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Phytochemical screening of wild Ganoderma species harvested from different ecological zones in Nigeria

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ABSTRACT

The Ganoderma genus is known to have curative properties against a wide range of human illnesses. This study seeks to examine the presence and quantitative levels of phytochemicals in wild Ganoderma species collected from five ecological zones in Nigeria. The results revealed the presence of saponins, alkaloids, flavonoids, phenols, tannins, coumarin, steroids, terpenoids, triterpenes and anthroquinone in ten Ganoderma species. Saponin levels ranged from 1.10% in G. applanatum to 2.80% in G. lucidum (GALAG). Notably, G. lucidum (GALAG) and G. lucidum (GOYO2) exhibited significantly higher saponin content (2.80% and 2.51%, respectively). Alkaloid percentages were significantly higher in G. lucidum (4.82 ± 0.04%) and G. resinaceum (4.69 ± 0.05%) compared to other species. Flavonoids varied substantially, as G. sinensis demonstrated the highest flavonoid content (3.44 ± 0.068 QE), significantly surpassing all others, followed by G. resinaceum 2 (2.85 ± 0.040 QE) and G. leucocontextum (2.66 ± 0.002 QE). Phenol content, measured as gallic acid equivalents (GAE), was highest in G. resinaceum 2 (1.82 ± 0.030 GAE) and G. sinensis (1.57 ± 0.037 GAE), showing significant differences (P < 0.05). Tannin content was most pronounced in G. applanatum (1.14 ± 0.000 GAE) (GAKOG) and G. resinaceum 2 (1.08 ± 0.010 GAE) (GABUK), with significant differences (P < 0.05) from others. Interestingly, the lowest tannin concentrations (0.06 ± 0.000 GAE) were observed in G. lucidum (GIMO). There were significant differences (P < 0.01) across all phytochemical parameters among the Ganoderma species. Ganoderma resinaceum, G. sinensis, and G. applanatum emerged as the most promising candidates for pharmaceutical exploration, particularly for their elevated levels of alkaloids, flavonoids, and tannins. Furthermore, G. resinaceum 2 emerged as the most phytochemically enriched species, leading in four out of five phytochemical categories–marking it a strong candidate for functional food and pharmaceutical development pipelines.

Keywords: Ganoderma, phytochemical, quantitative, ecological, species

INTRODUCTION

The Polyporaceae family of the Basidiomycota division is well known to be a harbinger of macrofungal medicinal compounds. Kalliyaperumal (2013) described over 250 G*anoderma* species worldwide belonging to this family. *Ganoderma* species are known to naturally possess diverse bioactive substances, especially polysaccharides, triterpenoids, sterols, and proteins (Chen and Seleen, 2007). The mushroom produces other bioactive compounds such as mannitol, phenols, alkaloids, organic germanium, and other rare minerals (Shiao, 2003). Galappaththi *et al.* (2022) compiled nearly 500 bioactive substances that have been detected in the mushroom. The peculiarity of this mushroom is mostly linked to the presence of phytochemicals, particularly polysaccharides and triterpenoids, especially Ganoderic acids (Quereshi *et al*., 2010; Bharadwaj, 2019). Some of these substances have been demonstrated to exhibit extensive therapeutic and pharmacological properties, particularly antitumor, anti-hypotensive, anti-obesity, anticancer, anti-inflammatory, and antioxidative and antimicrobial capabilities, including antibacterial, antiviral, antifungal, and antiparasitic (Prasad *et al.,* 2008; Quereshi e*t al.,* 2010; Hyde *et al*., 2019; Ohimain, 2020). In the past thirty years, over 150 triterpenes and 50 carcinostatic polysaccharides have been detected, which are known to be unique to *Ganoderma* mushrooms (Quereshi *et al*., 2010). Sun *et al.* (2012) reported the in vitro inhibitory effects of the ethanol extracts of *G. lucidum* against various cancer cell lines, including gastric carcinoma, melanoma, and inflammatory breast cancer. Other authors have reported the anticancer

