International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Phytochemical screening of multiple Turmeric (*Curcuma longa* L.) extracts against multidrug resistant bacteria

Qudsia Kanwal [1*], ***Nawaz Rasool*** [1], ***Tayyaba Amjad*** [2], ***Aysha Batool*** [2], ***Nuzhat Jamil*** [3,4**], ***Muhammad Zubair Kamran*** [1], ***Muhammad Shakeel Alam*** [1], ***Hafiz Muhammad Saad Ali*** [1], ***Muhammad Yasir*** [1], ***Mudasir Majeed*** [5]

[1]*Department of Chemistry, The University of Lahore, Lahore, Pakistan*

[2]*Department of Chemistry, Superior University, 17Km Raiwind Road, Kot Araian, Lahore, Pakistan*

[3]*Nanotechnology Division, National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, Pakistan*

[4]*Institute of Industrial Biotechnology, Government College University, Lahore, Pakistan*

[5]*Department of Applied Chemistry, Government College University, Faisalabad, Pakistan*

Abstract

Turmeric, a naturally occurring kitchen spice, possesses a wide range of medicinal properties. It has been reported to exhibit analgesic, anti-inflammatory, anti-bacterial, antifungal, antioxidant and wound healing properties. Yet, a detailed investigation is required for its screening against clinical isolates of multidrug resistant bacteria, so that it could be used as, cost effective, indigenous and readily available kitchen spice in crude form for the treatment of these bacterial infections at home. In current study, three fractions of ethyl acetate extracts of turmeric were screened against four multidrug resistant bacterial strains. Disc diffusion method was used to perform antibacterial activity and by calculation the Minimum Inhibitory Concentration (MIC). It was confirmed that all bacterial strains were highly sensitive towards all turmeric fractions. GCMS analysis of various fractions exhibited the presence of various flavonoids and polyphenols, their presence was further ascertained by chemical tests. It has been proposed that the synergistic effect of curcumin as well phenolics, crude extracts of turmeric showed promising antibacterial potential against multidrug resistant bacteria.

Keywords: *Curcuma longa*, Multidrug resistant, Antibacterial, GCMS, *Pseudomonas aeruginosa*, *Staphylococcus aureus*.

Full length article *e-mail: qudsia.kanwal@chem.uol.edu.pk; *Nuzhat Jamil*,** e-mail: ashee.jamil@yahoo.com https://doi.org/10.62877/24-IJCBS-24-26-20-24

1. Introduction

Curcuma longa, a member of *Zingiberaceae* family, is most common kitchen spice widely used in every kitchen of Asian countries as food components, flavoring and coloring agent as well as for traditional treatment of various infections and wound dressing [1-6]. It has grown worldwide in various tropical and subtropical areas [7-8]. It has magical medicinal properties like antibacterial [8-10], anti-inflammatory [6-11-12], antifungal [13], wound healing, hypoglycaemic [free radical scavenging, traditional cosmatics, anti-arthritic [14-15], anti-ageing properties [16], antiangiogenttic, [16]s, anti-enzymatic[17], anti-tumor, antiAlzheimer's [18], anti-cancer, antiulcer, antimalarial [19-20], scavenging free radicals [21-22], snake venom [22] and dog bite toxicity reducing agent [23-24], anti-microbial [25], antiproliferative [24], anti-angiogenic [26], anti-tumor [23-27], and antiulcer [28]. Such outstanding biological properties could be due to the presence of potent constituents of bioactive phytochemicals, curcuminoids (1–6%) are one of these versatile compounds which may have vital role in treatment of various diseases. Curcuminoids are the major part of turmeric constituents, which belong to class polyphenolics, comprising curcumin and its derivatives (dimethoxy curcumin and bisdemethoxy curcumin). A lot of work has been done and reported for various medicinal and biological properties of curcuminoids, especially for the last twenty years [6].

Its antimicrobial properties due to the presence of very effective and potent molecule curcumin and curcuminoids. A lot of studies has been done on

antibacterial properties of turmeric and curcumin but it has not been used extensively against wide range of bacteria which are multidrug resistant and human clinical isolates. Curcumin has been reported for its effects against such bacteria [20-30]. The aim of study is to screen the turmeric crude extracts like methanolic, ethyl acetate and chloroform against multidrug resistant bacteria like *E. Coli*, *Strepococus aureus*, *Psedomonas auregosa* to make easy use of this indigenous non, toxic and cost-effective spice for the treatment of various infections at home.

2. Materials and Methods

2.1. Extraction methodology

Turmeric powder (1450g) was extracted in methanol, ethyl acetate and chloroform (150 g/L each) and kept for 1 week. After filtration, these extracts were concentrated on a rotary evaporator at 40 ºC under reduced pressure. The solid mass obtained from methanol extract (35g) chloroform extract (20g) and ethyl acetate extract (28g) respectively. Each extract was further fractionated with petroleum ether and ethanol using separating funnel. The ethanol fraction obtained from Ethyl Acetate Extract was termed as T_1, Chloroform Extract T_2 and that from Methanol Extract was given the name as T_3. All T_1, T_2, & T_3 fractions were screened for their antimicrobial potential against four bacterial strains (multidrug resistant) and further subjected to GC-MS analysis.

