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Determination of the total phenolic content and antibacterial activity of isolated Cyanobacteria from Algerian freshwater against some nosocomial pathogens bacteria

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ABSTRACT

Nosocomial infections are a major challenge for public health due the high rates of morbidity and mortality generated. It was considered that the excessive or inappropriate use of antibiotics triggers the emergence of such resistant strains. Therefore, this situation obligated many researchers how to overcome this obstacle, mainly by searching or synthesizing new molecules to neutralize microbes and to overcome the phenomenon of resistance. Cyanobacteria characterized by their richness in some biologically active compounds, which was manifested such pharmaceutical importance. Hence, the present work has been focused on the study of the total phenolic component and the antibacterial activity of seven isolated filamentous Cyanobacterial species from freshwater of the river of Mekerra and waterfalls of El-Ourit (Sidi Bel Abbes and Tlemcen), located in North West region of Algeria.

The extracted methanol and water of intracellular substances (from biomasses) and ethyl acetate of extracellular substances (from the culture supernatants) were screened for the estimation of total phenolic content by the using of Folin-Ciocalteu assay and investigated against different strains of Gram-positive such as Staphylococcus aureus and Gram-negative as Escherichia coli, Klebsiella pneumoniae, Acinetobacter baumannii and Pseudomonas

aeruginosa) bacteria, where the tested strains were isolated from the patients suffered from a nosocomial pathogen bacteria. The obtained results indicated that solvents with different polarities have various effects on phenolic content. Furthermore, the obtained results indicated that among the tested solvents, the methanol extracts revealed the highest phenolic content. The study of the antagonistic activity of the isolated, selected seven Cyanobacteria indicated that the Methanolic extract of Anabaena sp revealed an excellent inhibition of Staphylococcus aureus. Furthermore, the ethyl acetate extracts of the isolated, selected seven Cyanobacteria was manifested an evident antagonistic activity against several pathogenic bacteria, with the absence of any effect on the growth of Pseudomonas aeruginosa. The pattern of inhibition in the bacterial bioassays indicated that various antibacterial substances are involved.

Keywords: *Antibacterial activity. Cyanobacteria. Folin–Ciocalteu method. Algerian freshwater. Nosocomial bacteria. Phenolic content.*

INTRODUCTION

There has been an increasing incidence of multiple resistances in human pathogenic microorganisms in recent years, largely due to the indiscriminate use of commercial antimicrobial drugs commonly employed in the treatment of infectious diseases [1, 2]. This has forced scientist to search of new compounds with antimicrobial potential from various naturel sources to fight against pathogens with novel strategies [3]. Therefore, such newer natural bio resources could act as the reservoir for such molecules, and led us to opt for the little explored Cyanobacterial flora [4]. Historically, actinomycetes have been the most prolific producers of new bioactive metabolites. The Cyanobacteria are among the oldest phototrophic organisms. Their cultivation without organic substrate can be an economical advantage over the microorganisms [5].

Cyanobacteria (also known as blue-green algae) are an assemblage of Gram-negative eubacteria that occur in fresh water, marine and terrestrial habitats [6, 7]. Various strains of Cyanobacteria are known to produce intracellular and extracellular metabolites with diverse biological activities such as antibacterial [8], antifungal [9], antiviral [10], insecticidal [11], and algicidal [12] with many more activities. Among these metabolites, heptadecane and tetradecane from *Spirulina platensis* [13], phenolic compounds from *Nostocm uscorum* [14], fatty acids, tetraamine spermine and piperazine derivative from *Oscillatoria spp* [15] and laxaphycins from *Anabaena laxa* [16] have been reported to possess antimicrobial activity.

Generally, the study of the antibacterial effects of Cyanobacteria has been investigated for two main objectives. One major aim of the present work was the exploration of a new approach for pharmaceuticals and biocontrol application. The second object was the understanding of the interaction between of bacterial strains within their natural community [17]. A few studies have been achieved on antibacterial activity of Cyanobacteria from Algeria. Therefore, the main objectives of the present work were the isolation of *Cyanobacteria* from freshwater (Algerian), the determination of their total phenolic content and antibacterial activity against many pathogenic bacteria isolated from patients suffered from nosocomial infections.

