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ORIGINAL RESEARCH

ANTIOXIDANT AND ANTIBACTERIAL PROPERTIES OF WILD POLYPORE MUSHROOMS FROM LASU, OJO CAMPUS.

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Abstract:
Introduction: Mushrooms have been broadly used in folk medicine for the treatment of various diseases for years. Polypores are cosmopolitan mushrooms that are widely investigated for their useful properties in battling multidrug-resistant pathogens.
Aims: This study investigated the phytochemical, antioxidant and antibacterial properties of wild *Bondarzewia berkeleyi* and *Ganoderma lucidum*. The fruiting bodies of *G. lucidum* and *B. berkeleyi* were collected at Lagos State University, Ojo Campus.
Materials and Methods: Extraction was done using methanol and acetone. Standard tests were carried out to detect different phytochemical compounds present in the mushroom extracts. These phytochemical compounds were further estimated and quantified using standard methods. The antioxidant activity of the extracts was evaluated using a DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging assay, while antimicrobial activity on *Pseudomonas aeruginosa* and *Salmonella typhi* was carried out using the paper disc diffusion assay.
Results: Results showed that reducing sugar, terpenoids, steroids, phenolics, flavonoids and triterpenoids were present in both mushrooms while tannins, alkaloids and anthraquinones were absent. Saponins appeared to be present only in the methanolic extracts, while cardiac glycosides were detected only in the acetone extract of both mushrooms. The highest antioxidant activity was recorded in the acetone extract of *G. lucidum* (90.435±0.112) and the least was recorded in the acetone extract of *B. berkeleyi* (26.632±0.129), while both mushroom extracts showed antibacterial effects against both tested organisms. The highest inhibition zone was exhibited by the methanolic extract of *G. lucidum* against *P. aeruginosa* ranging from 10 mm to 14 mm while the least inhibition zone ranging from 0 mm to 11 mm was exhibited by S. typhi for the extracts. Nevertheless, *P. aeruginosa* appeared to be more sensitive to *G. lucidum* extract than *S. typhi*, which exhibited the smallest zones of inhibition.
Conclusion: Based on this research result, these mushroom extracts are a good source of phytochemicals that show potential for antibacterial and antioxidant activity; therefore, they can be exploited as therapeutic products.
Keywords: phytochemicals, antioxidant, antimicrobial, extraction, mushroom extracts, inhibition, polypore.

All co-authors agreed to have their names listed as authors.

1. INTRODUCTION

Nature has been a source of medicinal agents for thousands of years and an impressive number of modern drugs have been isolated from natural sources for use in traditional medicine [1]. Herbal medicines serve the health needs of about 80% of the world's population, especially millions of people in the vast rural areas of developing countries. Moreover, more than 65% of the global population depends on medicinal plants as a primary healthcare modality to combat infections and diseases [2]. Therefore, there is a continuous search for new “naturally derived” antimicrobial agents. In light of this, wild-growing edible mushrooms are of interest to scientists, not only because of their high nutritional properties but also due to their high antimicrobial activities and antioxidant properties [3]. Wild mushrooms are well known for being used by certain local or ethnic tribes for food and medical purposes. Also, several new mushroom species with medicinal properties have been discovered over the past decades [4]. Therefore, to prevent over-exploitation and loss of these wild mushrooms, it is pertinent to understand the ecology of mushrooms and define them in order to preserve these macro fungi [4].

In areas with high humidity, wild mushrooms grow naturally on tree trunks or rotting woody debris. They are typically abundant worldwide during the wet season and have been discovered to grow on different substrates [5]. They play a significant role in the environment as recyclers and decomposers of organic matter [6]. They are also used as nutritious foods and therapeutic sources worldwide because they contain a diverse range of bioactive compounds, such as nucleotides, phenols, steroids, glycoprotein, terpenoid derivatives, and polysaccharides with antimicrobial, antitumor, antioxidant, immunomodulatory, and antiviral properties [7], [8] [9]. Antioxidant compounds have an important ability to trap free radicals and thus inhibit the oxidative mechanisms that lead to degenerative diseases. Naturally occurring antioxidants found in whole grains, fruits, vegetables, teas, spices and herbs have also been reported in mushrooms [10].

Ganoderma spp. are well-known medicinal polypore fungi widely used in East Asia, America, and other countries for therapeutic properties. Among the over 400 species of *Ganoderma* in existence, only red, white, black, yellow, blue, and purple Reishi have been explored for their potential health-beneficial properties [11]. Of these, red Reishi (*G. lucidum*) and black Reishi (*G. sinensis*) have shown the most significant health-strengthening effects [12]. *G. lucidum*, a cosmopolitan mushroom species, is a polypore rack mushroom that changes colour during the morphogenesis process from orange-white to bright red. Many bioactive components have been identified from its fruiting bodies, mycelia, spores, and culture media. Major chemical constituents of *G. lucidum* and related species include polysaccharides, triterpenoids, nucleotides, sterols, steroids, fatty acids, and proteins/peptides with the most pharmacologically active compounds being triterpenoids and polysaccharides [13].