properties of *Ganoderma* extracts against various forms of cancer (Martínez Montemayor *et al*., 2019), including breast cancer (Yue *et al*., 2006) and prostate cancer (Wu *et al*., 2018), some of which have been tested for efficacy clinically (Wong *et al*., 2020). Notwithstanding, the exact mechanism of antitumour action of the mushroom is not fully understood. The bioactivity of *Ganoderma* mushrooms seems to depend not only on the species and habitat of growth (Egwim *et al*., 2011), but also on the solvent used for extraction. For instance, Alves *et al.* (2012) show that the antimicrobial activity of different *G. lucidum* extracts was different between acetone and methanol solvents. *Ganoderma* mushrooms are often extracted using organic hot water or organic solvents prior to use. This practice faces some challenges, including low extraction efficiency, complexity of extraction, degradation of bioactive components and the presence of potentially toxic organic solvents or other residues in extracts (Cui *et al.,* 2012). On the other hand, extraction of bioactive components of the mushroom with supercritical fluids using carbon dioxide as a solvent can provide a healthier alternative to organic solvents (Sun *et al*., 2012).

Ganoderma species, like any other macrofungi, naturally grow in the wild mostly on dead or living hardwood and sometimes on dead roots (Luangharn *et al*., 2021). Various species of *Ganoderma* have been detected in the wild in different ecological zones across Nigeria including tropical rainforest (Ozumba *et al*, 2018; Okigbo and Obanubi, 2020; Wood *et al*., 2021; Ihayere and Okhuoya, 2022; Poyeri and Ohimain, 2024; Jonathan *et al.,* 2024), mangroves (Adongbede, and Atoyebi, 2021; Jonathan *et al*., 2024) and in the Savannahs (Ogbe *et al*., 2009; Shamaki *et al.,* 2012; Jonathan *et al.,* 2024). Wild *Ganoderma* species are a major component of traditional African medicine (Osemwegie and Oghenekaro, 2010; Okigbo and Obanubi, 2020; Ohinain, 2020). Wood *et al.* (2021) attributed the health benefits of *Ganoderma* species to the presence of diverse phytochemicals, particularly polysaccharides, triterpenes, and others such as phenolics, lectins, sterols, and proteins. Studies on wild mushrooms show that the growth habitat influences the landscape and concentration of bioactive substances (Heleno *et al.,* 2013). Egwim *et al*. (2011) reported that the presence of phytochemicals in mushrooms could be due to metabolic reactions or environmental factors, particularly the composition of their substrates.

Currently, in Nigeria, only exotic *Ganoderma lucidum* is cultivated commercially on a small scale for medicinal use (Poyeri and Ohimain, 2024; Poyeri *et al.,* 2024) despite the fact that there are many indigenous diverse *Ganoderma* species found in the various ecological regions across the country. There is, however, limited information regarding the phytochemical properties of wild *Ganoderma* species in Nigeria. Hence, the need to examine the presence of phytochemicals in wild *Ganoderma* species across the various ecological zones of the country.

MATERIALS AND METHODS

Sample Collection

Ganoderma samples were collected randomly from the wild from different ecological zones across Nigeria, namely: freshwater swamp, rainforest zone, mangrove swamp, Sudan savannah, and derived savanna. Intact and mature fruiting bodies were harvested manually, cleaned with dry cotton wool to remove soil dirt, surface-cleaned with alcohol and taken to the mycology laboratory of the Botany Department, University of Ibadan, for analysis. The identity of the isolates was previously identified using their morphological characteristics and molecular methods (Jonathan *et al.* 2024). Ten samples were selected for phytochemical analysis across five ecological zones (Table 1).