MATERIALS AND METHODS

Sampling and culture establishment

Freshwater samples were collected from the River Mekkera, in the Sidi Bel Abbes area, and from a Waterfalls El Ourit, in the Tlemcen area in sterile samplers, during the spring period (May 2014), and transported immediately under refrigeration at temperature of 4°C to the laboratory for further analysis. The isolation and purification of *Cyanobacteria* has been achieved according to the described protocol by Ferris and Hirsch [18].

A sample was homogenized under shaking and the obtained triplicate aliquots were removed, diluted in a volume of 100 ml of sterile distilled water, which was filtered under vacuum by the using Millipore filters. After that, the filters were placed on the surface of the solid BG-11 culture medium [19], incubated at temperature 28°C for a period of 14 days. The obtained colonies were purified and further used for establishment monospecific cultures. The single colonies were aseptically picked, inoculated in 500 ml Erlenmeyer flasks containing a volume of 250 ml of BG-11 culture medium, incubated at temperature of 28 ± 2^0C and 3-4 Klux light intensity with cool white fluorescent light tubes under a 16/8 h light and dark cycles, under rotary shaking for two day to prevent cell clumping [19]. The identification of Cyanobacterial species was completed via microscopic observation and the use of the taxonomic guides written by Komarek and Anagnostidis [20].

Biomass harvesting

Cyanobacterial biomass was harvested in the stationary growth phase by centrifugation at 5000×g for 15 min (Sigma 3-16KL, Germany). The culture supernatant was collected and the cell pellet was washed three times with distilled water, freeze-dried (Fisher Bioblock ALPHA 1-2 LD, Spain) and used for the following analysis.

Preparation of supernatant and cell extracts

1g of freeze-dried biomass was suspended in a volume of 50 ml of pure methanol, homogenized by the using of ultrasonic bath **(**Bandelin Sonorex, Germany) for 7 minutes. The mixture was agitated overnight by the using of shaker at 150 rpm in the dark, filtered through filter paper Whatman N°1. The recuperated pellet from the methanol extraction was further extracted with water as described above. The obtained extracted substances from the culture supernatant by shaking of the 24 old hours cell-free culture was supplemented with equal volume of ethyl acetate and separated by the using of funnel. The above liquid phase was collected for harvesting of ethyl acetate extract according to the described protocol by Tuyet (2010), dried at temperature of 40°C under reduced pressure in a rotary evaporator (Stuart RE300DB, UK). After that, the dry extract was dissolved in dimethyl sulfoxide solution (DMSO) and maintained at temperature 4°C for further studies.

Determination of total phenolic content

The amount of total phenolics in extracts was determined by the using of Folin-Ciocalteu procedure according to the described protocol by Kahkonen [21]. For this purpose, a volume 200 µl of Samples was introduced into test tubes containing a volume of 1 ml of Folin-Ciocalteu's reagent (previously diluted tenfold with distilled water) and 0.8 ml of sodium carbonate solution at a concentration of 7.5%. The mixture was agitated for 30 min and the absorption was measured at weave length of 765 nm by the using Optizen 2120 UV/Vis spectrophotometer.

Used Bacterial strains

The used bacteria in the present work were isolated from patients suffered from nosocomial infections, which were hospitalized in the Regional Military University Hospitals of Oran and preserved as pure cultures. The identification of the bacterial isolates was carried out by the using of API 20E, API 20NE, API Staph, according to the manufacture (biomerieux, Marcy, l 'Etoile, France). The bacterial isolates were investigated for their resistance to antibiotics by the using of a disk diffusion method. For this purpose, a volume of 100 µl of each overnight grown culture of the bacterial isolates in a nutrient broth was inoculated, spread on the solid Mueller Hinton culture medium with the help of spreader and investigated antibiotic disks was deposed on the surface Mueller Hinton culture medium, incubated overnight at temperature 37°C for 24 hours. The tested antibiotic disks were ampicillin (10 µg), amoxycillin/clavulanic acid (20/10 µg), oxacillin (01 µg), ticarcillin (75 µg), ticarcillin/ clavulanic acid (75/10 µg), piperacillin (100 µg), imipenem (10 µg), aztreonam (30 µg), cefazolin (30 µg) , cefotaxime (30 µg) , ceftazidime (30 µg), cefoxitin (30 µg), amikacin (30 µg), gentamicin (10 µg), tobramycin (10 µg), ciprofloxacin (5 µg), tetracycline (30 µg), colistin (10 µg), vancomycin (30 µg), rifampicin (30 µg) and fosfomycin (50 µg). The antibacterial activity was determined by measuring of the diameter of the formed zone inhibition around the antibiotic disk and interpreted according to the standard chart (CLSI, 2011). The obtained results were confirmed by using Micro scan Walkaway System (Siemens, USA).

