

Novel Triazine Centred Manganese Based Complex: A Photophysical and Biological Studies

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In this work, Mn(II) complex of triazine based ligand has been synthesized and characterized using various physico-chemical methods including C,H,N elemental analysis, FT-IR, ¹H NMR and EI-mass analysis. The synthesized compounds serve as potential photoactive material as indicated from its characteristic fluorescent properties. The ligand and its metal complex were assayed for *in vitro* antimicrobial activity on four bacterial strains (*S. aureus*, *B. subtilis*, *E. coli* and *K. pneumoniae*) using well-diffusion method and it was observed that metal complex showed enhanced antimicrobial activity against all tested strains as compared to ligand.

Keywords: Triazine, Mn(II) complex, Fluorescent properties, Antimicrobial activity.

INTRODUCTION

1,3,5-Triazine (*s*-triazine) derivatives are salient class of heterocyclic compounds [1] that have an excellent potential for the formation in coordination chemistry, supramolecular chemistry and in material chemistry due to their π -interaction abilities and H-bond networks [2]. Triazines are heterocyclic analogue of benzene containing three nitrogen atoms with molecular formula C₃H₃N₃. Molecules containing triazine skeletons show considerable biological activities and used as precursors for the synthesis of various biologically active compounds [3-5]. The *s*-triazine scaffold provides the basis for the design of compounds with a variety of properties useful in medicinal and agricultural applications [6] having anti-malarial, antiviral, antibacterial, antifungal [7], antineoplastic [8], fungicides, insecticides, herbicides, anti-oxidant [9], anti-cancer, estrogen receptor modulators, anti-tubercular and anti-inflammatory activities [7] besides increased efficiency for the corrosion protection of steel in acidic solution in electro-chemical process [1].

Since there is a rapid development of pathogen resistance to most of the known antibiotics is becoming a serious health problem, to synthesis a new derivative of chalcone [6] based *s*-triazine to enhance the pharmacological activities is a requirement. It is well known that metal ions present in complexes

accelerate the drug action and the efficacy of the organic therapeutic agents. The pharmacological efficiencies of metal complexes depend on nature of the metal ions and the ligands. Manganese complex of nitrogen-oxygen chelating agents derived from Schiff bases have been studied extensively due to their pronounced applications in biological, clinical, analytical and pharmacological areas [10]. So, there is an increasing requirement for the discovery of new compounds having antimicrobial, antioxidant and antitubercular activities [11]. In an attempt to find a new class of agents, a novel Mn based chalcone bearing 1,3,5- triazine complex is synthesized using Claisen-Schmidt condensation with appropriate chemical reagents. The presence of α,β -unsaturated carbonyl moiety as well as of substituted aromatic rings renders the chalcones to possess a wide range of pharmacological activities such as cytotoxic, antiretroviral, antimalarial, antiplatelet, antitubercular, antimicrobial, *etc.* [6].

Manganese is an essential trace element for living creatures and its trace amount range is 16.00 - 443 ppb which is within the proper level according to the WHO guide [12]. It is widely distributed in soil, sediment, water and in biological materials. Manganese is used as a benign catalyst under mild conditions [13] and manganese sulfate is used to make a fungicide. Mn(III) complexes have been proposed as mimetics of anti-oxidant enzymes such as catalase and superoxide dismutase.

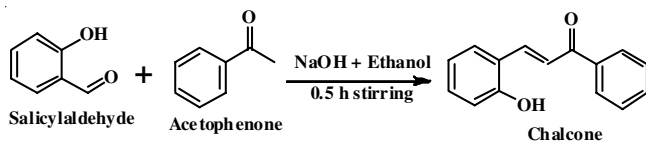
Mn(III)-citrate is believed to be the main Mn species to assess the brain in humans, leading to a cascade of redox-active based neurotoxic events [14]. Herein, we report the synthesis, spectral characterization, bioscreening and fluorescence study of Mn based metal complex derived from ligand which is formed from salicylaldehyde and acetophenone in combination with 6-phenyl-1,3,5-triazine [15-17]. The chemical structures of the ligand and complex are established on the basis of their FT-IR, ¹H NMR, UV, mass as well as elemental analysis. The newly designed compound is assayed for its *in vitro* antimicrobial activity against selected pathogens by well diffusion method.