Bondarzewia berkeleyi (Fr.) Bond. *et* singer (*Polyporus berkeleyi*) of the family Bondarzewiaceae (Basidiomycota) is another important polypore fungus. It is edible and grows at the base or roots of Abies and other conifers of the family Fagaceae [14]. *Bondarzewia* is a genus with a few species and a lot of records from all over the world [15], [16], [17]. Some species are edible and medicinal [18],[19], while others are pathogenic to their host trees [20]. They are not mycorrhizal and are saprobic, hence having the potential to be cultivated [21].

The goal of research in the treatment of microbial infections is the discovery of agents that suppress their multiplication without affecting normal cells. The unwanted side effects of antibiotics and the presence of resistant strains make the development of new agents a crucial requirement. The absence of side effects and the huge importance associated with these mushrooms make them ideal and acceptable as natural medicine. These medicinal mushrooms from the wild synthesize various antibacterial, antifungal, antiviral, anti-inflammatory, antioxidative, anti-hypertensive, anti-cancer and anti-hyperglycemic substances, which can be purified and applied in clinical practice. Some of the bioactive substances responsible for these therapeutic and medicinal properties include polysaccharides (high and low weight), phenols, sterols, and triterpenoids. *G. lucidum* has been used for years for the treatment of various ailments in South-western regions of Nigeria but *B. berkeleyi* has not been exploited. Therefore, the purpose of this study is to evaluate the phytochemical properties, antioxidant activity and antibacterial potency of methanol and acetone extracts of *B. berkeleyi* and *G. lucidum* collected from Lagos State University, Ojo Campus.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

2.1 Collection and Identification of Mushroom samples

The fresh sporocarps of mature mushroom species (*B. berkeleyi* and *G. lucidum*) were harvested from dead wood/trunk in Lagos State University, Ojo Campus (Latitude: 6° 28' 1.20" N, Longitude: 3° 10' 58.80" E). The polypores were identified by their corky, woody and leathery basidiocarps and other characteristics described by [22]. The macroscopic descriptions, including size, shape, colour, texture, and odour, were noted. The colour of the carpophore, the shape of the cap and stipe, the colour of the flesh and latex, and its smell and habitat were also noted (Fig. 1).

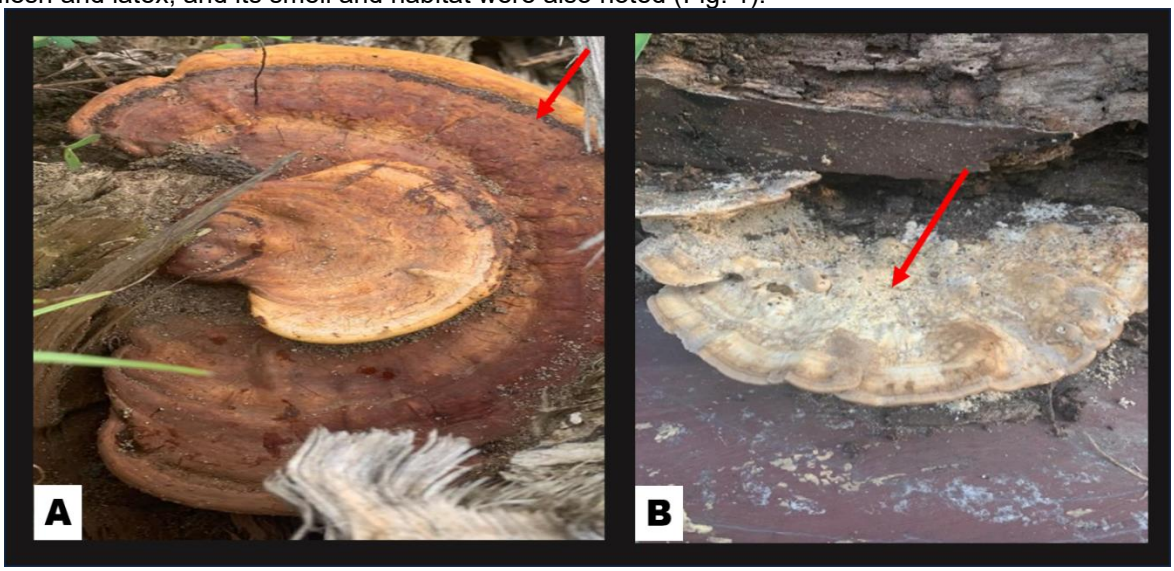

Fig. 1. Images of polypore mushrooms as seen in their natural habitat. (A) *G. lucidum*. (B) *B. berkeleyi*.

2.2 Preparation of Extracts from Mushrooms

The mushroom samples (*B. berkeleyi* and *G. lucidum*) were washed thoroughly under running water to remove dirt and sand particles. The samples were cut and oven-dried at 45°C for 5 hours. Dried samples were pulverized using QASA high-power blender (QBL-8008 pro), and stored in a pre-cleaned air-tight polyethylene bag for further analysis.