Determination of Antibacterial bioassay

The antibacterial activity of Cyanobacterial extracts against such pathogenic bacteria responsible for nosocomial infections has been achieved by the using of disk diffusion method according to the described protocol by Collins [22]. Each of bacterial suspension cultivated in liquid culture dilutions was inoculated in Muller Hinton Agar (MHA Oxoid-CM337), incubated at temperature of 37°C for 20 min to reach logarithmic phase then measured to 0.5 McFarland dilution (standard concentration), which delivered a final concentration of approximately 10^5 UFC per ml. Then, sterilized paper disks with diameter of 6 mm was deposed on the surface of solid Muller Hinton culture medium, impregnated with a volume of 6 µl of the harvested extract. The plates were kept for 2 hours at 4°C to allow the diffusion of the compounds into the solid culture medium, incubated overnight at temperature of 37°C. The sensitivity of different bacterial strains to the extracted molecules from the isolated, selected cyanobacterial strains was calculated by the measuring of the diameter (mm) of inhibition zone. Regarding were taken at the end of 24 hours and 48 hours. Bacterial showing a clear zone inhibition >6mm were considered to be sensitive. Experiments have been achieved triplicates for each combination of the extracts and the tested bacterial strains. Disc containing solvent (DMSO) were used as control. The antibacterial activity was evaluated by measuring of diameter of inhibition zone formed around the discs.

Statistical analysis

The experimental results were expressed as mean ± Standard deviation (SD). For the antibacterial activity, the statistical differences were performed with ANOVA by the using of statistical presentation system, Statistica version 6.

RESULTS AND DISCUSSION

Morphological identification

The main aim of the present work was the screening and the identification of the bacterial strains belonging to the cyanobacteria, which were isolated from freshwater of the river of Mekerra (Sidi Bel Abbes) waterfalls, El-Ourit (Tlemcen), located in North West region of Algeria and the evaluation of their antagonistic activity against some pathogenic bacteria responsible for nosocomial infection.The use of the morphological characters such as the microscopic observation according to the described methods by Komarek and Anagnostidis (1989; 2005) (Figure1 A–G) for the identification of the isolated Cyanobacteria strains,

indicated the presence of a total of 7 filamentous Cyanobacterial species (5 genera), belonging to the genus of *Leptolyngbya foveolarum*, B: *Leptolyngbya boryana*, C: *Leptolyngbya sp*, D: *Pseudanabaena sp*, E: *Anabaena sp*, F: *Geitlerinema sp*, G: *Limnothrix sp*

