

**Investigation on the interaction of dietary  
phenolic acids and their derivatives with  
biologically significant molecules: A multi  
spectroscopic analysis**

**Thesis submitted for the partial fulfillment of the  
requirements for the degree**

**Doctor of Philosophy in Science**

by

**Prasenjit Mondal**

*Under the Supervision of*

**Dr. Adity Bose**

**Department of Chemistry  
Faculty of Natural and Mathematical Sciences  
Presidency University  
Kolkata, India**

**2023**

**Thesis Title:** Investigation on the interaction of dietary phenolic acids and their derivatives with biologically significant molecules: A multi spectroscopic analysis

**Name of the Candidate:** Prasenjit Mondal

**Registration Number:** R-17RS205120098

**Date of Registration:** 10/07/2018

**Department:** Department of Chemistry

Prasenjit Mondal

15.05.2023

**Signature of the candidate with date**



**“NEVER THINK YOU KNOW EVERYTHING...  
ALWAYS TRY TO LEARN MORE”**

**DEDICATED  
TO  
MY PARENTS**

## ACKNOWLEDGEMENTS

*Preparing a Ph.D. thesis is a collaborative effort that involves multiple people, all of whom I would like to express my gratitude to.*

*First and foremost, I would like to express my gratitude to **Maa Kali**. You have always led my steps forward and given me the strength to trust in myself, the patience to work hard and pursue my objectives. I would not have been able to complete my thesis without my faith in you, the Almighty. It gives me a great pleasure to express my heartfelt gratitude to my supervisor, **Dr. Adity Bose**, for her wise counsel and for allowing me the freedom and opportunity to think and work creatively in the laboratory for my research work, as well as for providing me with this incredible opportunity. When my motivation was low, I would always remember her encouraging words and forbearance. In reality, I learnt a lot from her, including outstanding teaching, innovative thinking, and paper drafting, all of which play an important role in the life of a research scholar.*

*I am extremely thankful to **Dr. Sarmishtha Chanda**, for her continuous assistance and guidance during biological experiments. Her support was really stimulating which helped me to broaden my scientific horizon.*

*I would like to convey my regards to **Prof. Anuradha Lohia**, Vice Chancellor, Presidency University; **Dr. Debajyoti Konar**, Registrar of Presidency University; **Prof. Sankar Bose**, Dean of Faculty of Natural and Mathematical Science of Presidency University; **Dr. Arnab Halder**, Head of the Department of Chemistry. I am thankful to my doctoral committee members **Prof. Arnab Halder**, **Prof. Arabinda Nayak**, **Prof. Bijan Das**, **Prof. Sujoy Baitalik**, **Prof. Chhanda Mukhopadhyay**, **Dr. Dhruva Prasad Chatterjee**, and **Dr. Adity Bose** for their feedback, comment and discussions. My special thanks to **Prof. Gandhi Kumar Kar** for his priceless suggestions and continuous encouragement. I wish to extend my warmest thanks to all other faculty members of Department of Chemistry, Presidency University for their enlightening exchanges, help, sharing, supportive remarks, inspiration, and insightful analysis, which left me with a priceless memory. I am grateful to the entire staff and technicians of the Department of Chemistry for their technical support during my research.*

*I would also like to thank my friends especially **Purnananda Garu** for his friendship, who inspired me to join Ph.D. and have been of great help during my B.Sc. to Ph.D. studies.*

When I think about my lab mates there was an only person, **Dr. Priti Sengupta**, who supported me both personally and professionally, without her assistance I could not pursue my doctoral degree, as she helped me through every stage of my doctoral studies. I have learnt almost every technical aspects from her. I would like to thank my friends **Dr. Sandip Paul** and **Dr. Sarat Kanrar** for their continuous support too.

I am very thankful to **Dr. Kamalika Sen** from Department of Chemistry, University of Calcutta. She not only allowed me to work in her laboratory and helped me to publish a research article, but working with her has also enlarged my scientific knowledge. I would like to thank **Dr. Pritam Singh**, research scholar, from University of Calcutta, who supported me during my work in their laboratory and helped me in each and every step.

I would also like to acknowledge our collaborators, **Dr. Uttam Pal** (Post Doctoral fellow, Technical Research Centre, S.N. Bose National Centre for Basic Sciences, JD Block, Sector III, Salt Lake, Kolkata, India.) and **Dr. Pritam Roy** (Post Doctoral fellow, University of Illinois, Urbana-Champaign, Champaign, IL, United States.) for the theoretical studies. I would also like to thank **Dr. Sutapa Saha** (Department of Life Sciences, Presidency University), **Prof. Abhijit Chakraborty** and **Dr. Dipayan Bose** from Saha Institute of Nuclear Physics, for helping me in some crucial experiments and also **Dr. Tapendu Samanta** for his valuable suggestions.

I am also extremely thankful to **Dr. Pinki Saha Sardar** (Assistant Professor in Chemistry, The Bhawanipur Education Society College, Kolkata) for her valuable suggestion throughout my research career.

I would like to acknowledge **DST-SERB** (Project No. YSS/2014/000403, dated 26.11.2015) and **SVMCM** for providing with financial support.

