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Optimization of the Cultural Parameters for Improved Production of Antimicrobial Metabolites by *Streptomyces gulbargensis* DAS 131

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Authors' contributions

This work was carried out in collaboration between all authors.Author UKM performed the experimental part, authors MV and DA designed the study and author SP performed literature search and statistical analysis. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To investigate the influence of appropriate culture medium by optimizing the cultural conditions affecting the growth and bioactive metabolite production by *Streptomyces gulbargensis* DAS 131 under submerged culture conditions in order to reduce the cost of fermentation process to improve the formation of antimicrobial compounds.
Place and Duration of Study: Department of Botany and Microbiology, January 2012 to May 2012.
Methodology: The impact of environmental parameters such as incubation period, pH, temperature and salt concentration and effect of various nutrients such as carbon and nitrogen sources and minerals on the antimicrobial metabolite production by *Streptomyces gulbargensis* DAS 131 was evaluated by employing agar well diffusion

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assay. Growth was measured in the form of dry mycelial weight.
Results: The optimum pH and temperature for bioactive metabolite production were 7 and 35°C respectively. Highest antimicrobial metabolite production was found when the strain was inoculated into the medium amended with glucose at the concentration of 2%, soya peptone at the rate of 1% and NaCl at the concentration of 5% and incubated for six days under shaking conditions. The metabolites showed good antimicrobial activity against Gram positive and Gram negative bacteria, as well as unicellular and multicellular fungi.
Conclusion: *S. gulbargensis* DAS 131 isolated from the semi-arid soils of Gulbarga, Northern Karnataka province, India exhibited broad spectrum antimicrobial activity. It was found that the antimicrobial metabolite production by the strain was positively influenced by carbohydrates, nitrogen sources and minerals.

Keywords: Optimization; bioactive metabolites; nutritional factors; antimicrobial activity; Streptomyces gulbargensis DAS 131.

1. INTRODUCTION

The microbes are the source for many important drugs including antibiotics, antitumor compounds, Immunosuppressants, antiviral and antiparasitic agents. Over 10,000 of bioactive compounds have been produced by Actinomycetes which contribute to 45% of all the bioactive secondary metabolites discovered [1]. Microbes dwelling in extreme habitats have been focused as an important source for novel compounds in recent years. The majority of studies with microbes from extreme environments were confined to bacteria and the actinomycetes from these habitats have been relatively less explored [2]. As highlighted in many reviews [3], natural products are the origin for most of the antibiotics in the market today. These products are an important source for both the existing and new drugs. Among these, actinomycetes are a biotechnologically priceless group of prokaryotes. Actinobacteria form a distinct line in the 16SrDNA tree and produce metabolites that have medical contribution from antibiotics to enzyme inhibitors. They are ubiquitously distributed in terrestrial, fresh water and extreme environments such as marine ecosystems and alkali soils [4]. They are considered to be the important group of microbes due to their ability to produce novel chemical compounds that are complex and commercially important [5]. The solution to combat multidrug resistance of pathogens is to search for novel antimicrobial compounds so as to find a solution to overcome the global resistance to pathogenic bacteria.

It is widely accepted that alkaliphilic actinomycetes are a valuable source for medicinal and industrial products [6]. Extensive exploration of actinomycetes having unique therapeutic properties continues to be an important area of research. *Streptomyces* species belonging to actinomycetes have been known as prolific producers of useful bioactive metabolites. These species are also recognized as industrially important organisms for their ability to synthesize different kinds of novel secondary metabolites, accounting for 70-80% of all natural compounds produced by actinomycetes. *Streptomyces* are well documented as source for novel drug metabolites [7]. Some of the important compounds obtained from the alkaliphilic *Streptomyces* species include Pyrocoll [8], Chinikomycin and Lajollamycin, Mediomycins A and B, Clethramycin [9], Bleomycin [10] and Caboxamycin [11] with anti-tumor, anti-parasitic and anti-microbial properties. Several studies were aimed at isolation of *Streptomyces* and screening them for new antibiotics. Novel actinomycetes documented and the products derived from poorly explored habitats stress the need to probe into new habitats [2].

Media supplemented with carbon, nitrogen sources [12], sodium chloride [13] and mineral salts [14] and physico-chemical parameters like temperature, pH and incubation period also play a major role on growth and production of anti-microbial metabolites. The type, addition, removal and concentration of carbon, nitrogen, and phosphate together with trace elements are reported to influence the antibiotic biosynthesis by *Streptomyces* [15]. In order to achieve the highest level of metabolite production, the optimization of process parameters is very critical [16,17]. Hence an effort was made to understand the impact of different carbon and nitrogen sources, temperature, pH and incubation period on growth and bioactive metabolite production by *Streptomyces gulbargensis* DAS131.

2. MATERIALS AND METHODS

2.1 Isolation

During the course of screening for industrially important microorganisms, an alkali-tolerant and thermo-tolerant actinomycete isolate identified as *Streptomyces gulbargensis* DAS 131 was isolated from semi-arid soils of Gulbarga, Northern Karnataka province, India, by standard serial dilution technique using starch casein agar medium [18] and further maintained on Yeast extract malt extract dextrose (ISP-2) agar medium at 4ºC [19]. The 16S rRNA gene sequence of the strain has been deposited in the NCBI genbank with the accession number DQ317411 [20].

2.2 Selection of Culture Conditions for the Optimum Production of Bioactive Metabolites

Antimicrobial metabolite production by the strain was optimized by using different parameters such as incubation period, pH, temperature, NaCl, carbon, nitrogen sources and minerals.

2.3 Effect of Incubation Period

The growth pattern and bioactive metabolite production by the strain was studied at regular intervals up to 10 days. One week old culture of *S. gulbargensis* DAS 131was cultivated in ISP-2 broth (seed medium) comprising of yeast extract (0.4%), malt extract (1%), dextrose (0.4%), $CaCO_3$(0.2%) with pH 7.2 at 37°C for 48h. Seed culture at a rate of 10% was inoculated into the starch casein broth (production medium) consisting of soluble starch (1%), sodium caseinate (0.2%), K_2HPO_4 (0.02%), $MgSO_4$. $7H_2O$ (0.02%) $FeSO_4$. $7H_2O$ (0.001%) with pH 7.2.The fermentation process was carried out for 10 days under agitation at 150rpm. At every 24h interval, the flasks were harvested and the biomass was separated from the culture filtrate. Biomass was determined in terms of dry weight and antimicrobial metabolite production was determined in terms of their antimicrobial spectrum [21]. The crude bioactive compound produced in the fermentation medium by the isolate was extracted twice with equal volume of ethyl acetate (1:1) in a separating funnel at periodic intervals. The solvent layer was collected and evaporated in a rotary evaporator under vacuum. The crude residue thus obtained was dissolved in DMSO (dimethylsulfoxide) at a concentration of 1000µg/ml and employed for antimicrobial activity against test microorganisms like *Streptococcus mutans* (MTCC 497), *Staphylococcus aureus* (MTCC 3160), *Salmonella typhi* (ATCC 14028), *Pseudomonas aeruginosa* (ATCC 9027) and *Candida albicans* (ATCC 10231) by agar well diffusion method [22].