EXPERIMENTAL

2,4-Diamino-6-phenyl-1,3,5-triazine, 3-formylchromone, sodium hexafluorophosphate, salicylaldehyde were procured from Sigma-Aldrich. The other chemicals *viz.* acetophenone, NaOH, ethanol, dichloromethane and MnCl₂·4H₂O were obtained from various reliable sources.

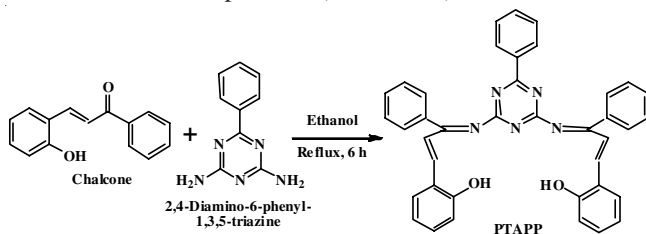
Synthesis of ligand

Synthesis of chalcone [(*E*)-3-(2-hydroxyphenyl)-1-phenylprop-2-en-1-one]: A solution of acetophenone (6 mL, 51 mmol) and salicylaldehyde (5.77 mL, 54 mmol) was dissolved at 0 °C in mixture of NaOH (3M, 20 mL) and ethanol (15 mL). It was stirred for 0.5 h and then heated in microwave oven at 360 °C for 30 s (4 times). It was cooled and the reddish black precipitate formed was filtered and recrystallized using ethanol (**Scheme-I**). The product was finally dried at room temperature.



Scheme-I: Synthesis of chalcone

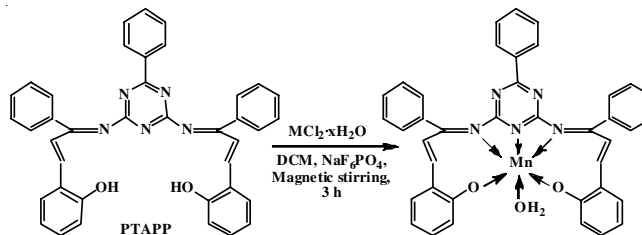
Synthesis of 2,2'-(6-phenyl-1,3,5-triazine-2,4-diyl)bis-(azanylylidene))bis(3-phenylprop-1-en-1-yl-3-ylidene))-diphenol (PTAPP): A solution of chalcone (4.4816 g, 20 mmol) and 6-phenyl-1,3,5-triazine-2,4-diamine (2 g, 1 mmol) was dissolved in minimum amount of ethanol and stirred under reflux for 6 h. The dark brown powder formed was filtered and recrystallized from ethanol and finally dried the product in vacuum at room temperature (**Scheme-II**).



Scheme-II: Synthetic scheme of ligand 2,2'-(6-phenyl-1,3,5-triazine-2,4-diyl)bis-(azanylylidene))bis(3-phenylprop-1-en-1-yl-3-ylidene))-diphenol (PTAPP) ligand

Synthesis Mn-PTAPP complex: MnCl₂·4H₂O was heated in a hot air oven for 2 h to remove the hydrated water molecules.

A solution of PTAPP ligand (0.59968 g, 1 mmol) in DCM-ethanol (50 %) was added to equimolar quantity of MnCl₂ (anhydrous). and stirred for 1 h. A spatula of sodium hexafluorophosphate was then added and then mixture was stirred magnetically for 3 h (**Scheme-III**). The product formed was filtered and recrystallized in hot ethanol and finally dried in vacuum at room temperature.



