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Antibacterial properties of wild edible and non-edible mushrooms found in Zimbabwe

Tsungai Reid[1]*, Chenjerayi Kashangura[2], Catherine Chidewe[1], Mudadi Albert Benhura[1] and Takafira Mduluza[1,3]

[1]Biochemistry Department, University of Zimbabwe, Mount Pleasant, Harare, Zimbabwe.
[2]Kutsaga Research Station, Airport Ring Road, Harare, Zimbabwe.
[3]School of Laboratory Medicine and Medical Sciences, University of KwaZulu Natal, Durban, South Africa.

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Mushrooms have been used extensively in traditional medicine as antimicrobial, antiviral and antitumor agents. Infectious diseases remain a major threat to human health, due to global antimicrobial resistance. This has led to an increase in the search for new and potent antimicrobial substances. The aim of the present study was to investigate the antimicrobial activity of the aqueous (cold and hot) and organic solvents (methanol, ethanol and acetone) extracts of ten mushroom species collected from the woodlands in Zimbabwe against common local bacterial isolates *Escherichia coli, Salmonella typhi, Staphylococcus aureus* and *Streptococcus pneumoniae* using agar disc diffusion method. The crude extracts of the mushrooms exhibited antibacterial properties to all the bacteria tested. Extracts obtained from ethanol were the most effective tested against bacteria (36.5%), followed by methanol (30.8%) and acetone (30.8%). Aqueous extracts exhibited the lowest effect on bacterial growth inhibition (1.9%), despite including the extract with the highest inhibitory activity (14 mm). The acetone extract of *Cantharellus symoensii* had the second highest inhibitory value of 11.5 mm followed by the methanol extract from *Cantharellus miomboensis* and the ethanol extracts of *Ganoderma lucidum* and *C. symoensii* with values 11.0, 10.67 and 10.0 mm, respectively. *Cantharellus heinemannianus* and *C. symoensii* had the highest effect on inhibition of bacteria as indicated by the different extracts showing high inhibitory properties ranging from 8-14 mm [15.4% (8) each] followed by *G. lucidum* [13.5% (7)], while *Boletus edulis, Coprinus* sp. and *Trametes strumosa* had the least [5.8% (3) each]. The positive results of screening local mushrooms for antibacterial activity forms the basis for further phytochemical studies and development of antimicrobial agents against common human bacterial and fungal infections.

Key words: Antibacterial activity, *Cantharellus* species, *Salmonella typhi*, organic extracts, aqueous extracts.

INTRODUCTION

The emergence of drug resistance globally, is currently presenting a large and growing problem in infections that account for most of Africa's disease burden, including tuberculosis (TB), respiratory and diarrheal diseases (Okon et al., 2013; Padmavathy et al., 2014; Sangeeth et al., 2014). In addition to the multi-drug resistance problem,

the nosocomial infections (healthcare-associated infections) are associated with high mortality. This has necessitated a need for a continuous search and development of novel antimicrobial substances from different biological sources to minimize the threat of further antimicrobial resistance (Padmavathy et al., 2014; Shah et al., 2014).

Mushrooms have been recognized as functional foods and as a source for the development of medicines and nutraceuticals (Alves et al., 2012). Basidiomycetes, to which mushrooms belong, are a group of higher fungi with distinctive fruiting bodies and reproductive structures. Some mushrooms are edible, while others are extremely poisonous. There are about 140 000 species of mushrooms and of these, only 22 000 are known, while only a small percentage (5%) has been investigated (Faridur et al., 2010). Mushrooms have been prescribed for treatment of various human diseases such as gastro-intestinal disorder, bleeding, high blood pressure and various microbial infections (Akyuz, 2010; Gbolagade and Fasidi, 2005). Many varieties of mushrooms have been identified as major sources of biologically active natural products, such as oxalic acid and sulphated lentinan from *Lentinula edodes*, triterpenes and ganodermin, an antifungal protein, both from *Ganoderma lucidum*, polysaccharopeptides from *Coriolus versicolor*, water-soluble lignins from *Inonotus obliquus* and velutin, a ribosome inactivating protein from *Flammulina velutipes* (Chaudhary and Tripathy, 2015; Collins and Ng, 1997; Lindequist, 2005; Moon and Lo, 2014; Wang and Ng, 2006). These compounds may be sources of natural antibiotics and may have immunomodulatory, cardio-vascular, antifibrotic, anti-inflammatory, antidiabetic, antioxidant, antiviral, antimicrobial and antitumor properties (Alves et al., 2012; Gan et al., 2013; Geethangili et al., 2013; Ramesh and Pattar, 2010; Tehrani et al., 2012; Wang and Ng, 2004).