2.4 Effect of pH and Temperature

To determine the influence of initial pH on growth and bioactive metabolite production, the strain was cultivated in the medium with different initial pH values ranging from 5 to 10 for six days. The strain was inoculated into production medium and grown at temperatures ranging from 20 to 50°C at pH 7 for six days to study the impact of temperature. The biomass and bioactive metabolite production were estimated and optimal pH and temperature achieved in this step was used for subsequent study.

2.5 Effect of NaCl Concentration

The impact of salinity on growth and bioactive metabolite production by *S. gulbargensis* DAS 131was recorded by cultivating the strain in the fermentation medium amended with different concentrations of NaCl (1-10%) at optimum pH and temperature for six days. The salt concentration in which the strain exhibits optimum levels of bioactive metabolites was fixed for further studies.

2.6 Effect of Carbon and Nitrogen Sources

To determine the effect of carbon sources on biomass and bioactive metabolite production, different carbon sources like galactose, lactose, fructose, sucrose, glucose, starch, mannitol, arabinose, raffinose and rhamnose each at a concentration of 1% were added separately into the production medium, maintaining all other conditions at optimum levels. The effect of varying concentrations of the best carbon source (0.5-5%) on bioactive metabolite production was examined. Similarly, the influence of various nitrogen sources on antimicrobial metabolite production was evaluated by amending different nitrogen sources like soya peptone, arginine, asparagine, meat extract, yeast extract, tryptone, soya flour, casein, beef extract and glycine each at a concentration of 0.5% were individually supplemented into the production medium containing an optimum amount of the superior carbon source. The growth and production of bioactive metabolite was determined after six days of incubation at optimum pH, temperature and salt concentration. Further, the impact of varying concentrations of optimized nitrogen source (0.1-2%) was studied to standardize the maximum antimicrobial metabolite production.

2.7 Impact of K_2HPO_4

To study the impact of K_2HPO_4 on growth and bioactive metabolite production, the strain was grown in the fermentation medium amended with different concentrations of K_2HPO_4 (0.01 to 0.1%), maintaining all other conditions at optimum levels.

2.8 Statistical Analysis

Results on cell growth and the production of bioactive metabolites by *S. gulbargensis* DAS 131exposed to different cultural conditions are statistically analyzed with two way analysis of variance (ANOVA).

2.9 Bioassays

The metabolites produced by the strain under optimized conditions were tested against bacteria and fungi by agar-well diffusion assay [22]. The test microorganisms used to evaluate the production of bioactive metabolites were *Staphylococcus aureus* (MTCC 3160), *Streptococcus mutans* (MTCC497), *Bacillus subtilis* (ATCC6633), *Lactobacillus casei* (MTCC1423), *Lactobacillus acidophilus* (MTCC495), *Xanthomonas campestris* (MTCC2286), *Bacillus megaterium* (NCIM2187), *Escherichia coli* (ATCC35218), *Enterococcus faecalis* (MTCC439), *Pseudomonas aeruginosa* (ATCC 9027), *Salmonella typhi* (ATCC14028), *Proteus vulgaris* (MTCC7299), *Candida albicans* (ATCC10231), *Aspergillus niger* (ATCC1015), *Aspergillus flavus* (ATCC9643), *Fusarium oxysporum* (MTCC3075) *and Penicillium citrinum* (MTCC 6489).

3. RESULTS AND DISCUSSION

3.1 Effect of Incubation Period

The growth pattern of *S. gulbargensis* DAS 131 was studied on starch casein broth. Exponential phase of the strain extended from lag phase after 24h to 72h. After that it exhibited stationary phase from 96h to 144h of incubation, then declined (Fig.1).The results revealed that the antimicrobial metabolite was early produced and reached maximum at the stationary phase. The cessation of growth in the stationary phase is most commonly caused by the exhaustion of the essential nutrients of the medium as well as accumulation of undesirable metabolites. The secondary metabolites obtained from six day old culture exhibited high antimicrobial activity against the test microorganisms. Thakur et al. [7] stated that the maximum incubation period required for optimum growth and antibiotic yield by the isolate *Streptomyces* sp. 201 was six days which was in complete accordance with the earlier report [23]. The incubation period for the production of bioactive metabolites seems to vary among *Streptomyces* strains. Metabolites elaborated from 5 day old culture of *Streptomyces* sp. KGG32 [24] and *S.ramulosus*-AZ-SH-29 [25] showed good antimicrobial activity. Metabolites collected from 10-day old culture of *S. crystallinus* AZ-A151producing Hygromycin-B exhibited good anti-microbialactivity [26].

3.2 Effect of Initial pH and Incubation Temperature

The environmental requirements and cultural conditions for growth and bioactive metabolite production by *S. gulbargensis* DAS 131 were studied. The antimicrobial metabolite production was found to be influenced by pH of the medium. The maximum biomass and bioactive metabolite production by the strain was obtained at pH 7 suggesting its inclusion in the neutrophilic actinomycetes group (Fig. 2). Medium maintained at pH 7.0 was reported to support enhanced anti-microbial metabolite production by *Streptomyces rochei* G 164 [27], *Streptomyces marinensis* [28], *Streptomyces albidoflavus* [21], *Streptomyces torulosus* KH-4 [29], *Streptomyces* spp.VITSVK9 [30] and *Streptomycesc heonanensis* VUK-A [31].