Scheme-III: Formation of [Mn-PTAPP] complex

RESULTS AND DISCUSSION

Infrared analysis: IR spectral analysis of free ligand and its metal complexes revealed the involvement of coordination sites in chelation [18,19]. The infrared spectral data of complex Mn-PTAPP is given in Table-1. The broad band observed in 3443-3394 cm⁻¹ region is assigned to the -OH stretching vibration of hydrate molecules. The band at 3216 cm⁻¹ corresponds to the *sp*² C-H stretch. The band exhibited at 1617 cm⁻¹ refers to stretching frequency of ν(C-O) of the ring. The band located at 2095 cm⁻¹ is attributed to stretching frequency ν_{asy}(N⁻). Further, the two bands observed at 1389 and 1323 cm⁻¹ are assigned to ν_{asy}(C-O) and ν_{sy}(C-O) [10]. The bands at 1389 and 1323 cm⁻¹ are referred to the presence of ν(C-N). The band at 817 cm⁻¹ refers to (C-N, *s*-triazine) and the same is reaffirmed by the band at 826 cm⁻¹ [6]. Two bands in the region (482-439 cm⁻¹) correspond to ν(Mn-N) and ν(Mn-O) as new bands [10]. The peak at 1537 cm⁻¹ corresponds to C=N stretch, which confirms the condensation reaction between chalcone and 6-phenyl-2,4-diaminotriazine. A peak at 1389 cm⁻¹ is due to C-N bending vibration. The three peaks observed at 1323 cm⁻¹ can be attributed to the C-O bending vibration of phenolic moiety. The band at 985 cm⁻¹ is due to 1,2-disubstituted *trans*-alkene. The peak at 817 cm⁻¹ arises due to C-H out of plane bending. A peak due to *o*-substitution of phenyl ring is observed at 746

TABLE-1
IR VIBRATION DETAILS OF Mn-PTAPP LIGAND

System	Vibration mode	Band position (cm ⁻¹)
Metal	Mn-O	439
Metal	Mn-N	482
Phenyl substitution on <i>s</i> -triazine	<i>o</i> -substitution	746
Alkene	C-H out of plane bending	826
Alkene	1,2-disubstituted <i>trans</i> alkene	985
Phenolic	C-O-H bending	1237
Phenolic	C-O bending	1323
Imine	C-N bending	1389
Imine	C=N	1537
Aromatic	Overtone	1899, 2095
Alkene	C=C-H stretching	3186
Phenolic	-OH	3394

cm^{-1} . The bands correspond to 439 and 482 cm^{-1} are due to $\nu(\text{Mn-O})$ and $\nu(\text{Mn-N})$ stretching, respectively, which confirms the coordination of manganese ion to PTAPP ligand. This suggests that imino nitrogen is coordinated to manganese metal ion.

UV absorption analyses: The UV-Vis absorption spectrum of the metal and ligand mixture was recorded in DMF solution. The spectrum of complex is dominated by intense intra-ligand charge transfer bands. The geometries are supported by their electronic spectra [20]. Absorption spectrum of the ligand is characterized by three strong absorption bands with major maxima at 211, 253 and 325 nm (Fig. 1). The absorption spectrum of metal complex is characterized by three strong absorption bands with major maxima at 239, 293 and 360 nm [21] (Fig. 2). For the metal complex the first two peaks lie at range 239 and 293 nm refer to 41841 and 34,129 cm^{-1} , respectively indicating $n \rightarrow \pi^*$ transitions, the third peak lies at 360 nm range refers to 27,777 cm^{-1} indicating $n-\pi^*$ transition. The different transitions exhibit bathochromic shift or hypsochromic shift when compared with that of free ligand (HL) leading to a square pyramidal structure [10,22].

^1H NMR analysis: ^1H NMR spectral analysis of the ligand PTAPP was carried out using Bruker 500 MHz and the solvent used was DMSO. The ^1H NMR spectra for PTAPP shows a broad

peak due to the two phenolic protons at 5.32 ppm. Two doublet peaks at 5.81 and 7.14 ppm are due to four alkene protons of chalcone. A multiplet peak in the range 7.32-7.72 ppm corresponding to thirteen protons, doublets at 7.75, 7.82, 8.12 and 8.37 ppm corresponding to two protons each are attributed to the aromatic protons (Table-2).

Signal position	Relative no of protons	Multiplicity	Inference
5.32	2H	br	OH
5.81	2H	d	-C=CH
7.14	2H	d	-C=CH
7.32-7.51	10H	m	Ar-H
7.75	2H	d	Ar-H (phenolic moiety)
7.82	2H	d	Ar-H (phenolic moiety)
7.85-7.98	3H	m	Ar-H (phenyl substituted on triazine)
8.12	4H	d	Ar-H (phenyl substituted on alkene)
8.37	2H	d	Ar-H (phenyl substituted on triazine)

Mass analysis: The molecular ion peak in mass spectrum of Mn-PTAPP complex is observed at m/z 672.63, which is in agreement with the calculated mass, corresponding to the molecular ion formula $\text{MnC}_{39}\text{H}_{29}\text{N}_5\text{O}_2^+$. The base peak is observed at 183 which correspond to a triazine mass fragment. The spectrum records the presence of fragments with m/z values 75, 101, 144, 183, 203 and 654. The possible fragmentation pattern is shown in Fig. 3.