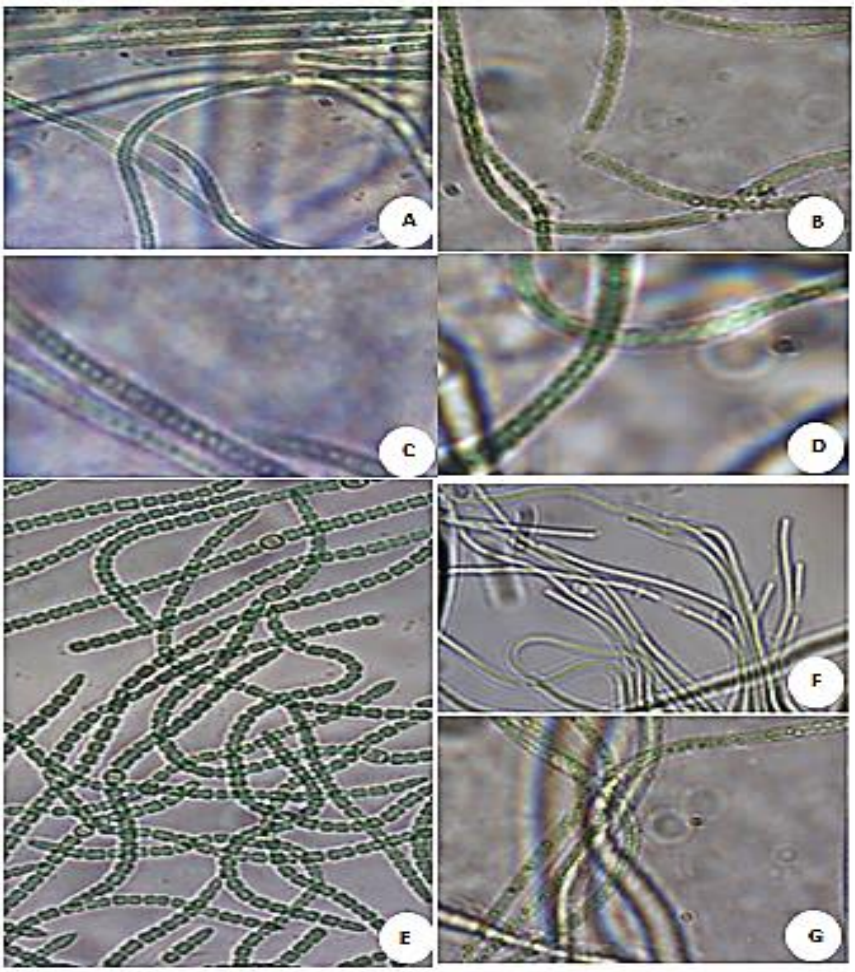

Figure-1: Photomicrographs of selected filamentous Cyanobacterial species (100x) from freshwater of Algeria: A. *Leptolyngbya foveolarum*, B: *Leptolyngbya boryana*, C: *Leptolyngbya sp*, D: *Pseudanabaena sp*, E: *Anabaena sp*, F: *Geitlerinema sp*, G: *Limnothrix sp*.

Table 1: The identification of the isolated Cyanobacteria strains from fresh water samples of lake of Sarnoand Sidi Mohamed Benali by the use of the external morphology microscopic observation.

Cyanobacterial strains	**Family**	**Site of collection**
Anabaena sp	*Nostocaceae*	Mekerra River
Geitlerinema sp	*Pseudanabaenaceae*	Mekerra River
Leptolyngbya boryana	*Pseudanabaenaceae*	El-Ourit Waterfalls
Leptolyngbya foveolarum	*Pseudanabaenaceae*	El-Ourit Waterfalls
Leptolyngbya sp	*Pseudanabaenaceae*	Mekerra River

Limnothrix sp	*Pseudanabaenaceae*	El-Ourit Waterfalls
Pseudanabaena sp	*Pseudanabaenaceae*	El-Ourit Waterfalls

Determination of the total phenolic content

Phenolic compounds were responsible for the antioxidant activity and many biological activities such as antibacterial, anticancer, anti-allergic, anti-diabetes, anti-aging, anti-inflammatory and anti-HIV activities the most important classes of natural products [23]. The produced total phenolic compounds by the biomass and extracellular substances of the isolated, selected Cyanobacterial strains, cultivated on the BG-11 culture medium were determined and expressed as Gallic Acid Equivalent (GAE) (Table 1).

Table 2: Determination of total phenolics compounds (mg GAE.g^{-1}), produced by the isolated, selected Cyanobacterial extracts.

Cyanobacterial strains	**Used Solvent**		
	Methanol	**Water**	**Ethyl acetate**
Anabaena sp	2.77±0.26	0.49±0.01	0.69±0.00
Geitlerinema sp	12.75±0.20	1.07±0.03	0.44±0.04
Leptolyngbya boryana	15.43±0.24	4.14±1.73	0.14±0.00
Leptolyngbya foveolarum	14.33±0.64	10.43±0.33	0.65±0.00
Leptolyngbya sp	1.89±0.16	0.15 ±0.00	0.69±0.01
Limnothrix sp	1.96±0.00	1.23±0.00	0.76±0.00
Pseudanabaena sp	0.72±0.01	0.43±0.00	0.15±0.10
Results are presented as the mean of triplicate measurements (n=3 ± SD).			