The effect of temperature on growth and bioactive metabolite production of the strain was recorded (Fig. 3). There was an increase in the growth as well as bioactive metabolite production with the increase of incubation temperature from 20ºC to 35ºC. However further increase in temperature (above 35ºC) resulted in the decline of growth and bioactive metabolite production. In terms of its optimum temperature for growth, the organism appeared to be mesophilic in nature. Atta et al. [26] reported that *Streptomyces crystallinus*,

AZ-A151 produced high levels of Hygromycin-B production at 35ºC. Ushakiranmayi et al. [32].stated that the optimum temperature capable of promoting antimicrobial metabolite produced by *Pseudonocardia* sp.VUK-10 isolated from Nizampatnam mangrove ecosystem was 35ºC.

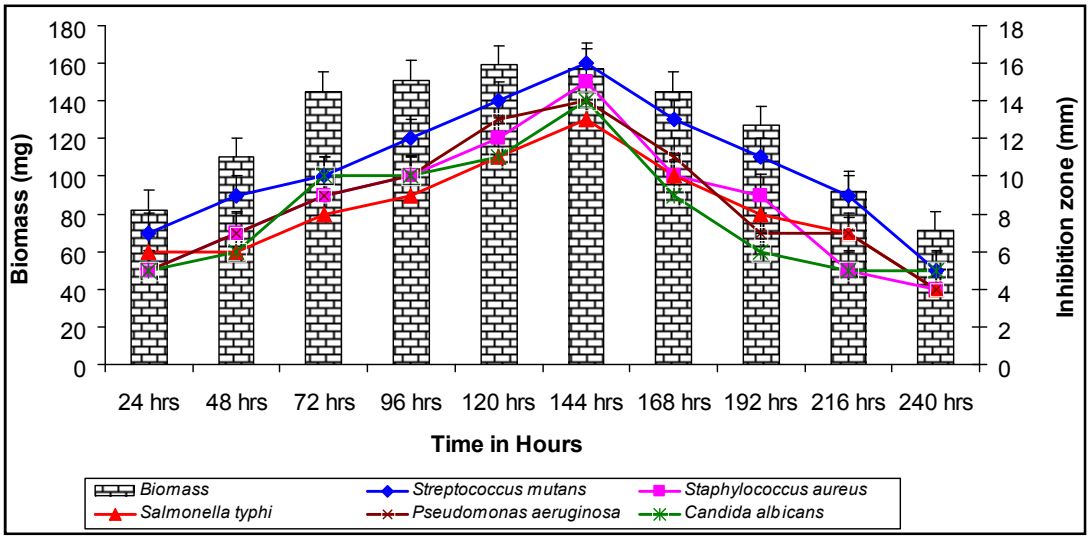

Fig. 1. Growth pattern and anti-microbial activity of *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

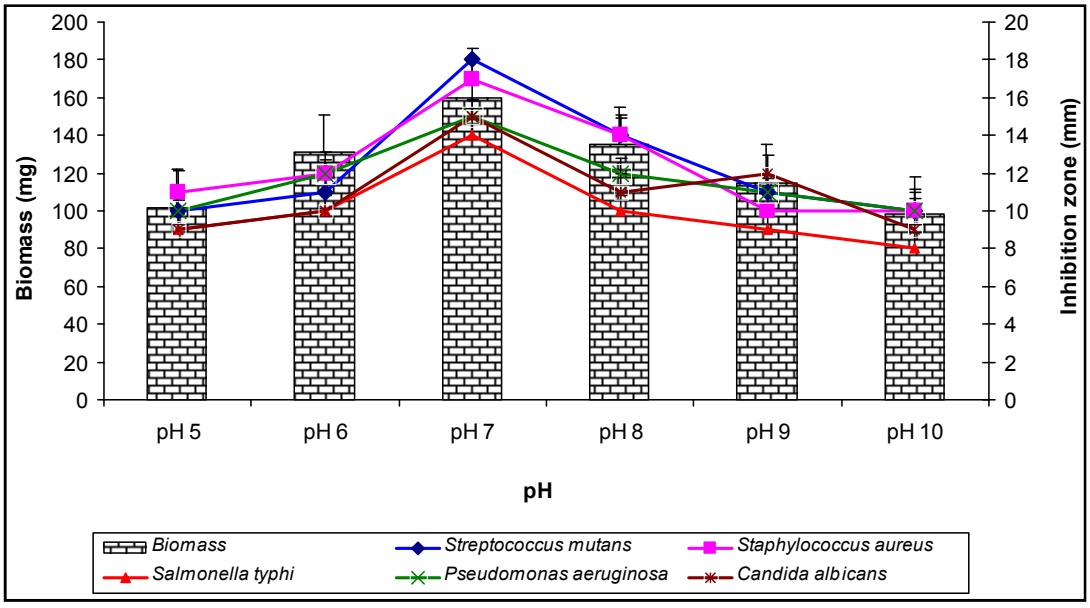

Fig. 2. Effect of pH on growth and bioactive metabolite yield of *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

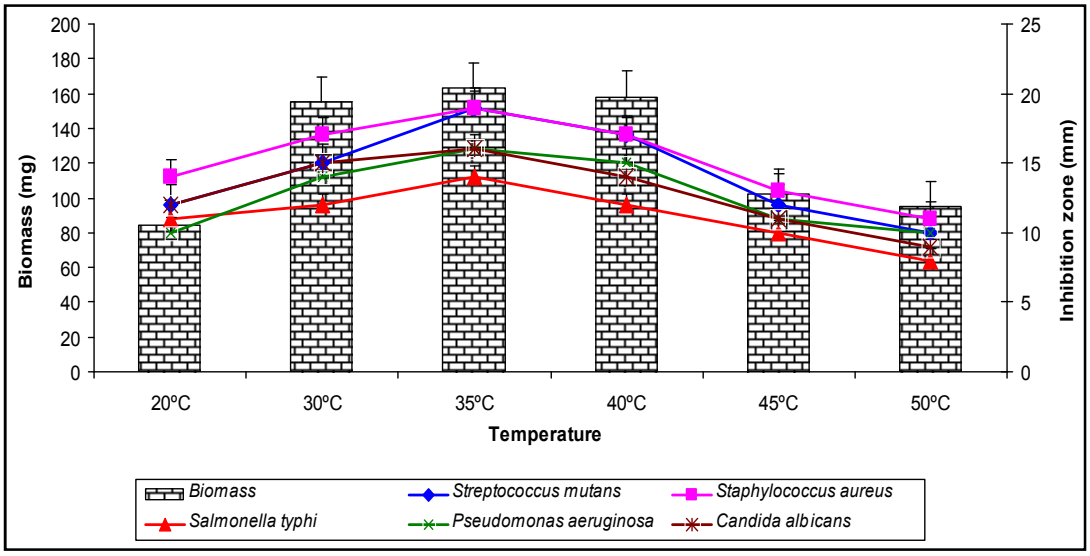

Fig.3. Effect of temperature on growth and bioactive metabolite yield of *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