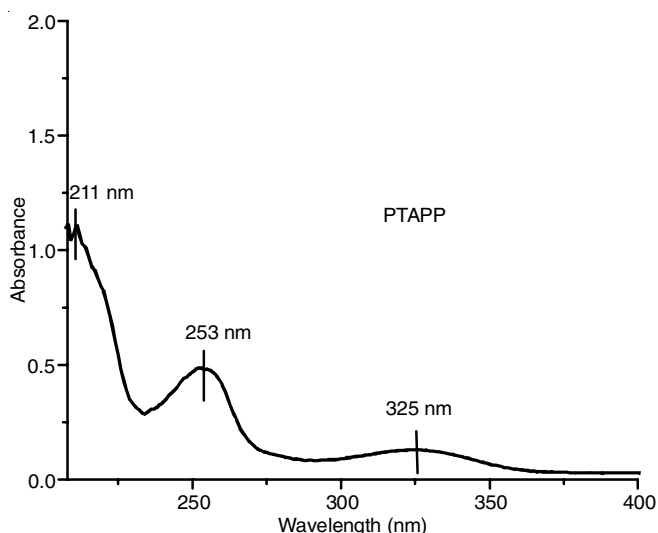


Fig. 1. UV spectrum of ligand PTAPP

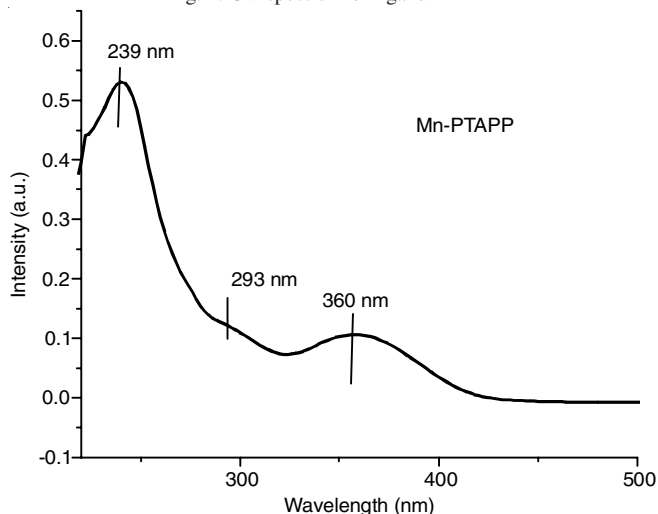


Fig. 2. UV spectrum of complex Mn-PTAPP

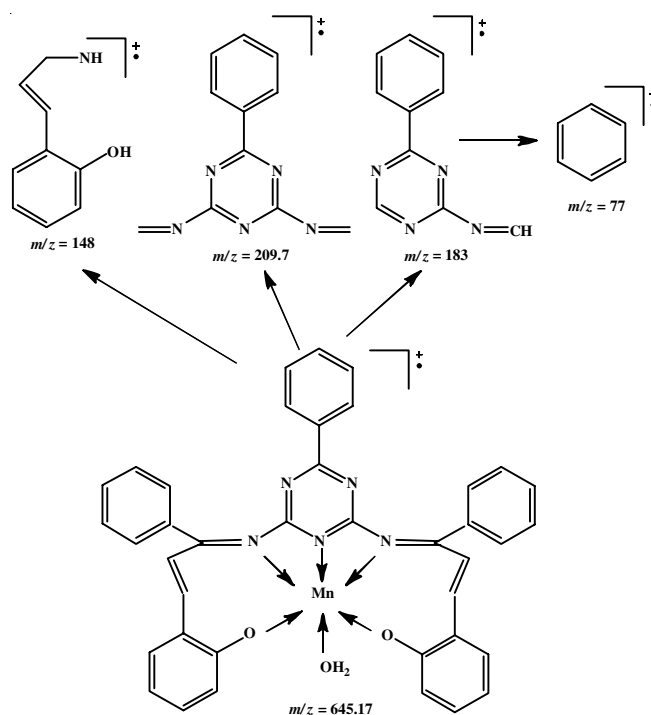


Fig. 3. Fragmentation pattern of Mn-PTAPP complex

Fluorescence studies: The fluorescent studies were carried out for ligand (PTAPP) and its metal complex in DMSO. The fluorescent spectrum of the metal complex is presented in Fig.