In recent years, a number of studies were conducted in various countries to determine the potential therapeutic properties of mushrooms. The reported bioactivities from mushrooms include antibacterial, antifungal, antioxidant and antiviral properties (Padmavathy et al., 2014; Reis et al., 2011). The species C*antherellus, Lentinus, Russula, Agaricus* and *Pleurotus* are examples of mushrooms that have shown antimicrobial properties against *Bacillus* species, *Enterococcus*, *Streptococcus*, *Staphylococcus* and *Micrococcus* species (Alves et al., 2012; Khan and Tania, 2012; Pushpa and Purushothama, 2010). Crude organic and aqueous extracts from *Ganoderma* have been reported to inhibit *in vitro* growth of *Escherichia coli*, *Staphylococcus aureus*, *Bacillus cereus*, *Neisseria meningitides*, *Alcaligenes faecalis* and *Proteus vulgaris,* bacteria known to cause wound infections, intestinal and urinary-genital tract infections and skin infections (Shikongo et al., 2013). The European *Ganoderma* has been reported to inhibit growth of most bacteria especially methillicin-resistant *S. aureas* (Linderquist et al., 2005).

Zimbabwe is rich in mushroom diversity. However, the potential of mushrooms as source of new drugs is still largely unexplored (Sharp, 2011, 2014). Despite many studies on potential therapeutic properties of different mushroom species globally, little or no work has been carried out on the antimicrobial activities of mushrooms in Zimbabwe. In addition, there are several wild edible species of mushrooms which are yet to be exploited in Zimbabwe. Thus, the main aim of this work was to investigate the antimicrobial potential of different extracts of ten selected wild edible and non-edible mushrooms found in Zimbabwe.

MATERIALS AND METHODS

Collection of samples

A total of ten different mushrooms, both edible and non-edible, were collected from the local woodlands of Zimbabwe (Table 1). Identification of the mushrooms (Figure 1) was done on the basis of morphological characteristics, including colour of the mushroom cap and spore print. Final identification was done by comparing the visual appearance and the recorded characters of mushroom species with standard mushroom collection guides by Sharp (2011) and Ryvarden et al. (1994).

Test microorganisms

A total of four bacteria, *E. coli, S. typhi, S. aureus* and *S. pneumoniae* were used in this study. *E. coli* and *S. aureus* were obtained from the Cimas Medical Aid Society laboratory, *S. pneumoniae* from Lancet laboratory and *S. typhi* from the University of Zimbabwe. The bacterial strains tested were isolated from local patients.

Preparation of mushroom crude extracts

The fresh mushrooms were sliced into thin strips and sun dried for 7 days. Dried mushrooms were ground to powder using an electrical grinder (Siebtechnik steel pulverizer 2, 376, GmbH). Dried mushroom powder was mixed with 15 ml of distilled cold water, absolute methanol, ethanol or acetone in 50 ml tubes. The samples were placed in an incubator shaker for 24 h at 150 rpm and 25°C. Hot water extracts were obtained by boiling the mushrooms in 15 ml of distilled water for 10 min and then allowing the suspension to cool to room temperature. Al l the suspensions were then filtered

*Corresponding author. E-mail: tsungi.reid@gmail.com. Tel: +2634303211. Ext: 17147.

Figure 1. Some of the mushrooms that were collected. A - *Cantharellus heinemannianus*, B - *Boletus edulis*, C - *Cantharellus symoensii*, D - *Ganoderma lucidum*, E - *Coprinus* sp., F- *Lactarius kabansus.*

Table 1. Different types of mushrooms collected locally.