3.3 Effect of NaCl

Optimum salt requirement for bioactive metabolite production was examined in the production medium supplemented with different salt concentrations ranging from 1-10%. NaClat the concentration of 5% was found to be optimum for maximum growth as well as antimicrobial compound production by *S. gulbargensis* DAS 131(Fig. 4). Further increase in salt concentration reduced the antimicrobial agent biosynthesis. The requirement of NaCl for the production of bioactive metabolites seems to be different among actinomycete strains. Optimum NaCl concentration for maximum growth as well as antimicrobial metabolite production was reported to be 2% for *Streptomyces tanashiensis* A2D [2], 1% for *Streptomyces felleus* YJ1 [33]and 5% for *Streptomyces* VITSVK9 [30].

3.4 Effect of Carbon and Nitrogen Sources

The effect of carbon sources on biomass and bioactive metabolite production by *S. gulbargensis* DAS 131 was evaluated (Fig.5). The production of biomass was high with lactose followed by sucrose and starch, while significant bioactive metabolite production was obtained by the strain in glucose amended media followed by galactose and fructose. El-Enshasy et al. [34] reported that glucose and sucrose in pure or in polymer forms were the best C-sources for erythromycin production. Antibiotic production from alkaliphilic *S.tanashiensis* strain A2D was high in medium containing glucose as carbon source [2]. Similarly glucose was found to be the best carbon source for antibiotic production by *Streptomyces torulosus* KH-4 [29], *S. griseocarneus* [35] and *S. kanamyceticus* M27 [36].

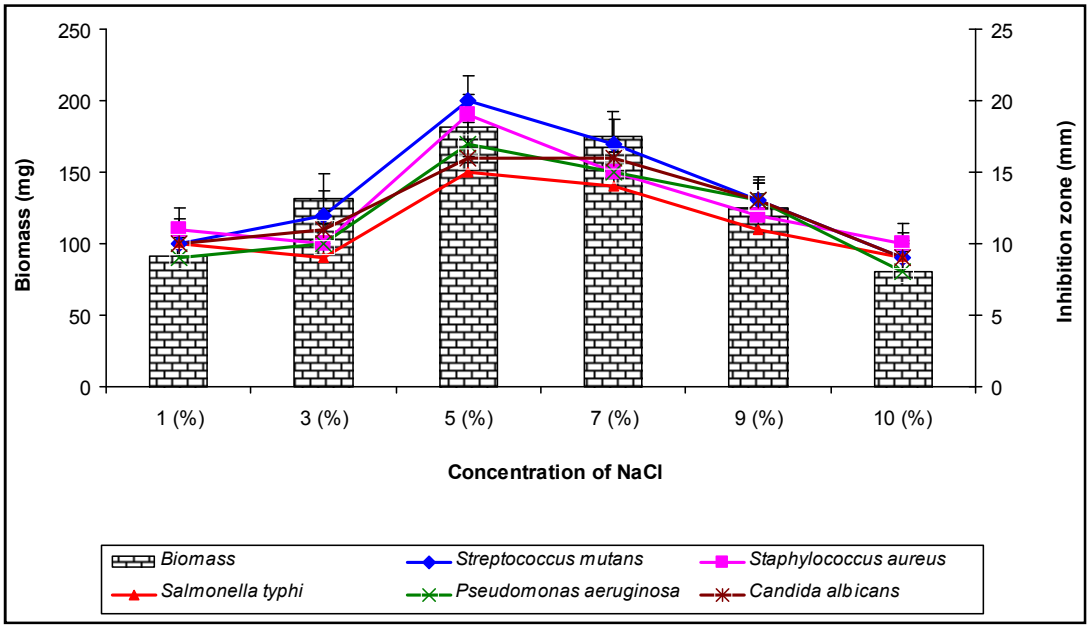

Fig. 4. Effect of NaCl on growth and bioactive metabolite yield of *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

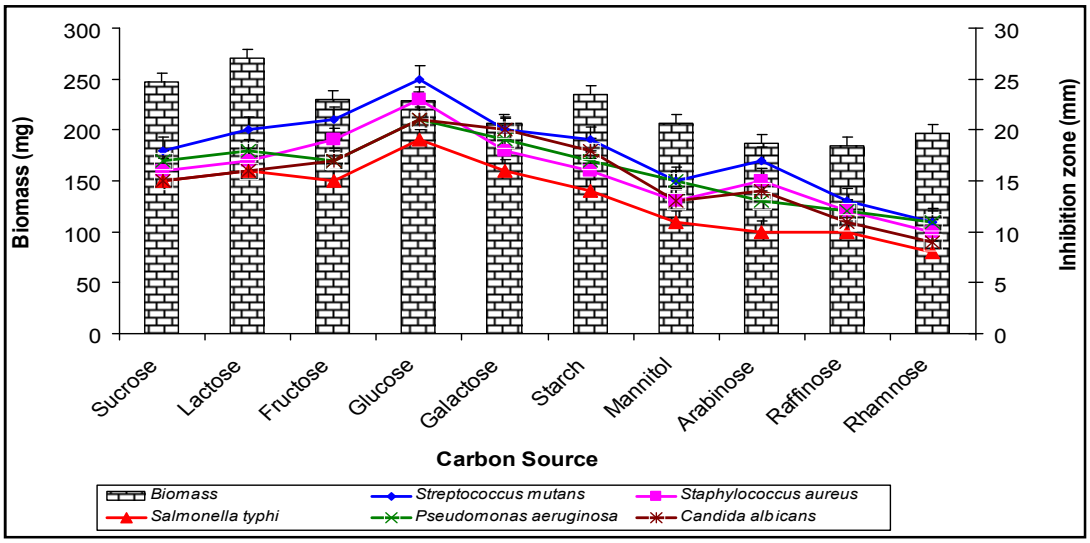

Fig. 5. Effect of different carbon sources on growth and bioactive metabolite yield of *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

As glucose emerged as the most preferred carbon source for bioactive metabolite production by the strain, varying concentrations of glucose (0.5-5%) was tested to determine its optimal

concentration. It is noted that glucose at 3% and 2% concentrations showed optimal yields of biomass and bioactive metabolites respectively (Fig. 6). Medium containing 2% glucose supported maximum levels of Natamycin production by *Streptomyces natalensis* and *Thermomonospora* sp. [37,38] while Atta et al. [25] reported that medium containing 2.5% glucose supported antibiotic production by *Streptomyces ramulosus* AZ-SH-29.