Phytochemical Screening

The procedures for the phytochemical screening, both qualitative and quantitative, were described by Harborne (1973). Alkaloids were determined using Hager's test. Saponin was analyzed after multi-solvent extraction using water, ethanol, diethyl ether and butanol using Froth's test. Total phenolic content was determined spectrophotometrically at 550 nm using the Folin-Ciocalteu method. Tannins were determined spectrophotometrically at 725 nm using the Folin-Ciocalteu method. Total flavonoid content was measured by the Alkaline reagent spectrophotometric method at 510 nm. Qualitative determination of Terpenoids was carried out by Salkowski's test after extraction with water and chloroform and dissolving the extracts in sulphuric acid. Steroids were determined qualitatively using the Salkowski test method after chloroform extraction. Qualitative analysis for phenols was determined using the Folin-Ciocalteu method after aqueous extraction. Glycosides were determined

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qualitatively after extraction using the Salkowski test. Coumarin was determined qualitatively through reaction with 10 % NaOH. Steroids were determined qualitatively using the Salkowski test. Cardiac glycosides were determined qualitatively using the Keller-Killiani test.

Table 1: Sample collection from 8 locations representing five agro-ecological zones in Nigeria

Sample location	Sudan Savannah	Guinea/Derived savannah	Rainforest	Mangrove	Fresh water	Species
Kano	GABUK					*Ganoderma resinaceum*
Kogi		GAKOG				*Ganoderma applanatum*
Benue		GABEN				*Ganoderma austral*
Oyo		GOYO (2)				*Ganoderma calidophilum, Ganoderma lucidum*
Osun		GOSUN				*Ganoderma leucocontextum*
Lagos				GALAG		*Ganoderna lucidum*
Bayelsa			GABAY		GABAY	*Ganoderma sanduense, Ganoderma sinensis*
Imo			GIMO			*Ganoderma lucidum*

Key: GABUK1=*Ganoderma* collected from BUK, Kano; GAKOG= *Ganoderma* collected from Lokoja, Kogi State; GABEN1= *Ganoderma* collected from Adikpo LGA, Benue State; *Ganoderma* 1 = *Ganoderma* collected from IITA, Ibadan and UI, Ibadan; GOSUN = *Ganoderma* collected from Osun State; GALAG= *Ganoderma* collected from Badagry, Lagos State; GABAY= *Ganoderma* collected from Odi, Bayelsa State and Yenagoa, Bayelsa State. GIMO= *Ganoderma* collected from FUTO, Owerri, Imo State.

To test for Quinones using the sulfuric acid test, 2 mL of ethanolic extract of the *Ganoderma* sample was introduced into a clean test tube. 1 mL of concentrated H_2SO_4 was added down the side of the test tube; the mixture was kept without shaking for 1-2 minutes and later observed for red or violet colouration.

Salkowski test was used to test for triterpenes: Here, 2 mL of chloroform was added to 2 mL of the ethanolic extract of the *Ganoderma* species in a test tube. Thereafter, 2 mL of concentrated H_2SO_4 was then added and kept for 5 min. The reaction observed was reddish colouration.

To test for Anthraquinones using the ammonia test, 2 mL of ethanolic extract from *Ganoderma* spp. was put in a test tube and then 5 mL of benzene was added, and shake gently for 2 minutes to allow anthraquinones to partition into the organic phase. The layers were allowed to separate, followed by adding 2 mL of 10% aqueous ammonia solution to the organic layer and shaking gently.

Statistical Analysis
The data generated were compiled in Microsoft Excel and analyzed using IBM SPSS version 26 (IBM Inc< Chicago). Analysis of variance was carried out on the data, while Duncan Multiple Range Test (DMRT) was used for multiple comparisons at P = 0.05