Latin name	Local Shona name	Edibility
Amanita zambiana	Nhedzi	Edible
Amanita sp.	-	Non-edible
Boletus edulis	Dindindi	Edible
Cantharellus miomboensis	Chihombiro	Edible
Cantharellus symoensii	Firifiti	Edible
Cantharellus heinemannianus	Tsvuketsvuke	Edible
Coprinus sp.	-	Non-edible
Ganoderma lucidum	Howa danda	Non-edible
Lactarius kabansus	Nzeveyambuya	Edible
Trametes strumosa	Howa danda	Non-edible

using Whatman no. 1 filter paper, dried under a stream of cold air and reconstituted to 10 mg/ml in sterile distilled water for water extracts or dimethyl sulfoxide for the rest of the extracts. A total of fifty different extracts were obtained. All the reagents used in the extractions were of analytical grade.

Determination of total phenolic content

Total phenolic content in each mushroom extract was determined using the Folin and Ciocalteu (FC) reagent method with gallic acid as the standard according to Gan et al. (2013) and Sun et al. (2014), with modifications. Briefly, 40 µl of each sample was diluted to 200 µl using distilled water or dimethyl sulfoxide and mixed with 200 µl of Folin and Ciocalteu's phenol reagent, diluted 1:9 ml in distilled water. After 6 min, 200 µl of 7.5% sodium carbonate was added to the mixture and adjusted to 2 ml with distilled water. The reaction was kept in the dark for 60 min after which the absorbance was measured at 725 nm using a spectrophotometer (Spectronic^R 20 Genesys™, Spectronic Instruments). Distilled water and dimethyl sulfoxide were used as blanks.

Determination of antibacterial activity

Antibacterial effect of the mushroom extracts on *E. coli, S. typhi, S. aureus* and *S. pneumoniae* was determined using the agar disc diffusion method. Briefly, a suspension containing $1x10^6$ cfu/ml of bacteria was inoculated into Mueller Hinton Agar (Mast Group Ltd., Merseyside, U.K.). The discs (6 mm) were dipped in 200 µg of mushroom extract, dried and placed on the inoculated agar. Negative controls were prepared with the same solvents used to dissolve the sample extracts. Kanamycin 50 µg/disc and vancomycin 30 µg/disc were used as positive controls for the tested bacteria. After 2 h, incubation at 4°C, inoculated plates were incubated at 37°C for 18 h. At the end of the incubation period, the inhibition zones were measured.

Table 2. Total phenolic content of mushrooms extracted using different solvents.

Mushroom type	Total phenolic content (mg GAE/ 100 g dry weight)				
	Methanol	Ethanol	Acetone	Cold water	Boiling water
Amanita zambiana	59.03±10.36^{a}	31.72±4.77^{b}	33.85±7.81^{b}	122.86±4.71^{c}	35.43±1.85^{b}
Amanita sp.	120.11±10.12^{a}	37.48±5.15^{b}	16.95±1.77^{b}	308.85±14.52^{c}	319.89±8.83^{c}
Boletus edulis	341.47±16.31^{a}	78.77±3.46^{b}	25.43±2.91^{c}	336.28±3.54^{a}	503.70±20.65^{d}
Cantharellus miomboensis	37.85±11.33^{c}	30.08±4.28^{c}	99.88±2.08^{b}	56.86±1.86^{a}	38.10±2.83^{a}
Cantharellus symoensii	35.13±7.32^{a}	14.95±2.07^{b}	7.89±0.34^{b}	132.53±7.50^{c}	87.52±3.56^{d}
Cantharellus heinemannianus	44.57±10.72^{b}	17.70±8.67^{a}	20.53±2.68^{a}	74.20±4.60^{c}	67.46±4.56^{c}
Coprinus sp.	35.33±10.76^{b}	5.75±2.36^{a}	11.13±3.11^{a}	176.20±10.58^{c}	159.01±6.30^{c}
Ganoderma lucidum	109.82±9.15^{b}	70.35±3.02^{a}	4.78±0.17^{c}	131.41±5.06^{d}	62.08±2.67^{a}
Lactarius kabansus	80.77±15.39^{a}	39.32±16.05^{b}	15.80±1.36^{b}	225.31±5.11^{c}	203.79±14.58^{c}
Trametes strumosa	6.60±.37^{a}	3.61±1.23^{a}	5.48±0.19^{a}	17.71±1.13^{b}	27.14±1.76^{c}

Data expressed as mean ± SD; n = 150, 36 df. Values in the same row that do not share a common superscript are significantly different at p‹ 0.05.