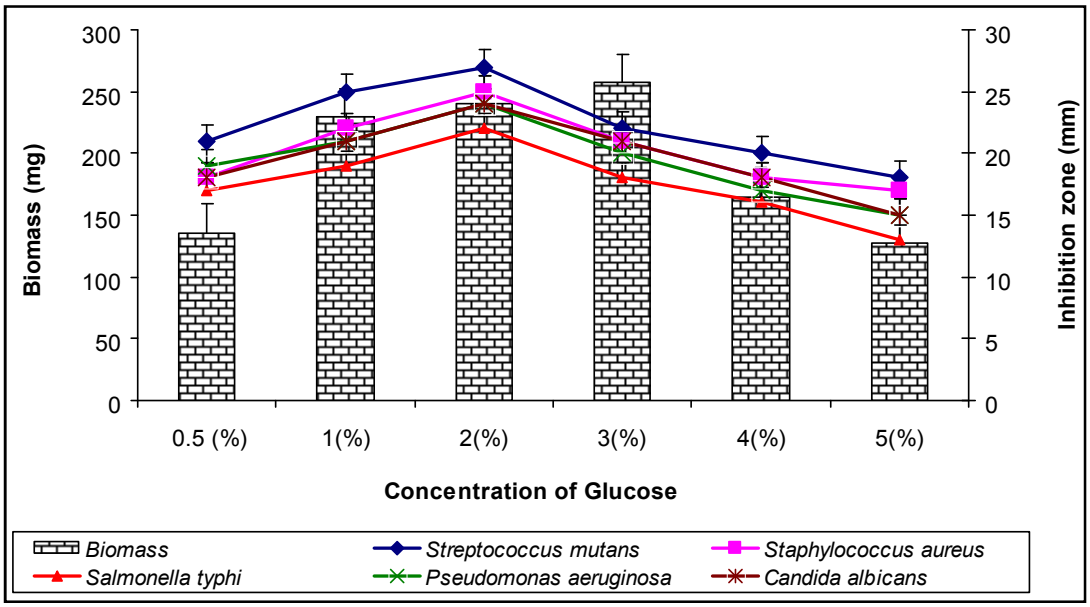

Fig. 6. Effect of different concentrations of glucose on growth and production of bioactive metabolite by *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

Nitrogen sources are important for the production of bioactive metabolites by microorganisms. Changes in the nature and concentration of nitrogen source seem to affect antibiotic biosynthesis in different organisms. Different nitrogen sources were found to have significant effect on growth and secondary metabolite production by *S. gulbargensis* DAS 131. Among the nitrogen sources tested amendment of soya peptone in the culture medium enhanced the biomass and bioactive metabolite production by the strain (Fig. 7). Viana et al. [39] recorded that soya bean flour increased the clavulanic acid production by *Streptomyces* DAUFPE 3060. In contrast Thakur et al. [7] found that basal medium amended with asparagine as nitrogen source was proved to be the best for 2-methylheptyl isonicotinate production by *Streptomyces sp.*201.

Influence of different concentrations of soya peptone on the production of bioactive metabolites is represented in (Fig.8). It is noted that soya peptone at a concentration of 1.5% and 1% exhibited optimal production of biomass and bioactive metabolites respectively. Himabindu and Jetty [40] reported that soya bean meal at a concentration of 1% and 0.5% enhanced growth and gentamicin production by *Micromonospora echinospora.* Whereas Qin Song et al. [33] stated that soya bean meal at a concentration of 2% increased the bioactive metabolite production by *Streptomyces felleus* YJ1.

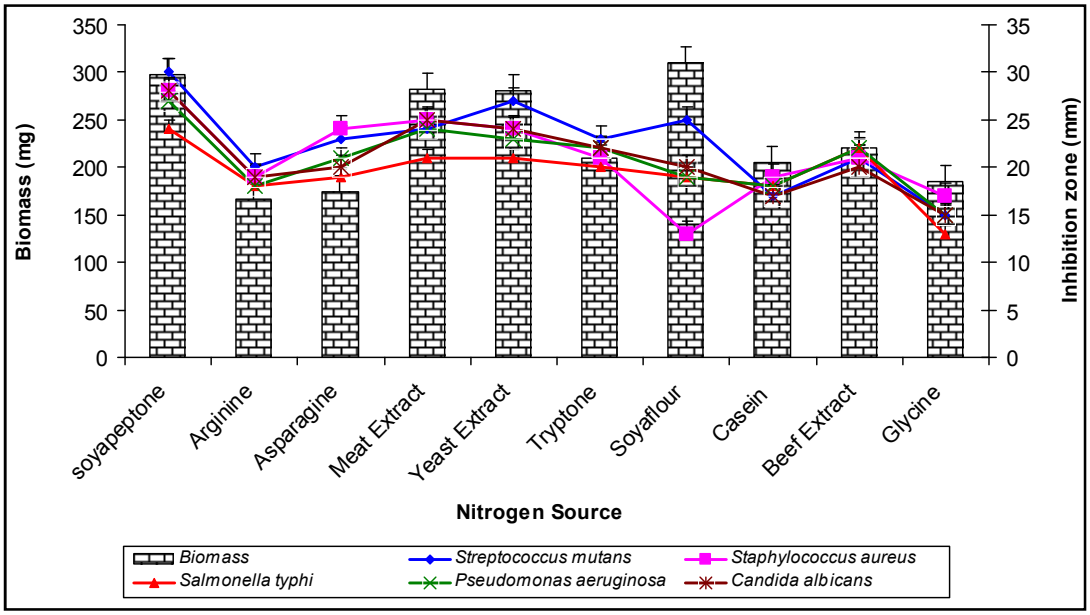

Fig. 7. Effect of different nitrogen sources on growth and bioactive metabolite production by *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