RESULTS AND DISCUSSION
Results obtained from the phytochemical analysis of wild Ganoderma mushroom samples collected across 5 predominant ecological habitats in Nigeria are shown in Tables 2 and 3. Field observations

of wild *Ganoderma* species across the major ecological zones in Nigeria revealed that the fruit body of most species blooms just before rains start in March and continues from April to October during the rainy season when the humidity (50-95%) and temperature (24-39 ^{0}C) are favourable for fruit body development. In the Sudan savanna, *Ganoderma resinaceum* was found attached to the roots of some horticultural plants. From field observation, it is important to state that there is a prevalence and abundance of this species in the Northern part of Nigeria. However, *Ganoderma lucidum*, the most common medicinal fungus in the world, can be seen only around the rainy season in the derived, rainforest and mangrove zones of Nigeria. *Ganoderma applanatum, Ganoderma calidophilum,* and *Ganoderma lucidum* were collected from the barks of trees and stumps in the derived savanna. In the Mangrove and tropical rainforest zones, *Ganoderma lucidum, Ganoderma sanduense, and Ganoderma sinensis* were equally found growing on decaying trees and roots of some hardwood trees.

Table 2: Qualitative phytochemical assessment among *Ganoderma* species

Parameters	*G. lucidum*	*G. sanduense*	*G. calidophilum*	*G. resinaceum*	*G. lucidum 2*	*G. applanatum*	*G. australe*	*G. sinensis*	*G. resinaceum 2*	*G. leucocontextum*
Saponin	+	+	+	+	+	+	+	+	+	+
Alkaloid	+	+	+	+	+	+	+	+	+	+
Flavonoid	+	+	+	+	+	+	+	+	+	+
Phenol	+	+	+	+	+	+	+	+	+	+
Tannin	+	+	+	+	+	+	+	+	+	+
Coumarin	+	+	+	+	+	+	+	+	+	+
Steroid	+	+	+	+	+	+	+	+	+	+
Terpenoid	+	+	-	-	+	+	+	+	+	+
Cardiac Glycosides	-	-	-	-	-	-	+	+	+	+
Quinones	+	+	+	+	+	+	+	+	+	+
Glycosides	-	-	-	-	-	-	-	-	-	-
Triterpenes	+	+	+	+	+	+	+	+	+	+
Anthraquinone	+	+	+	+	+	+	+	+	+	+

+ = presence. - = absence

Table 3: Quantitative phytochemical assessment of *Ganoderma* species

Species	Saponin (%)	Alkaloid (%)	Flavonoid (QE)	Phenol (GAE)	Tannin (GAE)
G. lucidum	1.72±0.090^a	4.6±0.220^a	2.58±0.050^b	0.68±0.010^e	0.06±0.000^c
G. sanduense	1.29±0.010^f	3.67±0.040^h	1.82±0.050^b	1.02±0.020^c	0.89±0.011^a
G. calidophilum	1.20±0.065^c	2.83±0.150^d	1.56±0.040^d	1.21±0.003^f	1.08±0.008^b
G. applanatum	1.10±0.000^g	2.86±0.070^e	2.64±0.025^e	1.41±0.016^d	1.14±0.000^c
G. resinaceum	2.80±0.000^g	4.33±0.190^c	2.31±0.044^c	0.60±0.037^a	0.17±0.000^c
G. sinensis	1.242±0.000^g	2.85±0.052^g	3.44±0.068^a	1.57±0.037^a	1.04±0.000^c
G. lucidum (2)	2.52±0.050^e	4.24±0.062^f	1.73±0.044^c	0.59±0.038^a	0.55±0.006^c
G. austral	1.80±0.074^b	3.74±0.201^b	1.79±0.025^e	0.49±0.031^b	0.17±0.000^c
G. resinaceum 2	2.42±0.013^f	4.55±0.050^g	2.85±0.040^d	1.82±0.030^b	1.08±0.010^a
G. leucocontextum	1.58±0.055^d	3.86±0.022^i	2.66±0.002^f	1.25±0.021c	1.02±0.000^c

The data are presented as mean± standard deviation, n=3. Along the columns, superscript letters showed that means are significantly different (P<0.05)