The obtained results indicated that the amount of total phenolics was varied considerably by the investigated isolated selected Cyanobacterial strains, where the methanolic extracts was manifested the greatest amount of total phenolic compounds, followed by water and ethyl acetate extracts respectively. The highest amount of phenolic compounds (15.43±0.24 mg GAE/g) was yielded by the extraction of the cultivated biomass of the selected cyanobacterial *Leptolyngbya boryana* with methanol. Unlike, the lowest amount of total phenolics content (0.14±0.00 mg GAE/g) was explored by the extraction of the recuperated culture supernatant of the selected cyanobacterial Cyanobacterium with ethyl acetate. Furthermore, the obtained amount of total phenolic compounds by the extraction of the cultivated biomass of both selected cyanobacterial *Anabaena sp* and *Leptolyngbya sp* with water was yielded less phenolics than their ethyl acetate extracts of the extracellular substances. The obtained results indicated that the used methanol for extraction of total phenolics compounds was considered as the best solvent, which could be probably explained by the presence of higher concentration and less polar phenolics [24]. In early studies, Abd El-Aty and Co-workers [25] have reported that the use of methanol for extraction of the total phenolic content has manifested a higher amount yield in *Oscillatoria agardhii* and *Anabaena sphaerica*. Furthermore, Manivannan and co-workers [26] has reported that the extraction with methanol was yielded a high levels of phenolic content than diethyl ether and hexane.

Antibacterial bioassay

In the present study, the antagonistic activity of the extracted crude of cyanobacteria (methanolic, water, ethyl acetate) against pathogenic Gram-negative and positive bacteria strains responsible for nosocomial infection such as *E. coli, K. pneumonia, Acinotobacter baumannii, Ps. aeruginosa and Sta. aureus* has been investigated by the using of agar-well diffusion method, based on the measure of the formed diameter of the zone inhibition.

From the study, it's clear that the diameter of the inhibition zone depends mainly on the type of the tested cyanobacteria strains, type of the used solvent for the extraction and the pathogenic bacteria. The obtained results indicated that 21 extracts of biomasses and culture supernatants of the 7 isolated, selected Cyanobacterial strains were investigated against Gram-positive and Gram-negative bacteria for their antibacterial activity, where the tested pathogenic bacterial strains has manifested an important resistance to conventional antibiotics (Table 3).

Table 3: Illustration of the antibacterial activity in the presence of some antibiotic against a pathogenic bacteria responsible for nosocomial infection such as *E. coli, K. pneumonia, Acinotobacter baumannii, Ps. aeruginosa and Sta. aureus* by the produced zone inhibition.

Bacterial strains				**Antibiotics**								
E. coli		AMP	AMC	TIC	PIP	CZO	CTX	CAZ	IPM	AMK	GEN	CIP
Strain 1		R	R	R	R	R	S	R	R	S	S	S
Strain 2		R	R	R	R	R	R	R	S	S	S	R
Kl. pneumoniae		AMP	AMC	TIC	PIP	CZO	CTX	CAZ	IPM	AMK	GEN	CIP
Strain 1		R	R	R	R	R	R	R	S	S	S	S
Strain 2		R	R	R	R	R	R	R	R	S	R	R
Aci.baumannii		TIC	PIP	TCC	CAZ	ATM	IPM	AMK	GEN	TOB	CIP	/
Strain 1		R	R	R	R	R	R	R	R	R	R	/
Strain 2		R	R	R	R	R	R	R	R	R	R	/
Ps. aeruginosa		TIC	PIP	CAZ	IPM	ATM	AMK	GEN	CIP	COL	FOS	/
Strain 1		R	S	S	S	R	S	S	R	S	S	/
Strain 2		S	R	S	R	S	S	S	R	S	R	/
St. aureus		AMP	OXA	FOX	GEN	AMK	RIF	VAN	TOB	TCY	/	/
Strain 1		R	R	R	S	R	S	R	/	R	/	/
Strain 2		R	R	R	R	S	S	R	R	R	/	/