2.2. Screening test for phytochemicals

Various tests were performed for the screening of phytochemicals such as flavonoids, aponins, terpenoids, alkaloids and tannins, as these compounds contribute an important role in different biological activities. All reagents and chemicals utilized for phytochemical tests were purchased from Sigma Aldrich. The tests performed for screening of various phytochemicals were described in Table 1.

2.3. Procurement of bacterial strains

Four bacterial strains *Staphylococcus aureus*, *Klebsiella pneumonia*, *Acinetobacter baumannii* and *Pseudomonas aeruginosa* were obtained from Jinnah Hospital and subjected to antimicrobial screening at the Institute of Molecular Biology and Biochemistry, University of Lahore.

2.4. GC-MS analysis

GC-MS was used to analyse the material (Agilent technologies -7890A GC equipped with Agilent 5975 MSD). Chemstation was the programme used to run the system. The Agilent Technologies column for phytochemical analysis (DB-5 MS 30). with dimensions (0.25mm×0.25 mm×0.25 μm) containing diphenyl (5%) and dimethylpolysiloxane (95%) stationary phase was used. The carrier gas helium (99.999 %) was selected, and flow rate was adjusted as 1 mL/min constantly. 70eV energy was used to create ionization and spectra were recorded at EI (electron impact) mode. To prevent overloading of solvent, during the very first minute ionization was maintained off. 25000 μs was the maximum ionization time at 35 m/z ionization level of storage. The MS-detector (Quadropole triple axis) temperature was set at 250°C. For the identification of compounds from the mass spectra, the chemstation was equipped with Wiley (main and rep) and National institute standard and technology (NIST) database library.

The results of the GC-MS were quantitatively analysed using MET-IDEA (version 1.2.0). After the initial round of MET-IDEA analysis, an ion-retention time list was created using AMDIS and manually edited to remove redundant peaks (R2 >0.8 and Rt 0.2 min) and unreliable peaks (Rt 5 min; Rt >42 min; or peak purity 50%). The improved ion-retention time list was utilized to obtain peak area data for the second phase of MET-IDEA analysis. The MET-IDEA parameters were: I GC; minimum peak width, 0.3; average peak width, 0.1; maximum peak width, 6; adjusted retention time accuracy, 0.95; peak start/stop slope, 1.5; range, 0.5; mass accuracy, 0.1; (iii) AMDIS: exclude ion list, 73, 147, 281, 341, 415; lower mass limit, 50; ions per component, 1. peak overload factor, 0.3; (ii) mass spectrometer: mass range, 0.5;. quadrupole; mass accuracy, 0.1; The peaks of p-chlorotoluene were employed as an internal standard for calibrating retention time.

2.5. Isolation of curcuminoids by TLC

The ethanol subfraction of T_1 was subjected to TLC solvent system chloroform: methanol (95:5). Three different spots were observed on TLC. The spots were identified on the basis of Rf value [29] as presented in Figure 1.

2.6. HPLC analysis for curcuminoids

The dried ethyl acetate extract of Turmeric was dissolved in ethanol (1mg/mL) after sonication for 10 minutes, it was diluted with 2.5mL ethanol to make the concentration 400mcg/mL. the resulting solution was further diluted to achieve 10mcg/mL. It was filtered using microfiltration membranes and subjected to HPLC (Shimadzu) analysis by keeping curcumin as standard. C-18 column (4.6 × 100 mm, 3.5 μm) was utilized for separation, The HPLC was equipped with Diode –Array/ UV detector. The analysis was carried out at 425nm wavelength. The mobile phase used was acetonitrile: H2O: acetic acid (60:40:10). The flow rate was adjusted to 1mL/min at 25 °C. Within 40 minutes, the best separation was attained with gradient elution of deionized water, methanol and acetic acid on a C18 column at 25. The peaks on chromatogram were confirmed by comparing the retention time of samples with those of pure curcumin used as reference standard

2.7. Antibacterial activity

Antibacterial activity of T1, T2 and T3 was carried out against two gram-positive and two gram-negative bacterial strains. Disc diffusion method was used for antibacterial study against four bacterial strains i.e. *A. baumannii, P. aeruginosa, K. pneumonia, S. aureus.* Pure isolates strains of both grams-positive and gram-negative bacteria were obtained Institute of Microbiology and Molecular Genetics Punjab University Lahore. These stains were grown as streaks on nutrient agar surface at 37ºC in an incubator. Antibacterial activity was carried out using Disc diffusion method. Distilled water and absolute ethanol was used to prepare extract stock solution (0.1g/100mL). Further dilutions of stock solution were carried out to 2.5, 5, 10, 20 and 50 mg/mL concentrations of extract. The Blank and sterile discs (6mm diameter) were loaded by impregnating each dilution (20 μL). For this purpose, each

disc was spotted using 5 µL of each concentration of extract on both sides of the discs alternatively. All the discs were dried before the spotting of the next 5 µL was spotted to confirm precise loading. Ethanol and distilled water -loaded discs were used as negative controls for ethanolic and aqueous extracts, respectively. For all strains, the discs of vancomycin antibiotic (Becton-Dickinson, USA) were prepared in same way and used as positive control. Inhibition zone diameter was calculated to measure the antibacterial potential. Three replicates were used for each activity. Antibacterial activity of turmeric extract was termed as the mean zone of inhibition diameters (mm).

