values for this species in southern China. Products from *Russula griseocarnosa* with higher economic value will be created based on information of their nutritional composition obtained in this study.

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Institutional Review Board Statement: The Ethical Committee of the Vietnamese Academy of Forest Sciences, Vietnam has granted approval for this study on 31 December 2023 (Ref. No. 168/QD-KHLN).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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