2.3 Preparation of crude extracts

The bioactive compounds in the pulverized mushroom samples were extracted in methanol and acetone using the procedure described by [3] with some modifications. The mushroom sample (60 g) was added to 600 mL of methanol and the mixture was placed on an orbital shaker at 150 rpm for 24 hours at 25°C. The extract was filtered through Whatman No. 1 filter paper and the process was repeated twice on the same residue using 100 ml of the solvent to ensure complete extraction. The extracts were pooled (Fig. 2) and dried in an oven at 40°C for further analysis. The same procedure was followed for acetone extraction. The yield of the mushroom extracts was estimated using the following expression;

Extraction Rate (%) = (Weight of extracts (g))/ (Weight of the mushroom powder before extraction (g)) x 100

Fig. 2. Beakers containing *G. lucidum* and *B. berkeleyi* acetone and methanolic extracts. **GA**= *G. lucidum* extracted with acetone, **BA** = *B. berkeleyi* extracted with acetone, **GM**= *G. lucidum* extracted with methanol, and **BM**= *B. berkeleyi* extracted with methanol.

2.4. Phytochemical analysis

2.4.1 Qualitative analysis of phytochemical compounds

Standard methods were employed to test for the presence of phytochemicals, and analysis was carried out in duplicates [23]. Reducing sugars, terpenoids, steroids, and phenolic compounds were analyzed using Fehling's, Liebermann's, Salkowski's and Lead acetate methods respectively. Flavonoids were tested in the extract using the Shinoda method, tannins using the ferric chloride assay, and alkaloids were tested using Wagner's and Dragendroff's methods. The mushroom extracts were also tested for the presence of triterpenoids, saponins, anthraquinones and cardiac glycoside using Liebermann-Burchard, Frothing, Borntrager's, and Keller Killani's tests.

2.4.2 Estimation of total phenolic compounds

The concentration of phenolic compounds in the extracts was estimated using the Folin Ciocalteau method described by [24], with some modification. An aliquot of the mushroom extract (I mL) was added to 5 mL of Folin Ciocalteau reagent followed by the addition of 4 ml 75g/L sodium carbonate solution. The absorbance of the mixture was measured in a spectrophotometer at 765 nm after 30 mins. Results were interpolated by preparing a standard curve with different concentrations of Gallic acid. The total phenolic contents in the extracts were determined using the following expression;

$$TPC = (C \times V)/M$$

Where, TPC (mg/g) = Total phenolic contents of Gallic acid equivalent in the extract
C (mg/mL) = Concentration of Gallic acid obtained from the calibration curve,
V (mL)= Total volume of extract used in the assay,
M (g) = Total weight of dry extract used in the assay.

2.4.3 Determination of Total flavonoids

The total flavonoids were determined according to [25], with slight modification. A 100 µl of mushroom extracts in methanol (10 mg/ml) was mixed with 100 µl of 20% aluminium trichloride in methanol. A drop of acetic acid was added and the volume was made to 5 ml with methanol. The absorption of the mixture was measured at 415 nm after 40 minutes of incubation at room temperature. Rutin solution (0.5 mg/ml) in methanol was used as the standard measured under the same conditions. Total flavonoid content was expressed as Rutin equivalents (mg Rutin/g extract). All determinations were carried out in triplicates.

2.4.4 Reducing Sugar Content

The reducing sugar content (RSC) was determined using the 3,5-dinitrosalicylic acid (DNSA) method. The measurement was performed according to the procedure of [26], with a slight modification. DNSA reagent was prepared by dissolving 1 g of DNSA and 30 g of sodium-potassium tartaric acid in 80 ml of 0.5 N NaOH at 45°C. After dissolution, the solution was cooled down to room temperature and diluted to 100 ml using distilled water. For reducing sugar estimation in the sample extracts, 2 ml of DNSA reagent was added to 1 ml of mushroom extracts (1 mg/ml) in a test tube and kept at 95°C for 5 min. After cooling, 7 ml of distilled water was added and the absorbance of the resulting solution was measured at 540 nm using a UV-VIS spectrophotometer. The reducing sugar content was calculated from the calibration curve of

standard D-glucose (200-1000 mg/L), and the results were expressed as mg D-glucose equivalent (GE) per gram dry extract weight.

2.4.5 Estimation of Steroids

To 1 ml of test extracts in 10 ml volumetric flasks, 2 ml of 4 N sulphuric acid, and 2 ml of 0.5% w/v iron (III) chloride were added, followed by 0.5 ml of 0.5% w/v potassium hexacyanoferrate (III) solution. The mixture was heated in a water bath maintained at 70 ± 2^0C for 30 min with occasional shaking and diluted to 10 ml with distilled water. The absorbance was measured at 780 nm against the reagent blank. Total steroids in extracts were expressed in terms of cholesterol equivalents (mg of CHO/g of extract).