3. Results and Discussions

3.1. Phytochemical Screening

The screening of phytochemical constituents gives us idea about the biological properties of the extract under consideration. For this purpose, qualitative analysis of all fractions of Turmeric was done using various tests for the indication and presence of various classes of phytochemicals. The results recorded can be found in Table 2. The obtained results showed that T_1 and T_3 have number of phytochemicals as compared to that of T_2. It means by increasing the solvent polarity, we can receive a variety of phytochemicals for more biological properties.

3.2. GC-MS analysis

Plants are an essential supply of potential bioactive fundamental for the developing of new medicinal factors. All over the world, the scientists are analyzing the potential of appropriate with the range of pharmacology effective substances from medicinal plants. Approximately 80% of the people use herbal medicines that deserve cheap cost, high efficient and less side effects.

In the present analysis, the methanolic extract of curcumin from turmeric was analyzed by GCMS. The effective components which were present for the extraction of curcumin by GC-MS such as molecular formula, retention time, molecular weight and concentrations. In methanolic extract eighteen compounds were determined by gas chromatography mass spectrometry. The active substances found in the methanolic extract were Ar-tumerone (58.22%), Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6-methylene (8.668%), 1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-(7.882%), Benzene, 1-(1,5-dimethyl-4-hexeny GCMS was used to identify eleven chemicals in a chloroform extract. The active compounds which were present like 6-(p-Tolyl)-2-methyl-2-heptenol (35.437%), aniline, methyl (30.480%). In ethyl acetate, extract of curcumin determined by GC-MS 22 compounds were present. The active compounds which were present in ethyl acetate extract DL-Phenylalanine, methyl ester (23.586%), Ar-tumerone (22.325%), 2-Methoxy-4-vinylphenol (9.205%). These compounds were used for the health benefits, cosmetics, traditional and antimicrobial activity, antifungal, antibacterial, antitumor and antioxidant activities [30]. GCMS analysis of all fractions under study is mentioned in Table 3, 4 & 5. Similar results of GC-MS analysis for turmeric rhizome extracts were also narrated by Momoh et al. [31].

Table 1: Summary of Phytochemical tests present in various fractions of Turmeric (*Curcuma longa*).

Sr. No.	Phytochemicals	Test	Inference
1	Alkaloids	Few drops of Mayer's reagent + 1 mL sample solution	White precipitate
2	Flavonoids	1.5 mL dil. NH_3 + 1mL sample solution + Sulfuric acid	Yellow color
3	Phenolic acids	Few drops of lead acetate + extract solution	Yellow color
4	Tannins	0.5 g of extract add in 20mL H_2O+ boiling + few drops of ferric chloride	Brownish green color
5	Glycosides	1mL of H_2O in Alcoholic extract + NaOH solution	Yellow color
6	Steroids	100mg extract + 2mL of chloroform + sulfuric acid	Reddish brown color
7	Saponins	Plant extract (1 mL) diluted with distilled water (20mL) and shaking in a graduated cylinder for 15 min.	Foamy layer
8	Terpenoids	Extract (5 mL) was mixed with chloroform (2 mL); then concentrated sulfuric acid (3 mL) was carefully added to form a layer.	Reddish brown coloration at the interface

Table 2: Results of Phytochemical screening of various *Curcuma longa* extracts.

Sr. No.	Test	T1	T2	T3
1	Alkaloids	+	+	+
2	Terpenoids	+	+	+
3	Tannins	+	-	+
4	Flavonoids	+	-	+
5	Steroids	+	+	+
6	Saponins	+	+	+
7	Glucosides	-	-	-

Table 3: Compounds identified in ethyl acetate extract (T1) of turmeric through GC-MS analysis.