R: resistant; S: sensitive – AMP: Ampicillin, AMC: Amoxycillin/clavulanic acid, TIC: Ticarcillin, PIP: Pipracillin, CZO: Cefazolin, CTX: Ce CAZ: Ceftazidime, IPM: Imipenem, AMK: Amikacin, GEN: Gentamicin, CIP: Ciprofloxacin, TCC: Ticarcillin/clavulanic acid, ATM: Aztreona Tobramycin, COL: Colistin, FOS: Fosfomycin, OXA: Oxacillin, FOX: Cefoxitin, RIF: Rifampicin, VAN: Vancomycin, TCY: tetracycline.

The antibacterial activity of the extracts of the isolated, selected of Cyanobacterial strains was presented in Table 3, where the total investigated extracts indicated a different degree of inhibition of the tested pathogenic bacteria. Whereas the bacterial growth of *S. aureus* was inhibited by the majority of the tested Cyanobacterial strains. Based on the used primary screening, the obtained results of the extraction of the cultivated biomass of *Anabaena sp* on the BG11 culture medium with methanol indicated a excellent antibacterial activity against *S. aureus*, with a diameter of inhibition zone of 12.2±0.13 mm.

Furthermore, the obtained investigated methanolic extract from the cultivated biomass of *Leptolyngbya foveolarum, Leptolyngbya sp and Limnothrix sp* on the BG11 culture medium and the extract of the culture supernatants of *Anabaena sp, Geitlerinema sp, Leptolyngbya foveolarum, Limnothrix sp* and *Pseudanabaena sp* with ethyl acetate has manifested a moderate antibacterial activity against *S. aureus.* From the 21 investigated Cyanobacterial extracts, 9 extracted crude indicated an excellent antibacterial activity against Gram-negative bacteria. Furthermore, the ethyl acetate extract from the culture supernatant of *Pseudanabaena sp* has manifested the highest antibacterial activity against *E. coli*, with diameter of inhibition zone of 6.5±0.21 mm. Interestingly, all extracts has inhibited the bacterial growth of Gram-negative bacteria, which were prepared from the culture supernatants of the cultivated Cyanobacterial strains (Table 3).

Table-4: Results of antibacterial activity by different extracts from Cyanobacteria.

Cyanobacterial strains	**Extract**	**Diameter of inhibition zone (mm)**									
		E. coli		***K. pneumonia***		***A. baumannii***		***P. aeruginosa***		***S. aureus***	
		Strain 1	**Strain 2**	**Strain 1**	**Strain 2**	**Strain 1**	**Strain 2**	**Strain 1**	**Strain 2**	**Strain 1**	**Strain 2**
Anabaena sp	MeOH	-	-	-	-	-	-	-	-	12.2±.13	6.4±.22
	H_2O	-	-	-	-	-	-	-	-	-	1.6±.02
	EA	4.6±.12	-	-	-	-	-	-	-	-	4.4±.02
Geitlerinema sp	MeOH	-	-	-	-	-	-	-	-	-	-
	H_2O	-	-	-	-	-	-	-	-	-	-
	EA	-	-	-	-	-	-	-	-	-	4.8±.03
Leptolyngbya boryana	MeOH	-	-	-	-	-	-	-	-	-	-
	H_2O	-	-	-	-	-	-	-	-	-	-
	EA	-	-	-	-	5.1±.00	-	-	-	-	-
Leptolyngbya foveolarum	MeOH	-	-	2.5±.20	3.8±.06	-	-	-	-	4.4±.00	7.3±.00
	H_2O	-	-	-	-	-	-	-	-	-	-
	EA	-	-	2.5±.34	-	-	-	-	-	3.6±.12	-
Leptolyngbya sp	MeOH	-	-	-	-	-	-	-	-	3.3±.01	6.2±.02
	H_2O	4.5±.40	-	-	-	-	-	-	-	-	-
	EA	3.9±.09	3.6±.13	-	-	-	-	-	-	-	-