Statistical analysis

Experimental values are given as means ± standard deviation (SD). Graph-pad prism was used to analyse the data. Statistical significance was determined by both one and two way variance analysis (ANOVA). All experiments were carried out in triplicate.

RESULTS AND DISCUSSION

Total phenolic composition

The results of the total phenolic composition of the different mushrooms from the crude extracts are shown in Table 2. With a few exceptions, extracts from cold and boiled water gave the highest levels of total phenolics (17.71 – 503.70 mg GAE/100 g dry mushroom), followed by methanolic extracts (6.60 – 341.47 mg GAE/100 g dry mushroom), while acetone extracts overly gave the lowest values (4.78 – 99.88 mg GAE/100 g dry mushroom). However, most of the yields from the acetone and ethanol extracts were not significantly different (4.78 – 99.88 mg GAE/100 g dry mushroom and 3.61 – 78.77 mg GAE/100 g dry mushroom, respectively). Statistical analysis by two way ANOVA showed that there is significant difference in the effect of solvents in extracting total phenols (4 df, F = 7.815, P-value = 0.000122) and that the total phenolic composition is also dependant on the mushroom type (9 df, F = 4.984, P-value = 0.000224). The high values in water extracts could be explained by the high polarity of water as compared to the other organic solvents, hence, more compounds dissolving in water. From the 10 different mushroom types studied, *Boletus edulis* was observed to have the highest total phenolic compounds (25.43 – 503.70 mg GAE/100 g dry mushroom) followed by *Amanita* sp. (16.95 – 319.89 mg GAE/100 g dry mushroom). Similar trends, where cold water extracts gave high total phenolic yields followed by hot water extracts, while acetone extracts gave the least yields, were as observed by Wang and Xu (2014).

Antibacterial activity

The antibacterial activities of methanol, ethanol, acetone, cold and hot water extracts of ten different mushrooms, against the four bacterial types tested are shown in Tables 3 to 7, respectively. The results showed that all the mushrooms exhibited inhibitory activities against at least one of the bacteria tested, as shown by the clear zone of inhibition around the tested mushroom extracts. The different mushroom extracts exhibited various degrees of inhibition of bacterial growth (6.3 – 14 mm diameter). It has been reported that mushroom species possess different constituents and in different concentration which account for their differential antimicrobial activity (Akyuz et al., 2010; Padmavathy et al., 2014). The highest *in vitro* antibacterial activity was shown by the cold water extract of *C. miomboensis* against *S. typhi* (14 mm zone of inhibition). This was followed in order by the acetone extract of *C. symoensii*, the methanol extract from *C. miomboensis* and the ethanol extracts of *G. lucidum* and *C. symoensii* with values 11.5, 11.0, 10.67 and 10.0 mm, respectively. *C. miomboensis*, *C. symoensii*, *Amanita* sp. and *B. edulis* all had the highest number of total extracts inhibiting at least one of the bacteria (12 each) closely followed by *C. heinemannianus* and *A. zambiana* (10 each), while *Coprinus* sp. had the least (6). *C. miomboensis*, *C. heinemannianus*, *C. symoensii*, *Amanita* sp., *A. zambiana*, *Lactarius kabansus* and *B. edulis* all had inhibitory effect on all the four bacteria tested. *C. heinemannianus* and *C. symoensii* had the highest effect on inhibition of bacteria as indicated by having the most extracts which had high inhibitory properties ranging from

Table 3. Antibacterial activities of methanol extracts of mushrooms on test organisms.