Sr. No.	Names of compounds	Molecular formula	Molecular weight	Retention time (min)	Peak area (%)
1	12,15-Octadecadiynoic acid, methyl ester	$C_{19}H_{30}O_2$	290.44	1.129	1.76
2	Carbonic acid, ethyl propyl ester	$C_6H_{12}O_3$	132.16	3.104	2.03
3	Toluene	C_7H_8	92.14	3.756	0.38
4	Propanedioic acid, methyl-, dimethyl ester	$C_6H_{10}O_4$	146.14	5.058	0.51
5	Benzene, 1,3-dimethyl-	C_8H_{10}	106.16	5.477	1.10
6	Benzeneethanol, à,á-dimethyl-	$C_{10}H_{14}O$	150.21	5.966	0.67
7	Cyclohexene, 3-(2,2-dimethylpropoxy)-	$C_{11}H_{20}O$	168.28	6.133	0.342
8	Benzenemethanol, à,à,4-trimethyl-	$C_{10}H_{14}O$	150.21	14.113	0.58
9	1,6,10-Dodecatriene, 7,11-dimethyl-3-methylene-, (Z)-	$C_{15}H_{24}$	204.35	20.695	4.32
10	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	$C_{15}H_{22}$	202.33	22.628	6.95
11	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)]-	$C_{15}H_{24}$	204.35	23.020	7.88
12	Cyclohexene, 1-methyl-4-(5-methyl-1-methylene-4-hexenyl)-, (S)-	$C_{15}H_{24}$	204.35	23.433	1.42
13	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6-methylene-, [S-(R*,S*)]-	$C_{15}H_{24}$	204.35	23.915	8.67
14	(1R,4R)-p-Mentha-2,8-diene, 1-hydroperoxide	$C_{10}H_{16}O_2$	168.23	24.159	0.41
15	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-	$C_{15}H_{26}O$	222.36	25.223	0.64
16	2-Cyclohexen-1-ol, 2-methyl-5-(1-methylethenyl)-	$C_{10}H_{16}O$	152.23	25.747	1.04
17	6-(p-Tolyl)-2-methyl-2-heptenol	$C_{15}H_{22}O$	218.33	26.414	0.92
18	Ar-tumerone	$C_{15}H_{20}O$	216.319	28.411	58.22

Table 4: Compounds identified in chloroform extract (T_2) of turmeric through GC-MS analysis.

Sr. No.	Names of compounds	Molecular formula	Molecular weight	Retention time (min)	Peak area (%)
1	Benzene, (butoxymethyl)-	$C_{11}H_{16}O$	164.244	3.737	15.35
2	Benzeneethanol, à,á-dimethyl-	$C_{10}H_{14}O$	150.22	5.470	0.98
3	Aniline, N-methyl-	C_7H_9N	107.15	10.588	30.48
4	Benzene, 2-methoxy-4-methyl-1-(1-methylethyl)-	$C_{11}H_{16}O$	164.120	14.221	1.58
5	Cyclohexanemethanol, 4-ethenyl-à,à,4-trimethyl-3-(1-methylethenyl)-, [1R-(1à,3à,4á)]-	$C_{15}H_{26}O$	222.37	20.680	1.75
6	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	$C_{15}H_{22}$	202.335	22.597	2.61
7	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)]-	$C_{15}H_{24}$	204.36	22.987	2.23
8	Cubenol	$C_{15}H_{26}O$	222.37	23.871	1.86
9	6-(p-Tolyl)-2-methyl-2-heptenol	$C_{15}H_{22}O$	218.33	28.168	35.44
10	(S)-(-)-2-Amino-3-phenyl-1-propanol	$C_9H_{13}NO$	151.206	29.098	7.72

Table 5: Compounds identified in methanolic extract (T_3) of turmeric through GC-MS analysis.

Sr. No.	Compounds	Molecular formula	Molecular weight	Retention time (min)	Peak area (%)
1	Toluene	C_7H_8	92.14	3.715	1.10
2	Aniline, N-methyl-	C_7H_9N	107.15	10.589	0.98
3	Benzene, 1-methyl-4-(1-methylethenyl)-	$C_{10}H_{12}$	132.20	11.187	0.79
4	Ethanone, 1-(2-methyl-1-cyclopenten-1-yl)-	$C_8H_{12}O$	124.180	11.332	1.07
5	2-Methyl-oct-2-enedial	$C_9H_{14}O_2$	154.21	12.870	0.50
6	Benzenemethanol, à,à,4-trimethyl-	$C_{10}H_{14}O$	150.22	14.078	4.33
7	Benzene, (ethenyloxy)-	C_8H_8O	120.15	15.149	5.64
8	2-Cyclohexen-1-ol, 2-methyl-5-(1-methylethenyl)-, acetate, (1R-cis)-	$C_{12}H_{18}O_2$	184.19	16.610	0.46
9	5-Isopropenyl-2-methyl-7-oxabicyclo[4.1.0]heptan-2-ol	$C_{10}H_{16}O_2$	168.24	17.005	0.57
10	s-(+)-5-(1-Hydroxy-1-methylethyl)-2-methyl-2-cyclohexen-1-one	$C_{10}H_{16}O_2$	168.24	17.412	0.49
11	2-Methoxy-4-vinylphenol	$C_9H_{10}O_2$	150.17	17.766	9.21
12	Benzene, 1-methyl-3,5-bis(1-methylethyl)-	$C_{13}H_{20}$	176.30	19.597	0.38
13	Vanillin	$C_8H_8O_3$	152.15	20.365	3.53
14	2H-Pyran, 2-(7-heptadecynyloxy)tetrahydro-	$C_{22}H_{40}O_2$	336.6	20.667	1.79
15	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-, acetate, (E,E)-	$C_{17}H_{28}O_2$	264.4	21.704	1.12
16	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	$C_{15}H_{22}$	202.335	22.575	4.03
17	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)]-	$C_{15}H_{24}$	204.34	22.962	0.97
18	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6-methylene-, [S-(R*,S*)]-	$C_{15}H_{24}$	204.34	23.844	0.66
19	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-	$C_{15}H_{26}O$	222.37	25.139	3.25
20	Benzene, 1-(1,5-dimethylhexyl)-4-methyl-	$C_{15}H_{24}$	204.34	25.718	(3.32
21	6-(p-Tolyl)-2-methyl-2-heptenol	$C_{15}H_{22}O$	219.45	26.316	3.33
22	Ar-tumerone	$C_{15}H_{20}O$	217.35	28.330	22.33
23	DL-Phenylalanine, methyl ester	$C_{10}H_{13}NO_2$	179.22	29.097	23.59

Table 6: Antibacterial potential of various fractions of *Curcuma longa* extract against multidrug resistant bacterial strains *A. baumannii, P. aeruginosa, K. pneumonia and S. aureus*.