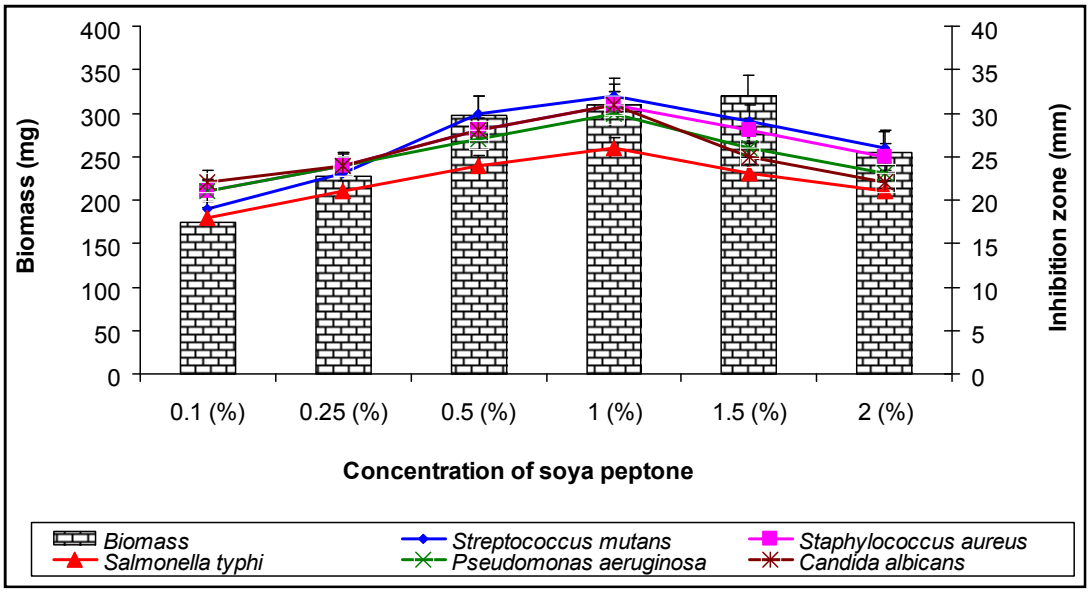

Fig. 8. Effect of different concentrations of soya peptone on growth and production of bioactive metabolite by *S. gulbargensis* DAS 131

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

3.5 Effect of K_2HPO_4

Effect of K_2HPO_4on biomass and bioactive metabolite production by the strain was studied (Fig. 9). A slight enhancement in growth and antimicrobial activity was obtained in medium supplemented with 0.05% of K_2HPO_4. Ripa et al. [41] reported that among different minerals tested, K_2HPO_4 showed positive influence on antibiotic production by *Streptomyces* RUPA-08PR. Narayana and Vijayalakshmi [21] also recorded that K_2HPO_4 slightly enhanced the production of biomass and bioactive metabolites of *Streptomyces albidoflavus.* Production of gentamicin by *M. purpurea* and antibiotic tylosin by a *Streptomyces* sp. was inhibited by high phosphate concentrations [42,43].

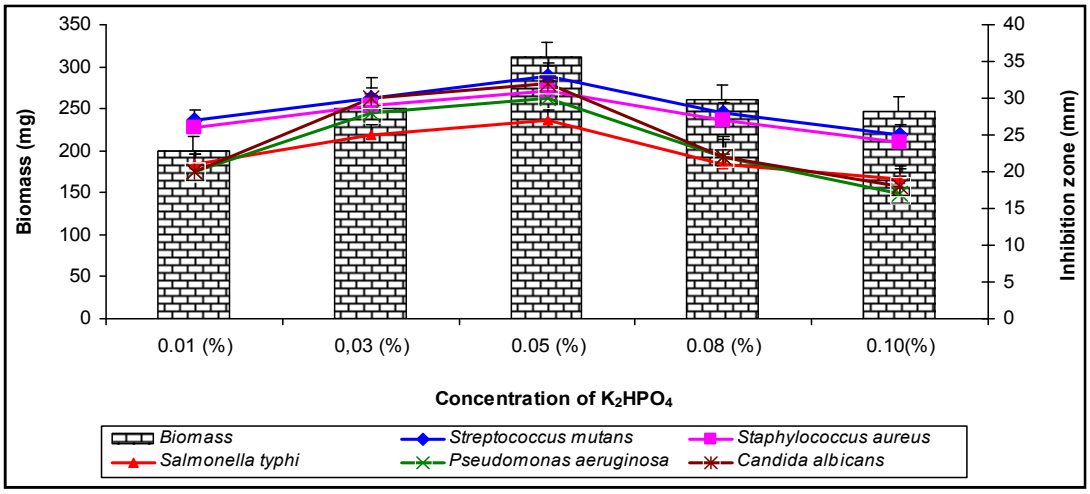

Fig. 9. Impact of K_2HPO_4 on growth and bioactive metabolite production of *S. gulbargensis* DAS 131*

**Data on cell growth and bioactive metabolite yield were statistically analyzed by Two-way ANOVA and found to be significant at 1%*

3.6 Bioassays

The antimicrobial metabolite produced by the strain under optimized conditions was tested against various test bacteria and fungi (Table 1) (Fig.10). Among the bacteria tested, *Xanthomonas campestris* (MTCC2286) and *Bacillus megaterium* (NCIM2187) were highly sensitive to the metabolites produced by *S. gulbargensis* DAS 131followed by *Streptococcus mutans* (MTCC497) and *Enterococcus faecalis* (MTCC439).Among the fungi tested, *Candida albicans* (ATCC10231) was highly sensitive to the metabolites produced by the strain followed by *Aspergillus niger* (ATCC1015) and *Aspergillus flavus* (ATCC9643). A significant antimicrobial activity was reported on the opportunistic and pathogenic bacteria and fungi tested.