Mushroom type	Zone of inhibition diameter (mm)			
	Gram positive bacteria		Gram negative bacteria	
	Staphylococcus aureus	***Streptococcus pneumoniae***	***Escherichia coli***	***Salmonella typhi***
Amanita zambiana	7.0 ±0.00	9.0 ± 0.20	7.0 ± 0.0	8.5 ± 0.0
Amanita sp.	-	9.33 ± 1.16	8.8 ± 0.0	7.83 ± 0.29
Boletus edulis	-	7.5 ± 0.87	8.0 ± 0.0	7.33 ± 0.29
Cantharellus miomboensis	6.5 ± 0.0	6.84 ± 0.29	-	11.0 ± 2.0
Cantharellus symoensii	7.23 ± 0.25	8.14 ± 0.90	7.6 ± 1.15	9.5 ± 0.5
Cantharellus heinemannianus	-	8.67 ± 0.76	8.5 ± 1.73	8.0 ± 0.0
Coprinus sp.	-	8.0 ± 0.0	-	7.33 ± 0.58
Ganoderma lucidum	-	8.33 ± 1.16	-	8.0 ± 0.0
Lactarius kabansus	-	9.33 ± 1.16	-	7.5 ± 0.5
Trametes strumosa	-	7.43		8.33 ± 0.29

(-): No inhibition. Each value is expressed as mean ± SD (n = 3).

Table 4. Antibacterial activities of ethanol extracts of mushrooms on test organisms.

Mushroom type	Zone of inhibition diameter (mm)			
	Gram positive bacteria		Gram negative bacteria	
	Staphylococcus aureus	***Streptococcus pneumoniae***	***Escherichia coli***	***Salmonella typhi***
Amanita zambiana	7.33 ± 0.58	7.83 ± 0.76	7.2 ± 0.0	8.67 ± 0.76
Amanita sp.	8.23 ± 1.25	7.07 ± 0.12	8.0 ± 0.0	9.0 ± 1.0
Boletus edulis	7.5 ± 0.5	6.6 ± 0.0	8.67 ± 0.58	7.5 ± 0.0
Cantharellus miomboensis	8.16 ± 0.29	7.67 ± 0.76	7.77 ± 0.25	9.17± 0.29
Cantharellus symoensii	8.2 ± 0.76	8.94 ± 0.31	7.4 ± 0.17	10.0 ± 0.0
Cantharellus heinemannianus	8.83 ± 0.29	8.4 ± 0.53	-	8.18 ± 0.58
Coprinus sp.	-	8.0 ± 0.0	-	8.0 ± 0.00
Ganoderma lucidum	-	8.0 ± 0.0	7.67 ± 1.16	10.67 ± 1.16
Lactarius kabansus	7.83 ± 1.04	8.5 ± 0.87	-	8.0 ± 0.5
Trametes strumosa	-	7.33 ± 0.76	-	6.5 ± 0.0

(-): No inhibition. Each value is expressed as mean ± SD (n = 3).

Table 5. Antibacterial activities of acetone extracts of mushrooms on test organisms.

Mushroom type	Zone of inhibition diameter (mm)			
	Gram positive bacteria		Gram negative bacteria	
	Staphylococcus aureus	***Streptococcus pneumoniae***	***Escherichia coli***	***Salmonella typhi***
Amanita zambiana	-	7.5 ± 0.0	-	9.0 ± 0.0
Amanita sp.	6.67 ± 0.29	7.67 ± 0.76	6.3 ± 0.0	9.0 ± 1.0
Boletus edulis	7.0 ± 0.0	7.33 ± 0.29	7.83 ± 0.58	8.17 ± 0.76
Cantharellus miomboensis	7.67 ± 0.29	6.67 ± 0.29	7.73 ± 0.25	8.67 ± 0.29
Cantharellus symoensii	8.67 ± 0.58	8.17 ± 0.29	-	11.5 ± 1.0
Cantharellus heinemannianus	8.07 ± 0.12	7.0 ± 0.0	-	9.17 ± 0.76
Coprinus sp.	-	7.0 ± 0.0	-	7.5 ± 0.5
Ganoderma lucidum	-	8.27 ± 0.64	8.0 ± 0.0	8.33 ± 0.76
Lactarius kabansus	-	8.43 ± 0.81	7.5 ± 0.5	9.5 ± 0.5
Trametes strumosa	9.5 ± 1.8	8.17 ± 0.76	-	7.5 ± 0.5

(-): No inhibition. Each value is expressed as mean ± SD (n = 3).