Extracts	Zone of inhibition (mm± SE)			
	A.baumannii	***P. aeruginose***	***K. pneumonia***	***S. aureus***
T_1	15.85± 0.08	8.02±0.02	11.0±0.03	16.23±0.03
T_2	8.55± 0.06	9.63±0.01	11.05± 0.06	15.35± 0.01
T_3	19.85±0.05	11.52±0.5	12.0± 0.03	10.65±0.08

Significant up to (P<0.0001)

Table7: MIC of Antimicrobial activity of the extracts determined against multidrug resistant bacterial strains

Bacterial strain	Name of fraction	Molarity	Compound concentration				
			500µl	250µl	125µl	63µl	32µl
A.baumannii	T1	0.05	+	+	+	-	-
	T2	0.05	+	+	-	-	-
	T3	0.05	++	+	-	-	-
K. pneumonia	T1	0.05	++	+	-	-	-
	T2	0.05	++	+	-	-	-
	T3	0.05	++	+	+		-
P. aeruginosa	T1	0.05	++	+	+	-	-
	T2	0.05	+	+	-	-	-
	T3	0.05	++	++	+	-	-
S. aureus	T1	0.05	++	+	+	-	-
	T2	0.05	+	+	-	-	-
	T3	0.05	++	+	+	-	-