Table1. Antimicrobial activity of *S. gulbargensis* DAS 131 against opportunistic and pathogenic bacteria and fungi under optimized conditions

Antimicrobial Activity of Bioactive Metabolite Produced by *S. gulbargensis* DAS 131 under Optimized Conditions	
Bacteria	
Test Microorganisms	**Zone of Inhibition(mm)**
Staphylococcus aureus(MTCC3160)	31
Streptococcus mutans(MTCC497)	33
Bacillus subtilis(ATCC6633)	30
Lactobacillus casei(MTCC1423)	32
Lactobacillus acidophilus(MTCC495)	31
Xanthomonas campestris(MTCC2286)	34
Bacillus megaterium(NCIM2187)	33
Escherichia coli (ATCC35218)	31
Enterococcus faecalis(MTCC439)	33
Pseudomonas aeruginosa(ATCC9027)	30
Salmonella typhi(ATCC14028)	27
Proteus vulgaris(MTCC7299)	28
Fungi	
Candida albicans(ATCC10231)	32
Aspergillus niger(ATCC1015)	27
Aspergillus flavus(ATCC9643)	26
Fusarium oxysporum(MTCC3075)	19
Penicillium citrinum(MTCC6489)	20

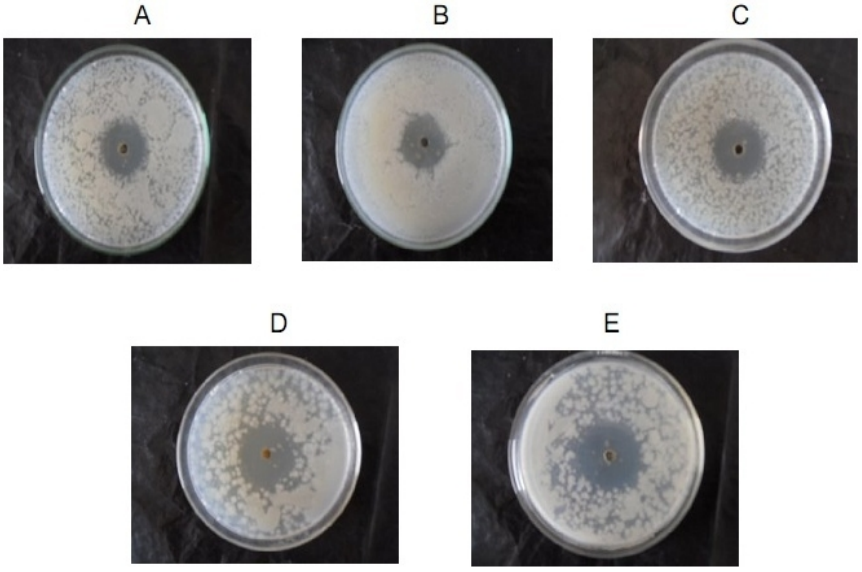

Fig. 10. Antimicrobial activity of S. *gulbargensis* DAS 131 against A. *Pseudomonas aeruginosa* (ATCC 9027) B. *Escherichia coli* (ATCC35218) C. *Salmonella typhi* (ATCC14028) D. *Bacillus subtilis* (ATCC6633) E. *Candida albicans* (ATCC10231)

4. CONCLUSION

In the present study *S. gulbargensis* DAS 131 exhibited high antimicrobial activity when cultured on production medium amended with glucose (2%), soya peptone (1%), NaCl (5%) and K_2HPO_4 (0.05%) at pH 7 for six days of incubation at 35°C. Among the bacteria tested, *Xanthomonas campestris* and *Bacillus megaterium* were highly sensitive to the metabolites produced by the strain while *Candida albicans* exhibited high sensitivity followed by *Aspergillus niger*among fungi. This is the first report on the optimization of bioactive metabolites produced by *S. gulbargensis* DAS 131.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

ACKNOWLEDGEMENT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bérdy J. Bioactive microbial metabolites. J Antibiot. 2005;58(1):1-26.
2. Singh LS, Mazumdar S, Bora TC. Optimization of process parameters for growth and bioactive metabolite production by a salt-tolerant and alkaliphilic actinomycete, *Streptomyces tanashiensis* strain A2D. Journal de Mycologie Medicale. 2009;19(4):225-223.
3. Blunt JW, Copp BR, Munro MHJ, Northcote PT, Prinsep MR. Marine natural products. Natural Product Reports. 2010;27(2):165-237.
4. Shuvankar B, Syed GD, Savita K. Biotechnological significance of actinobacterial research in India. Recent Research in Science and Technology. 2012;4(4):31-39.
5. Hopwood DA. Therapeutic treasures from the deep. Nature Chemical Biology. 2007;3(8):457-458.
6. Mitsuiki S, Sakai M, Moriyama Y, Goto M, Furukawa K. Purification and some properties of keratinolytic enzyme from an alkaliphilic *Nocardiopsis* spp. TOA-1. Biosci Biotechnol Biochem. 2002;66(1):164-167.
7. Thakur D, Bora TC, Bordoloi GN, Mazumdar S. Influence of nutrition and culturing conditions for optimum growth and antimicrobial metabolite production by *Streptomyces* spp. 201. Journal of Medical Mycologic. 2009;19(3):161-167.
8. Dietera A, Hamm A, Fiedler HP, Good fellow M, Muller WA, Brun RP. An antibiotic, antiparasitic and antitumor compound produced by a novel alkaliphilic *Streptomyces* strain. J Antibiot. 2003;56(7):639-646.