From this study, qualitative assessment of phytochemicals revealed the presence of saponins, alkaloids, flavonoids, phenols, tannins, coumarin, steroids, terpenoids, triterpenes and anthraquinone in all 10 *Ganoderma* species. However, cardiac glycosides were absent in *Ganoderma lucidum, Ganoderma saduense, Ganoderma calidophilum and Ganoderma resinaseum*. Glycosides were completely absent for all the *Ganoderma* strains. This is in line with the works and propositions of

other researchers (Kadiri and Fasidi, 1992; Akindahunsi, 2005; Afiukwa *et al*., 2013) who detected the presence of flavonoids, saponins, alkaloids, phenols, HCN, oxalates, and phytates in wild mushrooms, especially *Ganoderma* (Poyeri et al., 2024). According to Wood *et al.* (2021) and Egwim *et al.* (2011), the presence of phytochemicals could be inherent as a result of metabolic reactions or environmental influences due to the substrate composition where the mushroom inhabits.

Saponin levels ranged from 1.10% in *G. applanatum* to 2.80% in *G. lucidum* (GALAG). Notably, *G. lucidum* (GALAG) and *G. lucidum* (GOYO2) exhibited significantly higher saponin content (2.80% and 2.51%, respectively), surpassing the lowest concentration recorded in *G. applanatum* (1.10%) and *G. calidophilum* (1.20%). These findings align with previous reports highlighting the immunomodulatory and cytotoxic potentials of saponin-rich *Ganoderma* extracts (Sun *et al*., 2020. Poyeri *et al.* (2024) reported a saponin concentration of 0.04% in wild *G. lucidum* that was harvested from a tropical rainforest in Benin City.

Alkaloid content displayed considerable variability among the species, with *G. lucidum* (GIMO) recording the highest (4.6%), followed closely by *G. resinaceum* (GABUK, 4.55%) and *G. lucidum* (GALAG, 4.33%). Conversely, *G. calidophilum* (GOYO) and *G. applanatum* (GAKOG) recorded the lowest values (2.8%). These results echo the significance of alkaloid biosynthesis pathways in certain *Ganoderma* strains and their implication in antimicrobial and anticancer activities (Zhao *et al*., 2013). The DMRT of 0.1756 indicates that most of the *Ganoderma* species have meaningful differences in alkaloid content and correlates with variation in pharmacological activity, which is valuable for selecting species with higher therapeutic potential or for standardizing medicinal formulations. Poyeri *et al*. (2024) reported an alkaloid level of 0.5- 0.6%, while Ihayere and Okhuoya (2022) reported 0.54 ± 0.05% in wild *G. lucidum* that was harvested from a tropical rainforest in Nigeria.

Flavonoids, quantified as quercetin equivalents (QE), varied substantially among the species. *G. sinensis* demonstrated the highest flavonoid content (3.44 ± 0.068 QE), significantly surpassing all others ($P < 0.05$), followed by *G. resinaceum 2* (2.85 ± 0.040 QE) and *G. leucocontextum* (2.66 ± 0.002 QE). The lowest flavonoid content was detected in *G. calidophilum* (1.55 mg/g). These values affirm earlier studies that attributed potent antioxidant activities to flavonoid-rich *Ganoderma* species (Chen *et al*., 2019). The DMRT value (0.0645) supports the statistical significance of these findings. Poyeri et al. (2024) reported flavonoid content of 1.4-1.8% from wild *G. lucidum* that was harvested from Benin City.

Phenolic content, another critical group of antioxidants, measured as gallic acid equivalents (GAE), was highest in *G. resinaceum 2* (1.82 ± 0.030 GAE) and *G. sinensis* (1.57 ± 0.037 GAE), showing significant differences ($P < 0.05$), indicating strong oxidative stress mitigating potential. In contrast, species like *G. lucidum* (GOYO2 and GALAG) recorded the lowest values (0.6 mg/g), pointing to moderate to low phenolic contributions. The observed differences (DMRT = 0.0445) reiterate the influence of genetic and ecological factors on phenolic synthesis (Yang et al., 2015). Poyeri et al. (2024) reported phenolic content of 0.18-0.27%, while Ihayere and Okhuoya (2022) reported 5.90±0.27% from wild *G. lucidum* harvested from a tropical rainforest in Nigeria.