4. The spectral studies showed that the ligand (PTAPP) and its metal complex were highly fluorescent in nature. The ligand exhibits a broad emission band with a maximum wavelength of 270 nm upon photo excitation at 300 nm. Similarly, Mn(II) complex was characterized by the emission band around 451 nm. Significant differences in positions of emission maximum of ligand and its complex establish the complexation process.

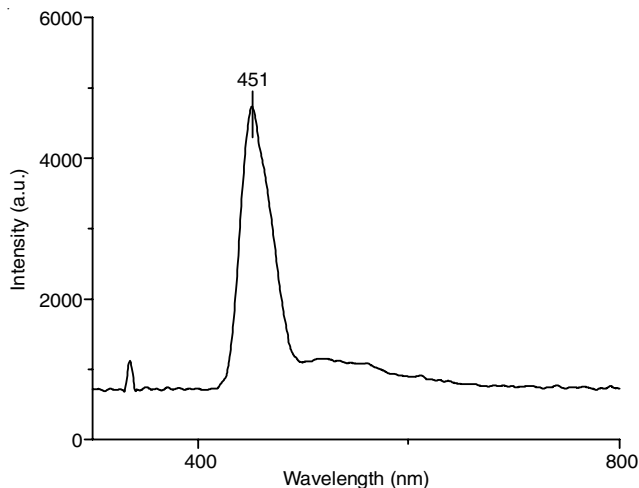


Fig. 4. Fluorescence spectrum of Mn-PTAPP complex

Biological activity: Antimicrobial activity of the ligand and complex were tested *in vitro* by well diffusion method against four bacteria. Amikacin was used as reference. All the bacterial strains were incubated in nutrient broth at 37 °C for 24 h and fungal isolates were incubated in PDA broth at 28 °C for 2-3 days. The wells each of 5 mm in diameter were made in Muller-Hinton agar using cork borer. The stock solution was prepared in 10^{-3} mL⁻¹ concentration (DMSO) and then 100 µL of the solution was transferred into each well. The plates were incubated for 24 h at 37 °C and examined for clear inhibition zone around the well. Metal complex and ligand were evaluated *in vitro* for their activities against *Staphylococcus aureus*, *B. subtilis*, *E. coli* and *K. pneumoniae*. Both the ligand and metal complex showed remarkable antibacterial activities (Table-3).

TABLE-3
BIOLOGICAL ACTIVITY DATA FOR
THE LIGAND AND ITS Mn(II) COMPLEX

Compounds	<i>B. subtilis</i>	<i>E. coli</i>	<i>K. pneumoniae</i>	<i>S. aureus</i>
Ligand (PTAPP)	12	10	12	10
[Mn(PTAPP)]	16	13	13	12
Amikacin	18	18	18	18

Conclusion

In this work, triazine based ligand PTAPP was synthesized in two steps. In the first step, chalcone was synthesized by condensation of salicylaldehyde with acetophenone. In second step, chalcone was made to undergo a condensation reaction with 2,4-diamino-6-phenyl triazine. Then the ligand successfully reacted with Mn(II) to form Mn-PTAPP complex, which has a square pyramidal geometry. The newly designed ligand and its Mn complex were assayed for its *in vitro* antimicrobial activity against selected pathogens. The complex showed appre-

ciable antimicrobial activity against all tested strains in comparison to its ligand.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