Table 6. Antibacterial activities of cold water extracts of mushrooms on test organisms.

Mushroom type	Zone of inhibition diameter (mm)			
	Gram positive bacteria		Gram negative bacteria	
	Staphylococcus aureus	***Streptococcus pneumoniae***	***Escherichia coli***	***Salmonella typhi***
Amanita zambiana	-	-	-	-
Amanita sp.	-	-	-	-
Boletus edulis	-	-	-	7.33 ± 0.29
Cantharellus miomboensis	-	-	-	14.0 ± 1.0
Cantharellus symoensii	-	-	-	-
Cantharellus heinemannianus	-	-	-	-
Coprinus sp.	-	-	-	-
Ganoderma lucidum	-	-	-	-
Lactarius kabansus	-	-	-	7.5 ± 0.0
Trametes strumosa	-	-	-	-

(-): No inhibition. Each value is expressed as mean ± SD (n = 3).

Table 7. Antibacterial activities of hot water extracts of mushrooms on test organisms.

Mushroom type	Zone of inhibition diameter (mm)			
	Gram positive bacteria		Gram negative bacteria	
	Staphylococcus aureus	***Streptococcus pneumoniae***	***Escherichia coli***	***Salmonella typhi***
Amanita zambiana	-	-	-	-
Amanita sp.	-	-	7.0±0.0	-
Boletus edulis	-	-	-	-
Cantharellus miomboensis	-	-	-	-
Cantharellus symoensii	-	-	6.5±0.0	-
Cantharellus heinemannianus	-	-	6.5±0.0	-
Coprinus sp.	-	-	-	-
Ganoderma lucidum	-	-	-	-
Lactarius kabansus	-	-	-	-
Trametes strumosa	-	nt	-	-

(-): No inhibition. nt: not tested. Each value is expressed as mean ± SD (n = 3).

8-14 mm [15.4% (8) each] followed by *G. lucidum* [13.5% (7)], while *B. edulis, Coprinus* sp. and *Trametes strumosa* had the least [5.8% (3) each]. This shows that *C. heinemannianus*, *C. symoensii* and *G. lucidum* extracts contain compounds that are highly potent against the bacteria studied than the rest of the mushroom extracts found in this study.

In similar studies carried out by Quereshi et al. (2010), methanol, ethanol, acetone and cold water extracts of *G. lucidum* from India showed antimicrobial activity against the *S. aureus, S. typhi* and *E. coli* bacterial culture collections. From this study, the methanol extract showed no inhibition to *S. aureus* and *E. coli*, while the ethanol and acetone extracts inhibited growth of both *E. coli* and *S. typhi* but did not inhibit growth of *S. aureus*. The water extracts showed no inhibition to all the bacteria tested. Ethanol extracts of *G. lucidum* from Turkey inhibited growth of *E. coli* while the methanol extract showed no inhibition (Celik et al., 2014). In another study, acetone and ethanol extracts of *Cantharellus cibarius* collected in Turkey, exhibited antibacterial activity against *E. coli* and *S. aureus* but showed no inhibition against *S. typhi* (Dulger et al., 2004). Results of a study in Nigeria showed that methanol and ethanol extracts of *Cantharellus cibarius* from Nigeria inhibited *E. coli* and *S. typhi* growth but showed no inhibition against *S. aureus* and *S. pneumoniae* (Aina et al., 2012). Similarly, results obtained from this study show that methanol, ethanol and acetone extracts of the three *Cantharellus* species studied exhibited various degrees of inhibition against the four bacteria tested. This shows that different species of mushrooms exhibit different antimicrobial activity due to a number of factors such as the presence of different antimicrobial components, type of the extracting medium,

geographical location of the mushroom and the type of organism being tested.