9. Cai P, Kong F, Fink P, Ruppen ME, Williamson RT, Keiko T. Polyene Antibiotics from *Streptomyces mediocidicus*. J Nat Prod. 2007;70(2):215-219.
10. Chen C, Si S, He Q, Xu H, Lu M, Xie Y. Isolation and characterization of antibiotic NC0604, a new analogue of bleomycin. J Antibiot. 2008;61(12):747-751.
11. Hohmann C, Schneider K, Bruntner C, Irran E, Nicholson G, Bull AT. Caboxamycin, a new antibiotic of the benzoxazole family produced by the deep-sea strain *Streptomyces* spp. NTK 937. J Antibiot. 2009;62(2):99-104.
12. Adinarayana K, Prabhakar T, Srinivasulu V, Rao AM, Jhansi LP. Optimization of process parameters for cephalosporin C production under solid state fermentation from *Acremonium chrysogenum*. Process Biochem. 2001;39(2):171-177.
13. Noaman NH, Fattah A, Khaleafa M, Zaky SH. Factors affecting antimicrobial activity of *Synechococcus leopoliensis*. Microbiol Res. 2004;159(4):395-402.
14. Basak K, Majumdar SK. Mineral nutrition of *Streptomyces kanamyceticus* for Kanamycin formation. Antimicrob Agents Chemother. 1975;8(4):391-395.
15. Loun'es A, Lebrihi A, Benslimance C, Lefebvre G, Germain P. Regulation of spiramycin synthesis in *Streptomyces ambofaciens*: effect of glucose and inorganic phosphate. J Microbiol Biotechnol. 1996;45(1-2):204-211.
16. Moita C, Feio SS, Nunes L, Joa M, Curto M. Optimization of physical factors on the production of active metabolites by *Bacillus subtilis* 355 against wood surface contaminant fungi. Int Biodeterior Biodegrad. 2005;55(4):261-269.
17. Krishnakumar S, Premkumar J, Alexis Rajan R, Ravikumar S. Optimization of potential antibiotic production by salt-tolerant actinomycetes *Streptomyces* spp. MSU29 isolated from marine sponge. Int J Applied Bioengineering. 2011;5(2):12-17.
18. Kuster K, Williams ST. Selection of media for isolation of *Streptomycetes*. Nature. 1964;202(4935):928-929.
19. Williams ST, Cross T. Isolation, Purification, Cultivation and Preservation of Actinomycetes. In Booth C, editor. Methods Microbiology. 1971;4:295-334.
20. Dastager GS, Wen A, Dayanand BS, Mudgulkar KT, Shu PT, Xin, Xiao YZ. *Streptomyces gulbargensis*sp.nov, isolated from soil in Karnataka, India. Antonie van Leeuwenhoek. 2007;91(2):99-104.
21. Narayana KJP, Vijayalakshmi M. Optimization of antimicrobial metabolites production by *Streptomyces albidoflavus*. Research journal of pharmacology. 2008;2(1):4-7.
22. Cappuccino JG, Sherman N. Microbiology, Laboratory manual. Person education, INC, New Delhi; 2004.
23. Yarbrough GG. Screening microbial metabolites for new drugs, theoretical and practical issues. J Antibiot. 1993;46(4):535-544.
24. Oskay M. Effects of some Environmental Conditions on Biomass and Antimicrobial Metabolite Production by *Streptomyces* spp., KGG32. Int J Agric Biol. 2011;13(3):317-324.
25. Atta HM, Haroun BM, El-Sehrawi MH. Physico-chemical characteristics of vernamycin-A antibiotic biosynthesis by *Streptomyces* SP-AZ-SH-29. J Saudi Chem Soc. 2011;15(3):247-255.
26. Atta HM, Afifi MM, Elshanawany AA, Abdoul-raouf AU, El-Adly AM. Production of Hygromycin-B antibiotic from *Streptomyces crystallanius*. AZ-A151: II. Parameters controlling of antibiotic production. Academia Arena. 2012;4(3):37-52.
27. Chattopadhyay D, Sen SK. Optimization of cultural conditions for antifungal antibiotic accumulated by *Streptomyces rochei* G 164. Hindustan Antibiot Bull. 1997;39(1):64-71.

28. Adinarayana K, Ellaiah P, Srinivasulu B, Bhavani R, Adinarayana G. Response surface methodological approach to optimize the nutritional parameters for neomycin production by *Streptomyces marinensis* under solid state fermentation. Process Biochemistry. 2003;38(11):1565-1572.
29. Atta HM, Bayoumi R, El-Sehrawi M, Aboshady A, Al-Humiany A. Biotechnological application for producing some anti-microbial agents by actinomycetes isolates from Al-Khurmah Governorate. European Journal of Applied Sciences. 2010;2(3):98-107.
30. Saurav K, Kannabiran, K. Diversity and Optimization of process parameters for the growth of *Streptomyces* VITSVK 9sp. Isolation from Bay of Bengal, India. Journal of Natural and Environment sciences. 2010;1(2):56-65.
31. Ushakiranmayi M, Sudhakar P, Krishna N, Vijayalakshmi M. Influence of cultural conditions for improved production of bioactive metabolites by *Streptomyces cheonanensis* VUK-A isolated from Coringa Mangrove Ecosystem. Current Trends in Biotechnology and Pharmacy. 2012;6(1):99-111.
32. Mangamuri Usha Kiranmayi, Poda Sudhakar, Kamma Srinivasulu, Muvva Vijayalakshmi. Optimization of culturing conditions for improved production of bioactive metabolites by *Pseudonocardia* spp. VUK-10. Mycobiology. 2011;39(3):174-181.
33. Qin Song, Yun Huang, Hui Yang. Optimization of fermentation conditions for antibiotic production by actinomycetes YJ1 strain against *Sclerotinia sclerotiorum*. J Agri Sci. 2012;4(7):95-102.
34. El-Enshasy HA, Mohamed NA, Farid MA, El-Diwany AI. Improvement of erythromycin production by *Saccharopolyspora erythrea* in molasses based medium through cultivation medium optimization. Bioresour Technol. 2008;99(10):4263-4268.
35. Cruz R, Arias ME, Solveri J. Nutritional requirements for the production of phyla zoloisoquinolinone antibiotic by *Streptomyces griseocarneus* NCIMB 40447. Appl Microbiol Biotechnol. 1999;53(1):115-119.
36. Pandey A, Shukla A, Majumdar SK. Utilization of carbon and nitrogen sources by *Streptomyces kanamyceticus* M 27 for the production of an anti bacterial antibiotic. Afr J Biotechnol. 2005;4(9):909-910.
37. Farid MA, El-Enshasy HA, Ei-Diwany AI, El-sayed EA. Optimization of the cultivation medium for Natamycin production by *Streptomyces natalensis*. J Basic Microbiol. 2000;40(3):157-166.
38. Gupte M, Kulkarni P. A study of anti-fungal antibiotic production by *Thermomonospora* spp. MTCC 3340 using full factorial design. J Chem Tech Biotechnol. 2003;78(6):605-610.
39. Viana DA, Carneiro-Cunha MN, Araujo JM, Barros-Neto B, Lima-Filho JL, Converti A, et al. Screening of variables influencing the Clavulanic Acid Production by *Streptomyces* DAUFPE 3060 strain. Appl Biochem Biotechnol. 2010;160(6):1797-1807.
40. Himabindu M, Annapurna J. Optimization of nutritional requirements for gentamicin production by *Micromonospora echinospora.* Indian J Experimental Biol. 2006;44:842-848.
41. Ripa FA, Nikkon F, Zaman S, Khondkar P. Optimal conditions for antimicrobial metabolites production from a new *Streptomyces* spp. Rupa-08 isolated from Bangladesh Soil. Mycobiology. 2009;37(3):211-214.
42. Wu JY, Jenn-Wen H, Sin-Der SH, Wei-Chenand L, Yungehuan L. Optimization of cultivation conditions for fungi chromin production from *Streptomyces padanus* PMS-702. J Chin instChem Eng. 2008;39(6):67-73.

43. Majumdar MK, Majumdar SK. Effect of minerals on neomycin production by *Streptomyces fradiae*. ApplMicrobiol. 1965;13(2):190-193.

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