2.5 Determination of Antioxidant Activity

The antioxidant activity of the mushroom extracts was determined using the 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method. The reagent was prepared by dissolving DPPH crystalline solid in analytical-grade methanol and stored at 4°C. A 2 ml of DPPH solution was added to 2 ml of the extracts in a series of concentrations (10, 25, 50, 100 and 250 µg/ml). After 30 min of incubation in the dark, the absorbance was measured at 517 nm using a UV-Vis Spectrophotometer (Thermospectronic BioMate 3, U.S.A) against methanol as the blank. A series of concentrations of ascorbic acid was prepared and used as the standard for interpolation of results. The antioxidant activity was expressed as:

% Inhibition = [(Acontrol - Asample)/Acontrol] × 100%

2.6. Antimicrobial sensitivity assay of the mushroom extracts

2.6.1 Preparation of mushroom extracts

Stock solution of the crude mushroom extracts was prepared by dissolving 100 mg of each extract in 5 ml of DMSO (Dimethyl Sulfoxide), mixed well and transferred into a dark plastic bottle and stored at -20°C until analysis. Sterile filter discs were infused with working concentrations of 3, 7 and 10 mg/ml of the extracts to determine the antibacterial activity.

2.6.2 Test organisms

Pure cultures of pathogenic Gram-negative bacteria (*Pseudomonas aeruginosa* and *Salmonella typhi*) were obtained from Microbiology Laboratory, Lagos State University, Ojo, Lagos and maintained on nutrient agar. The isolates were cultured in Tryptic Soy Broth and the turbidity of the bacterial suspension was measured using a spectrophotometer till a 0.5 McFarland standard was obtained, giving an approximate bacterial suspension of 1.5 ×10^8 CFU.

2.6.4. Disc diffusion assay

Mueller Hinton agar was prepared by dissolving 38 g in 1000 mL of distilled water in a conical flask and sterilized in an autoclave at 121°C for 15 minutes. The sterilized medium was dispensed into sterile 9 cm Petri dishes under aseptic conditions and allowed to solidify. Bacterial suspensions previously cultured in nutrient broth for 24 hrs were diluted with sterile saline water to achieve a 0.5 McFarland standard at a concentration of 1.0 × 10^8 CFU mL-1. Aliquots of the diluted bacterial culture (100 µl) were spread on the surface of dried Muller- Hinton agar plates and the infused filter discs with the mushroom extracts were carefully placed on the inoculated plates, while erythromycin was used as a positive control. The plates were incubated at 35±2°C for 24 hours in an incubator. The antimicrobial activity of the test samples was determined by measuring the zones of inhibition observed around the filter discs and expressed in mm. All tests and measurements were carried out in duplicate.

3. RESULTS AND DISCUSSION

G. lucidum extracted with acetone had the highest percentage yield and *B. berkeleyi* extracted with acetone had the lowest yield as shown in **(Table 1).** The result showed that terpenoids and steroids were heavily detected in the methanol and acetone extracts of the mushrooms tested. Alkaloids, anthraquinones and tannins were absent in all the extracts of the mushrooms as shown in **(Table 2).** Cardiac glycosides were slightly detected in the acetone extracts of the mushrooms, while saponins were slightly detected in the methanol extracts of the mushroom as shown in **(Table 2).** For the quantitative analysis, it was observed that Reducing Sugar was highest in the acetone extract of *G. lucidum* (65.674) and least in the acetone extract of *B. berkeleyi.* (6.044). For the Phenolic compound, the highest value was recorded for the acetone extract of *G. lucidum* (49.549) and the least for the acetone extract of *B. berkeleyi* (3.135). For flavonoids, the highest value was the acetone extract of *G. lucidum,* and the least in the acetone extract of *B. berkeleyi.* Lastly, for steroids, the highest value was the acetone extract of *B. berkeleyi* (15.110) and the least in the methanol extract of *B. berkeleyi* (5.011) as shown in (Table 3).

Table 1: The yield percentage (%) of *G. lucidum* and *B. berkeleyi* in methanol and acetone solvent.

Mushroom Samples	Solvents Used	Percentage Yield (%)
G. lucidum	Methanol	0.21
G. lucidum	Acetone	0.23
B. berkeleyi	Methanol	0.16
B. berkeleyi	Acetone	0.04

Table 2: Qualitative phytochemical composition of *G. lucidum* and *B. berkeleyi* from methanol and acetone solvents.

TEST	METHOD	GM	BM	GA	BA
Alkaloids	Dragendorff's Test	-	-	-	-
	Wagner's Test	-	-	-	-
Saponins	Frothing Test	+	+	-	-
Reducing Sugar	Fehling's Test	+++	+	+++	+
Anthraquinones	Borntrager's Test	-	-	-	-
Cardiac glycosides	Keller Killani's Test	-	-	+	+
Terpenoids	Lieberman-Buchard's	+++	+++	+++	+++
Steroids	Salkowski's Test	++	++	+++	+++
Phenolic Compounds	Lead acetate Test	+++	++	+++	+
Tannins	Ferric chloride Test	-	-	-	-
Flavonoids	Shinoda's Test	+++	+	+++	+
Triterpenoids	Lieberman-Buchard's	+++	+++	+++	+++

*__GA__= *G. lucidum* extracted with acetone, __BA__ = *B. berkeleyi* extracted with acetone, __GM__= *G. lucidum* extracted with methanol, and __BM__= *B. berkeleyi* extracted with methanol.
Key: Heavily detected: +++; detected: ++; slightly detected: +; not detected: −.