I would like to express my sincere gratitude to my grandfather, Late **Bibhuti Bhushan Mondal** and grandmother **Mrs. Bharati Mondal**, for their kind encouragement and support towards my career. Their blessings inspired me to labour assiduously with strong determination.

There are many people in my life to whom I am thankful and grateful for their absolute faith in me. A simple “thank you” is insufficient for them. My adored parents, **Mr. Dipak Kumar Mondal** and **Mrs. Durga Mondal**, have always supported and encouraged me throughout every stage of my life. My parents' love, affection, and emotional support are always with me. I would like to express my sincere gratitude to my sister **Priyanka Mondal** and the rest of my family for their unwavering support and love. When I felt depressed, my little cousins like **Sumana**, **Aritra**, **Mita**, **Pritika**, **Aniket** and **Debargha** always make me smile and their

*parents give me constant support to overcome every hurdles. I am also very much grateful to Atasi Manna for giving me the courage and ability to handle every challenge. Finally, this thesis is intended to honor them, the most significant individuals in my life.*

Prasenjit Mondal

15.05.2023

*Signature of the candidate with date*

## DECLARATION

I hereby declare that this thesis contains original research work carried out by me under the guidance of Dr. Adity Bose, Assistant Prof. in Chemistry, Department of Chemistry, Presidency University, Kolkata, India as part of the Ph.D. programme.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

I also declare that, this work has not been submitted for any degree either in part or in full to any other institute or University before.

Prasenjit Mondal

15.05.2023

**Signature of the candidate with date**



PRESIDENCY UNIVERSITY  
KOLKATA

# Presidency University

Hindoo College (1817-1855), Presidency College (1855-2010)

## CERTIFICATE

This is to certify that the thesis entitled "*Investigation on the interaction of dietary phenolic acids and their derivatives with biologically significant molecules: A multi spectroscopic analysis*" submitted by Shri Prasenjit Mondal, Registration Number R-17RS205120098 and date of registration 10/07/2018, in partial fulfilment of the requirements for the award of "Doctor of Philosophy", is a record of bonafide research work carried out by him under my supervision. Neither his thesis nor any part of the thesis has been submitted for any degree/diploma or any other academic award anywhere before.

Date: 15.05.2023

Adity BOSE  
15.05.2023



Dr. Adity Bose  
Assistant Professor  
Department of Chemistry  
Presidency University, Kolkata - 700 073

Place: Kolkata

Signature of the Supervisor with date and official stamp

Dr. ADITY BOSE





# List of Publications

---

1. **Mondal, P.**, and Bose, A., 2019. Spectroscopic overview of quercetin and its Cu (II) complex interaction with serum albumins. *BioImpacts: BI*, 9, 115.
2. **Mondal, P.**, Sengupta, P., Pal, U., Saha, S. and Bose, A., 2021. Biophysical and theoretical studies of the interaction between a bioactive compound 3, 5-dimethoxy-4-hydroxycinnamic acid with calf thymus DNA. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 245, 118936.
3. **Mondol, P.**, Bose, A. and Chanda, S., 2022. Evaluation of Sinapic acid to ameliorate ionizing radiation induced peripheral blood mononuclear cell death. *Stem Cell Research International*, 5, 34.
4. **Mondal, P.**, Singh, P., Morgan, D., Bose, A. and Sen, K., 2022. Ni-sinapic acid nanocomposite in the selective sensing of permanganate ions. *Journal of Photochemistry and Photobiology A: Chemistry*, 437, 114458.

## Other publications

1. Sengupta, P., Pal, U., **Mondal, P.** and Bose, A., 2019. Multi-spectroscopic and computational evaluation on the binding of sinapic acid and its Cu (II) complex with bovine serum albumin. *Food chemistry*, 301, 125254.
2. Sengupta, P., **Mondal, P.**, Mukherjee, S., Chanda, S. and Bose, A., 2020. Rutin-serum albumin interaction in different media and its effective dose selection in radiation-induced cytotoxicity on human blood cells. *Journal of Herbal Medicine*, 21, 100322.
3. Sengupta, P., Bhattacharya, S., Das, D., **Mondal, P.**, Sur, R., Bose, A. and Sen, K., 2023. Milk protein micellization for encapsulation of dietary polyphenol rutin for enhanced bioaccessibility and sustained release. *International Journal of Biological Macromolecules*, (Communicated).

## Manuscripts under preparation

1. **Mondal, P.**, Sengupta, P., and Bose, A., Spectroscopic overview of gallic acid and ct-DNA.
2. **Mondal, P.**, Sengupta, P., and Bose, A., Beta-casein as an encapsulation tool for a bioactive flavonoid: Interactions and effect on bio-efficacies.