Table 4: Mean square variance for Quantitative Phytochemical assessment

Source	Df	Saponin %	Alkaloid %	mg/g Flavonoid (QE)	mg/g Phenol (GAE)	mg/g Tannin (GAE)
Species	9	1.12**	1.47**	1.087**	0.64**	0.576**
Replicate	2	0.005	0.067	1.607	0.0008	0.0001
Error	18	0.003	0.01	0.001	0.0006	0.00005
Corrected total	29					
Coeff Var		326.00%	272.00%	160.70%	244.00%	101.00%

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Tannin content was most pronounced in *G. applanatum* (1.14 ± 0.000 GAE) (GAKOG) and *G. resinaceum 2* (1.08 ± 0.010 GAE) (GABUK), with significant differences ($P < 0.05$) from the others. Interestingly, the lowest tannin concentrations (0.06 ± 0.000 GAE) were observed in *G. lucidum* (GIMO), suggesting species-specific metabolic specialization. Other tannin-rich species include *G. calidophilum* (GOYO, 1.08 mg/g). Tannins are associated with antimicrobial, antioxidant, and astringent properties, making species like *G. applanatum* and *G. calidophilum* potential sources for antimicrobial therapeutics (Ndhlala *et al*., 2010). The statistical significance is underlined by the DMRT value of 0.0126. Poyeri *et al*. (2024) reported tannin content of 0.12- 0.14%, while Ihayere and Okhuoya (2022) reported 4.60±0.32% from wild *G. lucidum* harvested from a tropical rainforest near Benin City.

Table 6: Locational effect showing Inter/Intra species variability for quantitative phytochemical assessment.

LOCATION	Saponin %	Alkaloid %	Flavonoid (GAE) mg/g	Phenol (GAE) mg/g	Tannin (GAE) mg/g
GIMO	1.72d	4.6a	2.58d	0.68f	0.06h
GABAY	1.29f	3.7f	1.82f	1.02e	0.89e
GOYO	1.2f	2.8g	1.55h	1.21d	1.08b
GAKOG	1.1g	2.8g	2.64c	1.4c	1.14a
GOYO2	2.51b	4.24d	1.73g	0.6g	0.55f
GALAG	2.80a	4.33c	2.31e	0.6g	0.17g
GABEN	1.8c	3.74c	1.79gf	0.9h	0.17g
GABAY2	1.24f	2.85g	3.44a	1.6b	1.03c
GABUK	2.43c	4.55b	2.85b	1.81a	1.08b
GOSUN	1.58e	3.87e	2.67c	1.25d	1.02d
LSD	0.0989	0.1756	0.0645	0.0445	0.0126

Key: GABUK1=*Ganoderma resinaceum*, GAKOG=*Ganoderma applanatum*, GABEN1= *Ganoderma australe*, GOYO1 =*Ganoderma calidophilum*, GOYO2 =*Ganoderma lucidum,* GOSUN1=*Ganoderma leucocontextum*, GALAG1=Ganoderma *lucidum,* GABAY= *Ganoderma sanduense*, GABAY2=*Ganoderma sinensis*, GIMO2=*Ganoderma lucidum*