Table 3: Quantitative phytochemical composition of *G. lucidum* and *B. berkeleyi* from methanol and acetone solvents.

Phytoconstituents	(mg/g of dry extract) Mean value			
	GM	BM	GA	BA
Reducing Sugar	42.413	18.546	65.674	6.044
Phenolic compound	26.342	32.330	49.549	18.786
Flavonoid	46.145	14.950	80.035	3.135
Steroid	5.011	3.072	10.076	15.110

*__GA__= *G. lucidum* extracted with acetone, __BA__ = *B. berkeleyi* extracted with acetone, __GM__= *G. lucidum* extracted with methanol, and __BM__= *B. berkeleyi* extracted with methanol.

The highest scavenging activity was observed in acetone extract of *G. lucidum* (90.435±0.112) and methanol extract of *G. lucidum* (90.360±0.075) respectively. While the least was observed in acetone extract of *B. berkeleyi* (26.632±0.129) as shown in (**Fig. 3**). For the antibacterial activity, the methanol extract of *G. lucidum* exhibited inhibition zones ranging from 12-14 mm against *P. aeruginosa* while *S. typhi* showed no antibacterial activity as shown in **(Fig. 4).** The acetone extract of *G. lucidum* showed antibacterial activity against *P. aeruginosa* ranging from 12-13 mm and no antibacterial activity was recorded against *S. typhi* as shown in **(Fig. 5.)** The methanol extract of *B. berkeleyi* showed antibacterial activity against *P. aeruginosa* ranging from 10 -14 mm at 30 %-100 % concentration and the least against *S. typhi* ranging from 10 mm to 11 mm at 30 % and 70 % concentrations only as shown in **(Fig. 6**). The acetone extract of *B. berkeleyi* showed highest antibacterial activity against *P. aeruginosa* ranging from 11 mm to 12 mm at 30 %-100 % and the least against *S. typhi,* ranging from 10-11 mm at 30 %-100 % concentrations in (Fig. 7).

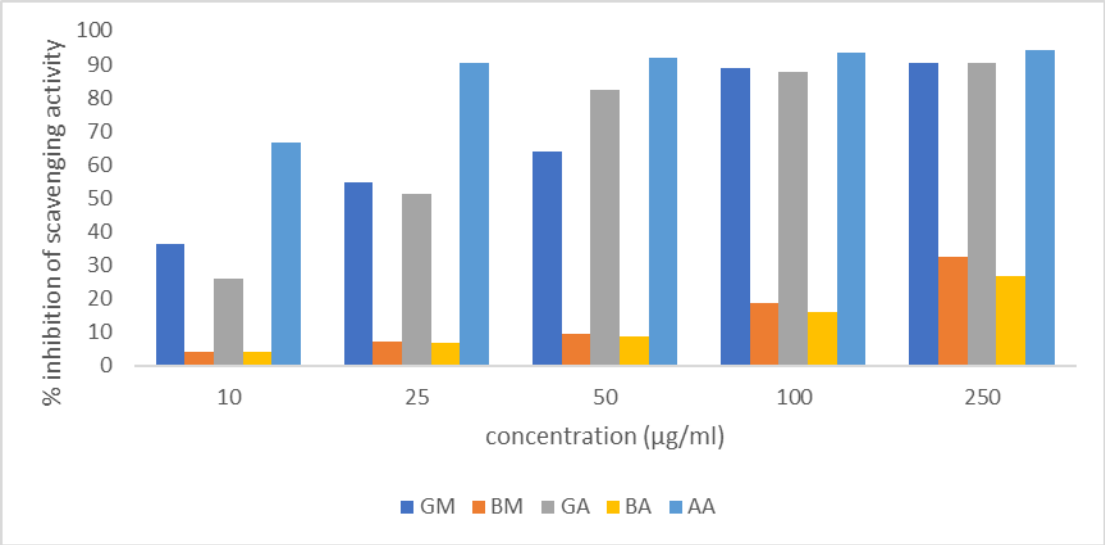

Fig. 3. DPPH scavenging activity of methanol and acetone extracts of *G. lucidum* and *B. berkeleyi*. Mean values are averages of 3 values.