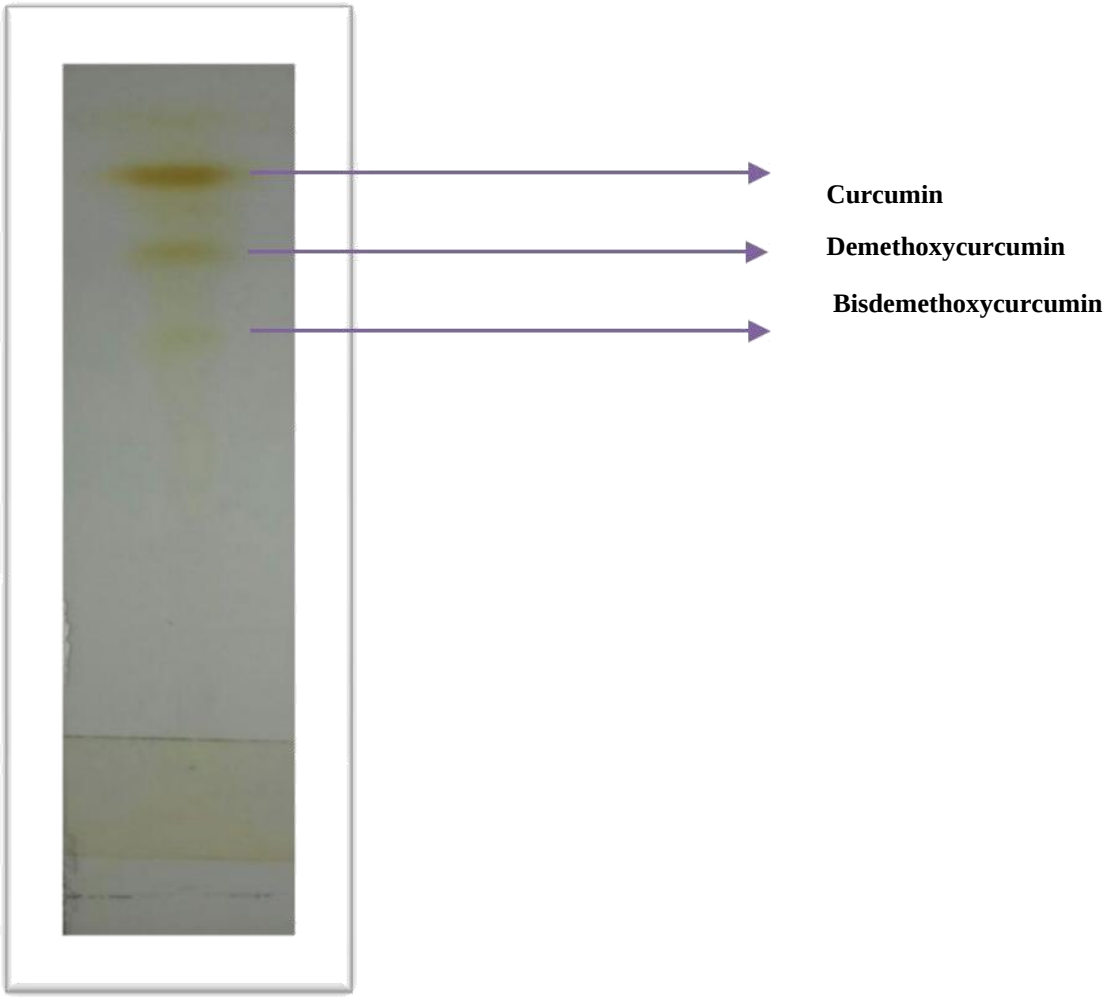

Figure 1: TLC analysis of curcuminoids from Turmeric ethyl acetate extract

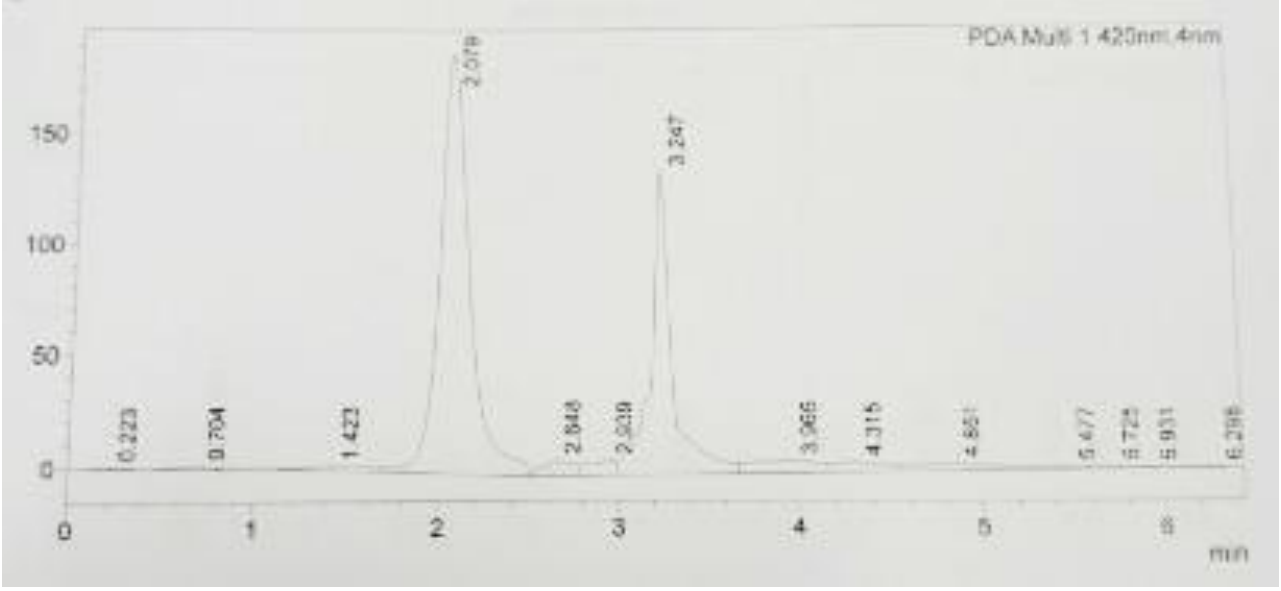

Figure 2: HPLC Chromatogram ethyl acetate extract

3.3. HPLC analysis

Three major peaks were observed in HPLC chromatogram, which indicate the presence of three major compounds. The peaks with value of retention time at 2.07, 2.648 and 3.247 minutes were assigned to curcuminoids, namely, bisdemethoxycurcumin, desmethoxycurcumin and curcumin respectively (Figure 2) as reported by HPLC characterization of Mudge et al. [32].

3.4. Antibacterial potential

The maximum antibacterial potential was exhibited by methanolic extract and the least potential was observed by chloroform extract against the bacterial strains under study. In this study we used both gram positive as well as gram negative bacterial strains. In this study we have used three gram-negative *Acinetobacter baumannii*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa*, and onegram positive bacterial strain *and Staphylococcus aureus*. For gram negative bacterial strains Gentamycin was used for Gram-negative bacteria, while chloramphenicol has high efficacy against Gram-positive bacteria. The maximum zone of inhibition (19.05± 0.05 mm) was obtained for T_3 against *A. baumannii* followed by 16.23± 0.03 mm for T_1 against *S. aureus*, 15.85± 0.08 mm for T_1 against *A. baumannii* and (11.0±0.03 mm) for *K. Pneumonia.* (9.63± 0.01 mm), T_2 showed maximum antimicrobial activity for *S. aureus* (15.35± 0.01 mm) followed by *K. Pneumonia* (11.05± 0.06 mm), *P. aeruginose* (8.2±0.03 mm) and *A. baumannii* (8.55±0.06mm) (Table 6 & 7). Such results were in close proximation with four concentrations of ethanolic extracts of turmeric native to Bangladesh (17.03 ± 0.30 mm against *Staphylococcus aureus*; 16.40 ± 0.38 mm against *Bacillus cereus* and 15.67 ± 0.38 mm against *Enterococcus faecium*) as reported by Khatun et al. [33].