Extracts obtained from ethanol gave the highest number of bacterial growth inhibition (33), followed by acetone (31) and methanol (28). In addition, ethanolic extracts showed the strongest antibacterial activity (8-14 mm) among the five extracts against the bacterial strains, followed by methanol and acetone. Water extracts exhibited the lowest number of antibacterial activity, despite having the extract with the highest inhibitory effect. This indicates, that the active compounds from the mushrooms studied which inhibit the growth of susceptible bacteria, may dissolve better in the organic solvents than in the aqueous solvents. These results are consistent with already reported literature that extracts from organic solvents give more consistent antimicrobial activity than water extracts (Kamra and Bhatt, 2012; Tiwari et al., 2011). It is interesting to note that, although cold water and hot water extractions gave highest values of total phenolic compounds in Table 2, these had the least effect on most bacteria. This shows that the antibacterial activity in the mushroom extracts depends not only on the presence of phenolic compounds but also on the presence of various secondary metabolites. Ethanol, acetone and methanol extracts were all effective against all the four bacteria indicating the broad spectrum of antibacterial activity of the extracts. However, Gram negative bacteria were slightly more susceptible to the extracts than Gram positive bacteria (52 and 46 extracts, respectively). Many antibiotics are designed to attack the integrity of the cell wall by preventing cell wall synthesis, therefore killing the cell. Although, all bacteria have an inner cell wall, Gram negative bacteria have a unique outer membrane which prevents certain drugs and antibiotics from penetrating the cell. Thus, antibiotics that affect the cell wall will impair Gram positive bacteria and not Gram negative bacteria. The results obtained in this study suggest that the antibacterial extracts may act by affecting not just the cell wall, but other cell growth mechanisms like protein synthesis, bacterial DNA replication and transcription. Among the four bacteria tested, *S. typhi* was the most susceptible bacteria as indicated by its highest number of inhibitions as well as the highest number of most potent extracts in the 8-14 mm diameter range. A decline in the number of multi-drug resistant clinical isolates (*S. typhi*) has been reported (Madhulika et al., 2004). Thus, the study shows that the *S. typhi* isolate studied, may be a phage type that is susceptible to most antibiotics.

The antibacterial activity of the ethanolic, methanolic and acetone extracts against *E. coli, S. typhi, S. aureus* and *S. pneumoniae* is of great importance in the human healthcare system. *S. pneumoniae* is the most common cause of community acquired pneumonia (CAP) in children while *E. coli* accounts for more than 70% of the infections of the urinary tract worldwide (Blossom et al., 2006; Sangeeth et al., 2014). *S. typhi* is the cause of typhoid fever, which was recently epidemic in Zimbabwe. *S. aureus* is the most common cause of bacterial infections and abscesses of skin, joints and bones (Stanely et al., 2013). Resistance to antibiotics has been reported in *S. aureus*, *S. pneumoniae, S. typhi* and *E. coli* (Blossom et al., 2006; Okonko et al., 2009; Rowe et al., 1997; Sangeeth et al., 2014; Stanely et al., 2013). All the bacterial strains used were clinical isolates from individuals in Zimbabwe. *E. coli* and *S. aureus* are mostly encountered in urinary tract infections while isolated cases of *S. typhi* are common. Thus, the antibacterial activity found in the mushroom extracts can be further investigated for future use in the development of therapeutic agents to treat infections caused by these bacteria.

Conclusion

Wild edible and non-edible mushrooms can be used as agents in the development of new drugs for bacterial infections. This study indicated that the antibacterial effects of mushrooms vary depending on the type of mushroom, the solvent medium used and the type of organism tested. *C. heinemannianus* and *C. symoensii* had the highest effect on inhibition of bacteria as indicated by the different extracts showing high inhibitory properties ranging from 8-14 mm [15.4 (8) each], followed by *G. lucidum* [13.5% (7)], while *Boletus edulis, Coprinus* sp. and *Trametes strumosa* had the least effect [5.8% (3) each]. Extracts obtained from ethanol were the most effective tested against bacteria (36.5%), followed by methanol (30.8%) and acetone (30.8%) and lastly, aqueous extracts (1.9%). Thus, of the five solvents tested, ethanol, methanol and acetone were determined to be the solvents of choice for isolation of antibacterial compounds from the majority of mushrooms studied. However, identification of the phyto-constituents responsible for the antibacterial activity is required for large commercial production.

Conflict of interest

The authors declare that there is no conflict of interest.

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