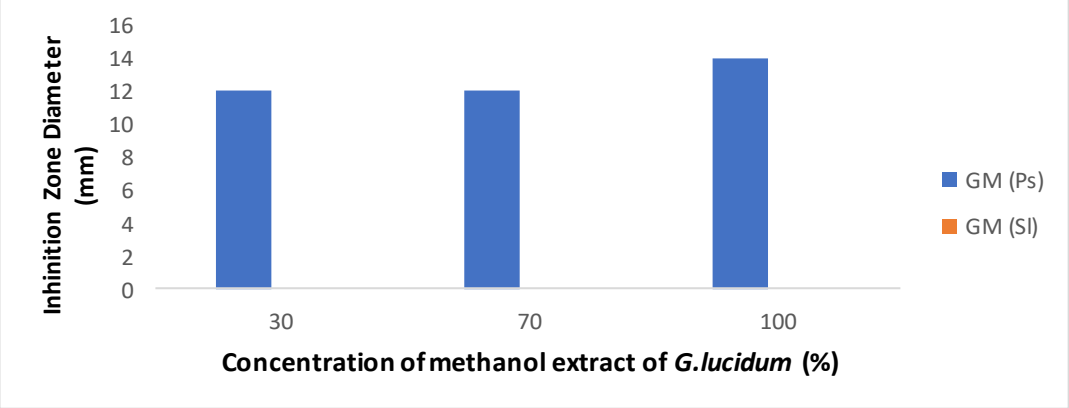

Fig. 4. Antibacterial activity of *G. lucidum* (methanol extract) against *P. aeruginosa* and *S. typhi* Mean values are averages of 3 values.

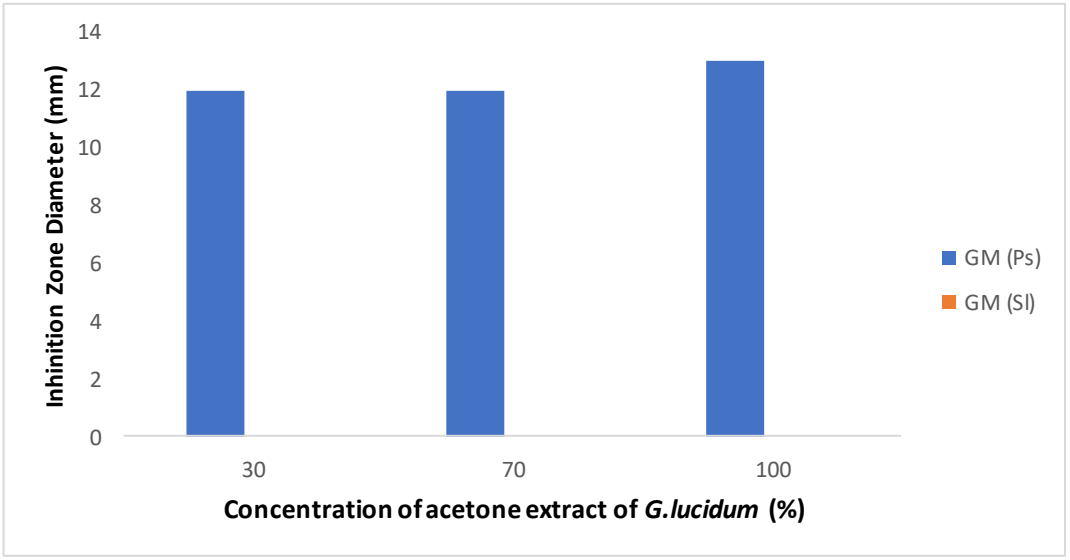

Fig. 5. Antibacterial activity of *G. lucidum* (acetone extract) against *P. aeruginosa* and *S. typhi*. Mean values are averages of 3 values.

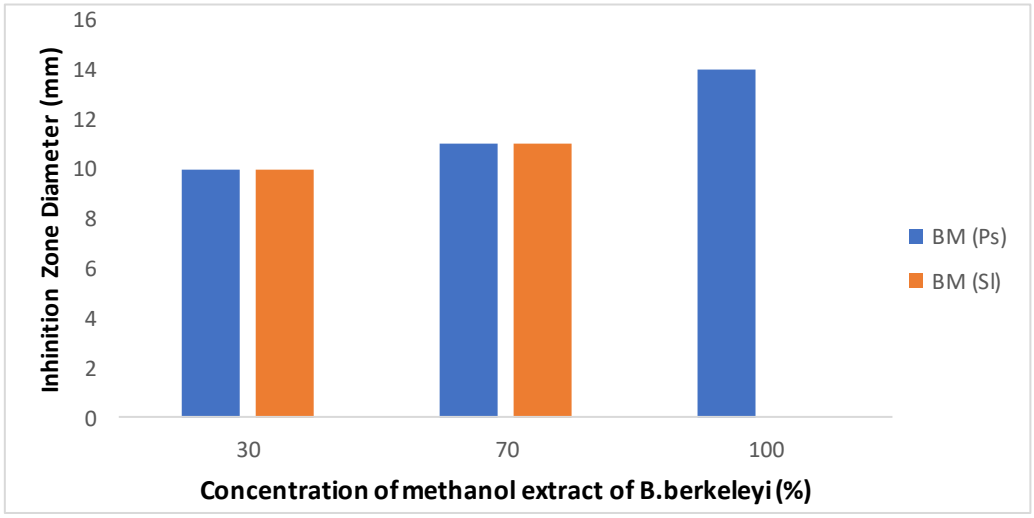

Fig. 6. Antibacterial activity of *B. berkeleyi* (methanol extract) against *P. aeruginosa* and *S. typhi*. Mean values are averages of 3 values.