4. Conclusions

From the results it can be concluded that *Curcuma longa* rhizome may be a possible nontoxic and cost-effective source for the treatment of infections caused by multidrug resistant bacteria. It has been found that *Curcuma longa* possesses several antibacterial agents like flavonoid, alkaloids, tannins, polyphenols along with its magical molecule curcumin which possess wide range of medicinal properties. Due to the synergistic effect of all the phytochemicals along with curcumin kill the multidrug resistant bacteria effectively. It would be highly beneficial to use turmeric at home as a remedy effectively. From the results, it has been clearly verified that *Curcuma longa* possess great potential to be an alternative medicinal plant which can be used in pharmaceutical, food products, functional tea and products.

References

[1] B. Joshi, G.P. Sah, B.B. Basnet, M.R. Bhatt, D. Sharma, K. Subedi, P. Janardhan, R. Malla. (2011). Phytochemical extraction and antimicrobial properties of different medicinal plants: Ocimum sanctum (Tulsi), Eugenia caryophyllata (Clove), Achyranthes bidentata (Datiwan) and Azadirachta indica (Neem). Journal of Microbiology and Antimicrobials. 3(1): 1-7.

[2] A. Siviero, E. Gallo, V. Maggini, L. Gori, A. Mugelli, F. Firenzuoli, A.J.P.i.M. Vannacci. (2015). Title: Curcumin, a golden spice with a low bioavailability.

[3] P. Chen. Methods and Application of Food Composition Laboratory: Beltsville, MD.

[4] S. Prasad, B.B.J.H.M.B. Aggarwal, C.A.n. edition. (2011). Turmeric, the golden spice.

[5] K.P. Nair. (2019). Turmeric (Curcuma Longa L.) and Ginger (Zingiber Officinale Rosc.)-World's Invaluable Medicinal Spices: The Agronomy and Economy of Turmeric and Ginger. Springer: pp.

[6] M. Grover, T. Behl, A. Sehgal, S. Singh, N. Sharma, T. Virmani, M. Rachamalla, A. Farasani, S. Chigurupati, A.M.J.M. Alsubayiel. (2021). In vitro phytochemical screening, cytotoxicity studies of curcuma longa extracts with isolation and characterisation of their isolated compounds. 26(24): 7509.

[7] E. Abdel-Lateef, F. Mahmoud, O. Hammam, E. El-Ahwany, E. El-Wakil, S. Kandil, H. Abu Taleb, M. El-Sayed, H.J.A.P. Hassenein. (2016). Bioactive chemical constituents of Curcuma longa L. rhizomes extract inhibit the growth of human hepatoma cell line (HepG2). 66(3): 387-398.

[8] G. AlBasher, M.M. Abdel-Daim, R. Almeer, K.A. Ibrahim, R.Z. Hamza, S. Bungau, L.J.E.S. Aleya, P. Research. (2020). Synergistic antioxidant effects of resveratrol and curcumin against fipronil-triggered oxidative damage in male albino rats. 27(6): 6505-6514.

[9] C. Changtam, H.P. de Koning, H. Ibrahim, M.S. Sajid, M.K. Gould, A.J.E.j.o.m.c. Suksamrarn. (2010). Curcuminoid analogs with potent activity against Trypanosoma and Leishmania species. 45(3): 941-956.

[10] M.A. Rizk, S.A.E.-S. El-Sayed, I.J.P. Igarashi. (2021). Effects of Methanolic Extract from Turmeric (Curcuma longa) against the In Vitro Multiplication of Several Babesia Species and Theileria Equi. 1(4): 188-196.

[11] L. Péret-Almeida, A. Cherubino, R. Alves, L. Dufossé, M.J.F.R.I. Glória. (2005). Separation and determination of the physico-chemical characteristics of curcumin, demethoxycurcumin and bisdemethoxycurcumin. 38(8-9): 1039-1044.

[12] M.A. Khan, R. El-Khatib, K. Rainsford, M.J.B.c. Whitehouse. (2012). Synthesis and anti-inflammatory properties of some aromatic and heterocyclic aromatic curcuminoids. 40: 30-38.

[13] C.-Y. Loo, R. Rohanizadeh, P.M. Young, D. Traini, R. Cavaliere, C.B. Whitchurch, W.-H.J.J.o.a. Lee, f. chemistry. (2016). Combination of silver nanoparticles and curcumin nanoparticles for enhanced anti-biofilm activities. 64(12): 2513-2522.

[14] R. Bradūnaitė, L. Leonavičienė, L. Akramas, M. Leonavičiūtė-Klimantavičienė, A. Vasiliauskas, I. Dumalakienė, I. Jonauskienė, J. Baleišis, Z.J.V.A. Mackiewicz. (2020). Anti-inflammatory and antioxidant effects of turmeric extracts in rat adjuvant arthritis. 90(4): 393-402.

[15] J.P. Sahoo, L. Behera, J. Praveena, S. Sawant, A. Mishra, S.S. Sharma, L. Ghosh, A.P. Mishra, A.R. Sahoo, P.J.A.J.o.P.S. Pradhan. (2021). The golden spice turmeric (Curcuma longa) and its feasible benefits in prospering human health—a review. 12(3): 455-475.