Table 6 revealed a comparative analysis of phytochemical variability both within and between *Ganoderma* species. The use of DMRT revealed that, for saponins, *G. lucidum* (GALAG) displayed the highest value (2.80%), statistically distinct from *G. applanatum* (GAKOG, 1.10%) and *G. calidophilum* (GOYO, 1.20%). Notably, *G. lucidum* variants (GOYO2, GALAG, GIMO2) consistently had higher saponin concentrations, which is suggestive of conserved biosynthetic capabilities within this clade (Sun *et al*., 2020). Alkaloid distribution showed that *G. lucidum* (GIMO) had the highest content (4.6%), closely followed by *G. resinaceum* (GABUK, 4.55%) and *G. lucidum* (GALAG, 4.33%). These species form a high-alkaloid cluster that may have evolved specialized nitrogen-based secondary metabolic pathways with implications for anticancer drug development (Zhao *et al*., 2013). Flavonoid content was particularly high in *G. sinensis* (GABAY2, 3.44 mg/g), with significant statistical separation from species such as *G. calidophilum* (1.55 mg/g). This interspecies variability highlights

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G. sinensis as a potential antioxidant-rich species, in line with its traditional medicinal usage (Chen *et al.,* 2019). Phenolic content peaked in *G. resinaceum* (GABUK, 1.81 mg/g), followed by *G. sinensis* (1.6 mg/g). This reinforces their therapeutic relevance, as phenolics are essential contributors to radical scavenging capacity and cellular protection (Yang *et al*., 2015). The lowest phenolic content (0.60 mg/g) in *G. lucidum* (GOYO2, GALAG) may suggest species-level trade-offs in metabolite investment. Tannin accumulation was most prominent in *G. applanatum* (GAKOG, 1.14 mg/g), followed by *G. calidophilum* (GOYO, 1.08 mg/g), and *G. resinaceum* (GABUK, 1.08 mg/g). Conversely, *G. lucidum* (GIMO2) had the lowest tannin content (0.06 mg/g), possibly indicating diminished defence mechanisms against microbial antagonists in this species (Ndhlala *et al*., 2010).

The intra-species comparisons among *G. lucidum* strains (GIMO2, GOYO2, GALAG) revealed considerable variability across all measured parameters, suggesting that species-level genetic differences substantially influence metabolite biosynthesis. This finding has profound implications for fungal species improvement and selection in industrial mycotechnology. The inter-species variability was significant ($P < 0.05$) across all phytochemical traits, as determined by the DMRT post hoc test. The relatively high coefficients of variation (CVs), especially for saponins and alkaloids, further underscore the inherent metabolic diversity within and between *Ganoderma* species. This diversity may stem from genotypic differences, environmental influence, or both.

This study underscores the diverse phytochemical profiles among *Ganoderma* species. *G. resinaceum*, *G. sinensis*, and *G. applanatum* emerged as the most promising candidates for pharmaceutical exploration, particularly for their elevated levels of alkaloids, flavonoids, and tannins. The variation detected in this analysis not only affirms the chemotaxonomic utility of these bioactive compounds but also supports the strategic selection of species for nutraceutical development and drug discovery programs.

CONCLUSION

This study demonstrates distinct interspecific variability in the phytochemical architecture of *Ganoderma* species, with *G. resinaceum*, *G. lucidum*, and *G. sinensis* being the most bioactive. The phytochemical analysis, as deduced in this eco-diversity assessment, has further established the *Ganoderma* genus as a potential source of medicinal substances with the potential to address several health issues due to the rich content of phytochemicals. This study has further shown that Nigerian *Ganoderma* spp. irrespective of their ecological niche, are diverse both within and between species. These results justify their inclusion in targeted metabolomic and genomic studies for drug discovery and support their application in evidence-based traditional medicine. Future studies should explore seasonal, developmental, and environmental modulation of these phytochemicals to optimize their biotechnological exploitation.

DECLARATIONS

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

The authors of this work have declared the data and content of this research work open-source for further scholarly and scientific utilization.

Competing interests

We declare no conflict of interest.

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Authors' contributions

TTW: Conceptualisation, project administration, supervision, visualisation, writing – original draft and

final version.
OOJ: Sample collection, reviewed draft manuscript and approved final version.
EIO: Result validation, visualisation, reviewed draft manuscript and approved final version.

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