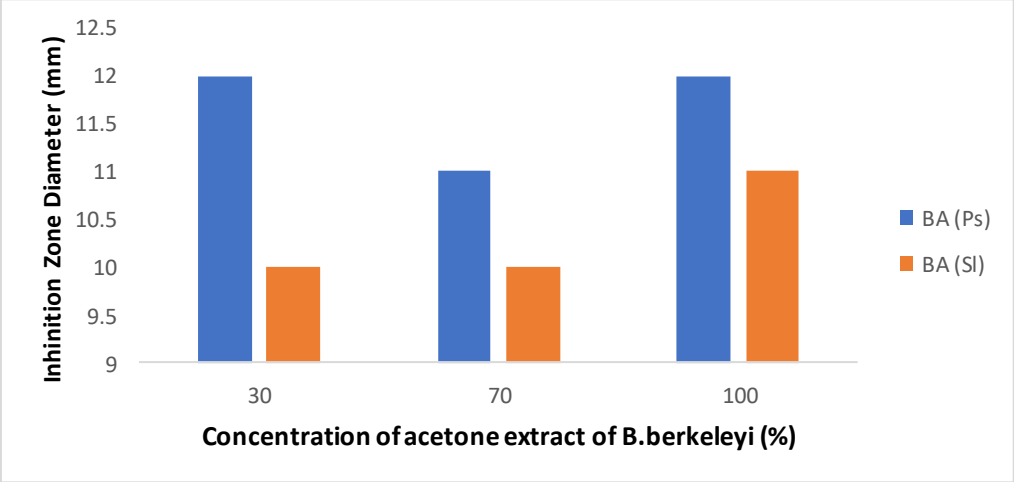

Fig. 7. Antibacterial activity of *B. berkeleyi* (acetone extract) against *P. aeruginosa* and *S. typhi*. Mean values are averages of 3 values.

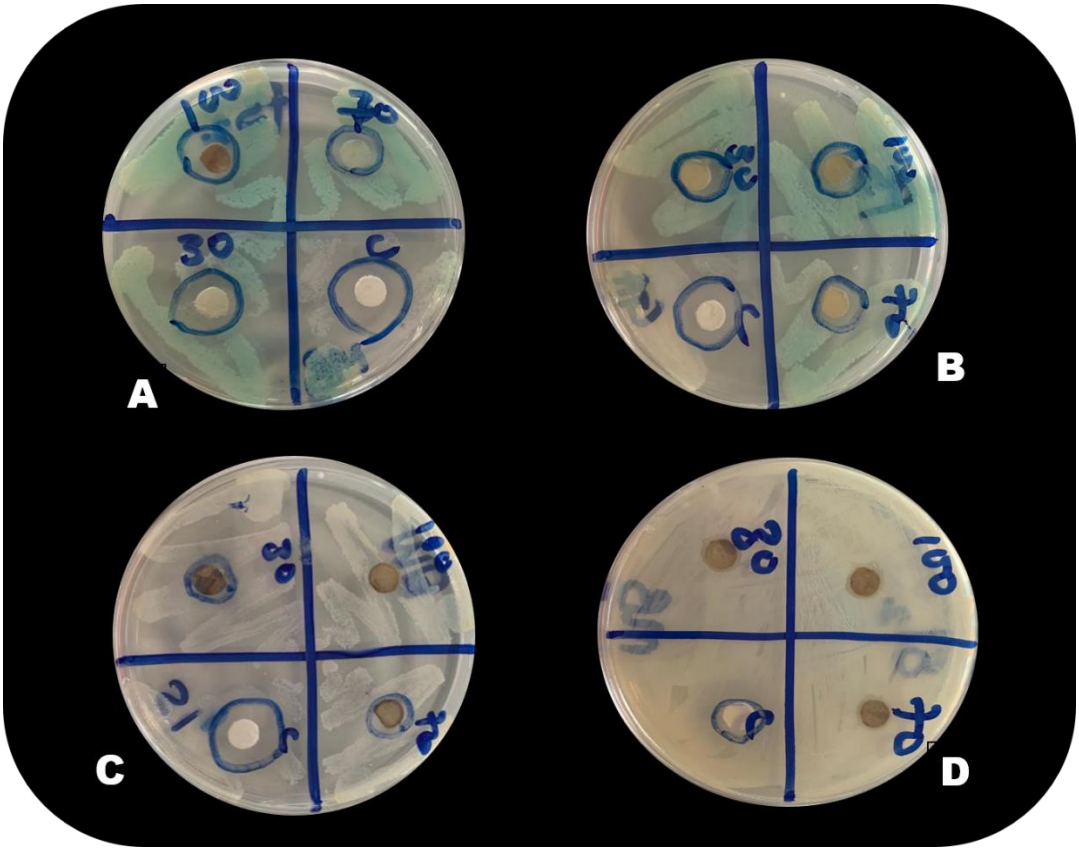

Fig. 8. (A & B) Antibacterial activity of mushroom extracts against *P. aeruginosa;* (C & D): Antibacterial activity of mushroom extracts against *S. typhi.*