Limnothrix sp	MeOH	-	-	-	-	-	-	-	-	2.9±.08	-
	H_2O	-	-	-	-	-	-	-	-	-	-
	EA	-	-	-	-	-	4.0±.17	-	-	3.5±.04	4.5±.00
Pseudanabaena sp	MeOH	-	-	-	-	4.2±.04	-	-	-	-	-
	H_2O	-	-	-	-	-	-	-	-	-	-
	EA	6.5±.21	-	-	-	4.0±.04	-	-	-	3.5±.05	-
Solvent Control (DMSO)	-	-	-	-	-	-	-	-	-	-	-

Results are the means of diameter values ± SD. MeOH (Methanol), H_2O (Water), EA (Ethyl Acetate). The obtained results indicated the feeble antibacterial activity of the water extract against the investigated Gram positive and negative bacteria, with the exception of that *E. coli* and *S. aureus* have manifested a considerable sensitivity by the using of water extracts of *Leptolyngbya sp* and *Anabaena sp*, respectively. Oufdou and co-workers (2001) [27] have reported that the used water extracts of Cyanobacterial strains, isolated from some Moroccan aquatic ecosystems have manifested any antibacterial activity. Kreitlow and co-workers [28] have reported that the water extracts of 12 Cyanobacterial strains belonging to genera *Anabaena, Oscillatoria, Pseudanabaena, Limnothrix* and *Synechocystis*, isolated from fresh and brackish water, and two water blooms collected from the Baltic Sea, has manifested a feeble antibacterial activity than the organic extracts [29], has reported that the water extracts of *Oscillatoria sp*, *Phormidium sp* and *Lyngbya majuscule* has manifested an excellent antibacterial activity against both Gram-positive and Gram-negative bacteria. Recently, the investigated antibacterial activity of the isolated, selected Cyanobacterial strains *Nostoc* [30], *Anabaena, Oscillatoria, Synechocystis* [31], *Calothrix, Oscillatoria* [32] and *Spirulina* [33] by the using of different organic solvents such *as* methanol, water, ethyl acetate has showed an excellent inhibition of both Gram-positive and Gram-negatives bacteria. Mundt *et al*., 2001; Ghasemi *et al*., 2003; Soltani *et al*., 2005; Taton *et al*., 2006; Martins *et al*., 2008) [34-38] has reported that the bacterial growth of Gram-positive bacteria was more inhibited in the presence of methanolic extracted of the isolated, selected Cyanobacterial strains than a Gram-negatives bacteria.

It was explained by the presence of the membrane extern in Gram-negative bacteria, where the active compound present in the extracts might be encountered a big difficulties during their penetration through the membrane, which contains porins that impede the influx of drugs and a multiple-drug pump efflux system that expels most drugs from the bacteria, a well-documented phenomenon [39]. The crude extracts of Cyanobacterial strains may contain diverse bioactive compounds, which include various classes of secondary metabolites such as polyketides, amides, alkaloids, lactones, peptides and lipopeptides, responsible for the antibacterial activity [40, 41]. Bloor and England [42] has reported that the metabolites produced by Cyanobacteria offer many advantages since the culture of biomass can be readily established on the BG-11 culture medium and optimized for sustainable yields on an industrial scale. In the present study, the investigated extracts of the isolated, selected Cyanobacterial strains showed an excellent antibacterial activity against some pathogenic bacteria responsible nosocomial infection. Furthermore, the obtained results provided the evidence to support the use of Cyanobacterial strains in area of development of new molecules and drug discovery.

Statistical analysis

Statistical analysis of the antibacterial activity gave a value of $p<0.05$, that means that the extracts acted significantly against bacterial strains which was resistant to antibiotics.

CONCLUSION

From the present study, the isolated Cyanobacterial strains from freshwater of Algeria are a promising source for production of new bioactive natural molecules. Furthermore, it is of interest to explore which molecules were responsible for the antibacterial activity and their use as a promising candidate for the production of new antimicrobials. Therefore, a further studies are required for the characterization of the molecules responsible for the antibacterial activities, where the basic knowledge may useful in various applications such as pharmaceutics and agricultures.

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