1. A. El-Faham, S.M. Osman, H.A. Al-Lohedan and G.A. El-Mahdy, *Molecules*, **21**, 2 (2016); <https://doi.org/10.3390/molecules21060714>.
2. L. Pavelek, V. Ladányi, M. Nečas, Z. Moravec and K. Wichterle, *Polyhedron*, **119**, 134 (2016); <https://doi.org/10.1016/j.poly.2016.08.035>.
3. M.N. Arshad, A. Bibi, T. Mahmood, A.M. Asiri and K. Ayub, *Molecules*, **20**, 5852 (2015); <https://doi.org/10.3390/molecules20045851>.
4. S.J. Ren, R.B. Wang, K. Komatsu, P.B.-Krause, Y. Zyrianov, C.E. McKenna, C. Csipke, Z.A. Tokes and Eric J. Lien, *J. Med. Chem.*, **45**, 410 (2002); <https://doi.org/10.1021/jm010252q>.
5. R. Shanmugakala, P. Tharmaraj, C.D. Sheela and C. Anitha, *Int. J. Inorg. Chem.*, **7**, Article ID 301086 (2012); <https://doi.org/10.1155/2012/301086>.
6. A. Solankee, K. Kapadia, A. Ciric, M. Sokovic, I. Doytchinova and A. Geronikaki, *Eur. J. Med. Chem.*, **45**, 513 (2010); <https://doi.org/10.1016/j.ejmech.2009.10.037>.
7. S.S. Machakanur, B.R. Patil, D.S. Badiger, A.H. Pathan, K.B. Gudasi and S.W.A. Bligh, *Lett. Org. Chem.*, **9**, 29 (2012); <https://doi.org/10.2174/157017812799304051>.
8. M. Mastalir, B. Stöger, E. Pittenauer, G. Allmaier and K. Kirchner, *Org. Lett.*, **18**, 3186 (2016); <https://doi.org/10.1021/acs.orglett.6b01398>.
9. N. Deibl and R. Kempe, *J. Am. Chem. Soc.*, **138**, 10786 (2016); <https://doi.org/10.1021/jacs.6b06448>.
10. J.S. Sultan, S.M. Lateef and D.K. Rashid, *Open J. Inorg. Chem.*, **5**, 102 (2015); <https://doi.org/10.4236/ojic.2015.54011>.
11. K.S. Patel, J.C. Patel, H.R. Dholariya, V.K. Patel and K.D. Patel, *Open J. Metal*, **2**, 9 (2012); <https://doi.org/10.4236/ojmetal.2012.23008>.
12. H.M.S. Hussein, *J. Water Resour. Prot.*, **7**, 79 (2015); <https://doi.org/10.4236/jwarp.2015.71006>.
13. N.A. Espinosa-Jalapa, A. Nerush, L. Shimon, G. Leitus, L. Avram, Y. Ben-David and D. Milstein, *Chem. Eur. J.*, **23**, 5934 (2017); <https://doi.org/10.1002/chem.201604991>.
14. S.B. de Lemos e Silva, A. Arndt and B.P. Espósito, *J. Water Resour. Prot.*, **2**, 209 (2010); <https://doi.org/10.4236/jwarp.2010.23023>.
15. L. Pavelek, V. Ladányi, M. Nečas, Z. Moravec and K. Wichterle, *Polyhedron*, **119**, 134 (2016); <https://doi.org/10.1016/j.poly.2016.08.035>.
16. R.-R. Duan and Z.-B. Ou, *Spectrochim. Acta A Mol. Biomol. Spectrosc.*, **151**, 64 (2015); <https://doi.org/10.1016/j.saa.2015.05.063>.
17. V.S. Padalkar, A.B. Tathe and N. Sekar, *Arab. J. Chem.*, **9**, S1793 (2016); <https://doi.org/10.1016/j.arabjc.2012.04.036>.
18. R. Shanmugakala, P. Tharmaraj, C. D. Sheela and C. Anitha, *Int. J. Inorg. Chem.*, **2012**, Article ID 301086 (2012); <https://doi.org/10.1155/2012/301086>.
19. R.T. Morrison and R.N. Boyd, *Organic Chemistry*, Prentice-Hall of India Pvt. Ltd.: New Delhi, 6th ed., p. 590 (1997).
20. A.-N.M.A. Alaghaz, M.E. Zayed and S. A. Alharbi, *J. Mol. Struct.*, **1084**, 36 (2015); <https://doi.org/10.1016/j.molstruc.2014.12.013>.
21. L. Pavelek, V. Ladányi, M. Nečas, Z. Moravec and K. Wichterle, *Polyhedron*, **119**, 131 (2016); <https://doi.org/10.1016/j.poly.2016.08.035>.
22. K. Singh, R. Thakur and V. Kumar, *Bent-Suef Univ. J. Basic Appl. Sci.*, **5**, 21 (2016); <https://doi.org/10.1016/j.bjbas.2016.02.001>.