The result from the phytochemical screening shows that the reducing sugars, terpenoids, steroids, phenolic compounds, flavonoids and triterpenoids were present in all the test samples (methanol and acetone extracts of the mushrooms). The presence of flavonoids and phenolic compounds in the test sample is in line with the works of [27], who also detected the presence of flavonoids, phenolic compounds, alkaloids and saponins in wild mushrooms. Saponins were only detected in methanolic extracts of *G. lucidum* and *B. berkeleyi*, which also correlates with the findings of [27]. Saponins were not detected in the acetone extract of *G. lucidum* and *B. berkeleyi* which may be due to the solvent or method of extraction. Also, tannins were not detected in the extracts of the mushrooms which agrees with the findings of [28] on *G. lucidum*, whereas [29] quantitatively demonstrated that *G. lucidum* contains 18.27% tannins and 1.26% saponins. However, Anthraquinones were not detected in all the samples. This correlates with the findings of [30], who worked on ten wild mushrooms, including *G. lucidum*, with no records of Anthraquinones. Alkaloids were not detected in all samples, which was in contrast to the work of [27] and [31], who both reported moderate compositions of alkaloids in the extracts of *G. lucidum* and *B. berkeleyi*, respectively. This result may be due to the environment where the mushroom species were collected. Lastly, cardiac glycosides were not detected in methanol *G. lucidum* and *B. berkeleyi*, while it was detected in acetone *G. lucidum* and *B. berkeleyi*, respectively.

The result obtained from the antioxidant assay shows that the methanolic and acetone extracts of *G. lucidum* had higher antioxidant activity when compared to the methanolic and acetone extracts of *B. berkeleyi*. This can be attributed to the presence of a high number of phenolic compounds and flavonoids detected from the extracts of *G. lucidum*. The phenolic compounds are regarded as the major contributors to the various pharmacological activities, including antioxidant and antimicrobial activities [32]. The results showed that high flavonoid content may be an important factor in determining significant antioxidant activities for the mushroom species. The results of the preliminary phytochemical investigation showed the presence of flavonoids and phenolic compounds, which correspond to the strong antioxidant activity shown by the extracts. Hence, the observed in vitro antioxidant activity may be because of these phytoconstituents, which need further investigation to isolate the purified compounds [33].

Methanol and acetone extract of *G. lucidum* and *B. berkeleyi* were seen to show gradual inhibition in the growth of test bacteria (*P. aeruginosa* and *S. typhi*). *P. aeruginosa* was found to be inhibited by various extracts of *G. lucidum* and *B. berkeleyi* at different concentrations but there was no antibacterial activity recorded with the extracts of *G. lucidum* against *S. typhi*. This correlates with the findings of [34] who reported that methanolic extract of *G. lucidum* showed remarkable antibacterial activity against *Escherichia coli*, *Salmonella species* and *Bacillus subtilis*. This is also in contrast with the findings of [35] who recorded inhibitory activities of the acetone extract of *G. lucidum* against *Escherichia coli*, *Salmonella typhi*, *Bacillus subtilis* and *Staphylococcus aureus* respectively. Acetone and methanol extracts of *B. berkeleyi* inhibited the growth of *P. aeruginosa* and *S. typhi* at different concentrations. Above all, *G. lucidum* methanol extract has the highest antibacterial activity, followed by *G. lucidum* acetone extract, *B. berkeleyi* methanol extract and *B. berkeleyi* acetone extract. The maximum inhibition zone was observed with the methanol extract of *G. lucidum* against *P. aeruginosa* ranging from 10 mm to 14 mm at all concentrations and the minimum inhibition zone was observed in the case *S. typhi* ranging from 0 mm to 11 mm at all concentrations for all the mushroom extracts. Different extracts of *G. lucidum* have been investigated by [36],[37] for their antibacterial activity against various micro-organisms. They reported that the methanolic extract of *G. lucidum* possessed maximum antibacterial activity as compared to other organic and aqueous extracts.

Biological active compounds interact differently with microorganisms indicating that different components may have different modes of action or that the metabolism of some microorganisms is better able to overcome the effects of the compound or adapt to it. However it is important to mention that a single compound may not be responsible for the observed activity but rather for compounds interacting in an additive or synergistic manner [38].

4. CONCLUSION

Mushrooms have long been associated with humans and provide profound biological and economic impact. The phytochemical compositions observed have shown the presence of some vital bioactive

compounds. The presence of these important phytoconstituents like reducing sugar, flavonoids, triterpenoids and phenolic compounds could be responsible for the antioxidant and antibacterial properties of the mushrooms. These mushroom metabolites or other related compounds could be used to develop nutraceuticals or drugs effective against pathogenic microorganisms resistant to conventional treatments. Further work regarding the specific activity of these biological compounds will provide more insight into the role of the mushrooms.

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AUTHORS' CONTRIBUTIONS

Oreshile, K.Y, designed and supervised the experiment, Oreshile, K.Y, Keshinro, T.A. and Ishola, H.M. performed the experiment, Oreshile, K.Y, Keshinro, O.M. and Keshinro, T.A. drafted the manuscript and Oreshile, K.Y and Ishola, H.M managed the analyses of the study. All authors read and approved the final manuscript.

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