[16] R. Dolgari, R. Amirsasan, J.J.D.M. Vakili. (2020). Effects of Pilates training with and without turmeric supplementation on serum Klotho and quality of life in post-menopausal overweight women: A randomized clinical trial. 27(3): 1-8.

[17] P.D.F. Dos Santos, C.R.L. Francisco, A. Coqueiro, F.V. Leimann, J. Pinela, R.C. Calhelha, R.P. Ineu, I.C. Ferreira, E. Bona, O.H.J.F. Gonçalves, function. (2019). The nanoencapsulation of curcuminoids extracted from Curcuma longa L. and an evaluation of their cytotoxic, enzymatic, antioxidant and anti-inflammatory activities. 10(2): 573-582.

[18] M. Thakur, R. Virk, P.S. Sangha, V.J.J.o.F.S. Saxena, N. Research. (2019). The Effects of turmeric on Alzheimer's patients. 2(4): 347-353.

[19] M.-M. Wei, S.-J. Zhao, X.-M. Dong, Y.-J. Wang, C. Fang, P. Wu, G.-Q. Song, J.-N. Gao, Z.-H. Huang, T.J.J.o.e. Xie. (2021). A combination index and glycoproteomics-based approach revealed synergistic anticancer effects of curcuminoids of turmeric against prostate cancer PC3 cells. 267: 113467.

[20] E. Hay, A. Lucariello, M. Contieri, T. Esposito, A. De Luca, G. Guerra, A.J.C.-b.i. Perna. (2019). Therapeutic effects of turmeric in several diseases: An overview. 310: 108729.

[21] B.H. Kebede, S.F. Forsido, Y.B. Tola, T.J.H. Astatkie. (2021). Free radical scavenging capacity, antibacterial activity and essential oil composition of turmeric (Curcuma domestica) varieties grown in Ethiopia. 7(2): e06239.

[22] S.M. Vaidya, A.R. Singh, V.G. Patel, N.A. Khan, R.P. Yewale, M.K.J.J.o.P. Kale, Phytochemistry. (2018). A review on herbs against snake venom. 7(6S): 05-09.

[23] A. Amalraj, A. Pius, S. Gopi, S.J.J.o.t. Gopi, c. medicine. (2017). Biological activities of curcuminoids, other biomolecules from turmeric and their derivatives–A review. 7(2): 205-233.

[24] P. Maiti, G.L.J.I.j.o.m.s. Dunbar. (2018). Use of curcumin, a natural polyphenol for targeting molecular pathways in treating age-related neurodegenerative diseases. 19(6): 1637.

[25] H. Gupta, M. Gupta, S.J.C. Bhargava, e. Dermatology. (2020). Potential use of turmeric in COVID-19. 45(7): 902-903.

[26] N. Ahangari, S. Kargozar, M. Ghayour-Mobarhan, F. Baino, A. Pasdar, A. Sahebkar, G.A. Ferns, H.W. Kim, M.J.B. Mozafari. (2019). Curcumin in tissue engineering: A traditional remedy for modern medicine. 45(2): 135-151.

[27] C. Ren, Y. Lin, X. Liu, D. Yan, X. Xu, D. Zhu, L. Kong, C.J.B.C. Han. (2021). Target separation and antitumor metastasis activity of sesquiterpene-based lysine-specific demethylase 1 inhibitors from zedoary turmeric oil. 108: 104666.

[28] H. Bangun, A. Arianto, E.J.O.A.M.J.o.M.S. Rehngenana. (2021). Anti-ulcer Effect of Gastroretentive Drug Delivery System of Alginate Beads Containing Turmeric Extract Solid Dispersion. 9(A): 19-27.

[29] S. Revathy, S. Elumalai, M.B.J.J.o.E.s. Antony. (2011). Isolation, purification and identification of curcuminoids from turmeric (Curcuma longa L.) by column chromatography. 2(7).

[30] S. Sabir, A. Zeb, M. Mahmood, S. Abbas, Z. Ahmad, N.J.B.J.o.B. Iqbal. (2020). Phytochemical analysis and biological activities of ethanolic extract of Curcuma longa rhizome. 81: 737-740.

[31] J.O. Momoh, A.A. Manuwa, Y.O. Bankole. (2022). Phytochemical screening, atomic absorption spectroscopy, GC-MS and antibacterial activities of turmeric (Curcuma longa L.) rhizome extracts. Journal of Advances in Microbiology. 22(9): 116-131.

[32] E.M. Mudge, P.N. Brown, C.A. Rimmer, M.M. Phillips. (2020). Determination of curcuminoids in turmeric dietary supplements by HPLC-DAD: Multi-laboratory study through the NIH-ODS/NIST Quality Assurance Program. Journal of AOAC International. 103(6): 1625-1632.

[33] M. Khatun, M.A. Nur, S. Biswas, M. Khan, M.Z. Amin. (2021). Assessment of the anti-oxidant, anti-inflammatory and anti-bacterial activities of different types of turmeric (Curcuma longa) powder in Bangladesh. Journal of Agriculture and Food Research. 6: 100201.