# National & International Seminar

---

- ❖ Research paper presented for the poster presentation on **8-9<sup>th</sup> January, 2020**, in Two-Day **International Seminar** on “Innovation, Expansion, Impacts and Challenges in Chemical and Biological Sciences,” organized by Department of Chemistry, Surendranath College, Kolkata, India.
- ❖ Research paper presented for the poster presentation on **December 23-24, 2019** in **4th Regional Science and Technology Congress (Southern Region)**, jointly organized by Department of Science and Technology and Bio-Technology, Government of West Bengal & Maulana Abul Kalam Azad University of Technology, West Bengal at Haringhata, Nadia.
- ❖ Research paper presented for the poster presentation in the **Frontiers in Modern Biology (FIMB) 2018** organized by the department of Biological sciences, Indian Institute of Science Education and Research Kolkata, Mohanpur Campus, India, between **January 19-21, 2018**.

# List of Abbreviations

---

Å	: Angstrom
ABTS	: 2,2' azinobis-3 ethylbenzothiazoline-6-sulfonic acid
Ac	: Acetyl group
aq	: Aqueous
Ar	: Aromatic group
b.p.	: Boiling Point
β-CN	: Beta Casein
BSA	: Bovine serum albumin
conc.	: Concentration
cm	: Centimeter
cm <sup>-1</sup>	: Wavenumbers (IR/UV spectroscopy)
°C	: Degree Celsius
cal	: calorie
CD	: Circular Dichroism
ct-DNA	: Calf thymus DNA
DMSO	: Dimethyl Sulfoxide
deg	: Degree (°)
DLS	: Dynamic light scattering
DSC	: Differential scanning calorimetric
DNA	: Deoxyribonucleic acid
DPPH	: 2,2-diphenyl-1-picrylhydrazyl
EtBr	: Ethidium bromide
eV	: Electron volt
EtOH	: Ethanol
EDTA	: Ethylenediaminetetraacetic acid
FTIR	: Fourier transform infrared
GA	: Gallic acid

HSA	: Human serum albumin
HCl	: Hydrochloric acid
ITC	: Isothermal titration calorimetry
KI	: Potassium Iodide
K	: Kelvin
kcal	: Kilocalorie
KBr	: Potassium bromide
kV	: kilovolt
LDH	: Lactate Dehydrogenase
L	: Litre
g	: gram
h/hr	: hour(s)
h $\nu$	: quantum of light/photon
Hz	: Hertz (cycles per second)
M	: concentration in mol/dm <sup>3</sup> (c)
Me	: methyl group
MeOH	: methanol
mg	: Milligrams
$\mu$ M	: Micromolar
$\mu$ g	: Microgram
$\mu$ l	: Microlitre
$\mu$ m	: micrometre
mM	: Milimolar
M	: Mole
mol	: Mole
mA	: Milliampere
ml	: Millilitre
MHz	: Mega Hertz
MIC	: Minimum inhibitory concentration

MTT	: (3-(4, 5-dimethylthiazolyl-2)-2, 5-diphenyltetrazolium bromide)
min	: Minute
mJ	MilliJoule
NMR	: Nuclear magnetic resonance
NOS	: Nitric oxide synthase
nM	: Nanomolar
nm	: Nanometer
NPs	: Nanoparticles
PEG-4000	: Polyethylene glycol 4000
PXRD	: Powder X-ray diffraction
PBS	: Phosphate buffer solution
PBMC	: Peripheral blood mononuclear cells
PA <sub>s</sub>	: Phenolic acids
PC <sub>s</sub>	: Phenolic compounds
pmole	: Picomoles
rpm	: Revolutions per minute
ROS	: Reactive oxygen species
SA	: Sinapic acid
SEM	: Scanning electron microscopy
SAA	: Serum amyloid A
Tris	: tris(hydroxymethyl)aminomethane
TEM	: Transmission electron microscopy
T	: Temperature
Trp	: Tryptophan
Tyr	: Tyrosine
UV-Vis	: Ultraviolet-visible
UV	: Ultraviolet
XPS	: X-ray photoelectron spectroscopy

## List of Figures

<b>Chapter 1</b>	<b>Page</b>
	<b>No.</b>
Fig. 1.1. Classification of secondary metabolites	3
Fig. 1.2. Classification of phenolic compounds with few well-known examples	4
Fig. 1.3. Application of PCs	7
Fig. 1.4. Schematic presentation of my molecule of interest for the present work	12
<b>Chapter 3A</b>	
Fig. 3A.1. Schematic diagram of different applications of phenolic acids	39
Fig. 3A.2. (A) represents the absorption spectra of SA (10 $\mu$ M) with an increasing concentration of ct-DNA (0-120 $\mu$ M). (B) represents the double reciprocal plot of ct-DNA with SA	46
Fig. 3A.3. Fluorescence quenching spectra of 30 $\mu$ M SA with varying concentration of ct-DNA (0-950 $\mu$ M) at room temperature (A) and Stern-Volmer plots of SA with ct-DNA at three different temperatures (B). Inset: Arrhenius plots for the fluorescence quenching of SA with the addition of ct-DNA at different temperatures. Modified Stern-Volmer plots for the interaction of SA with ct-DNA at three different temperatures (C)	49
Fig. 3A.4. The plot of $\log [(F_0-F)/F]$ vs $\log [Q]$ for SA-ctDNA complex at three different temperatures (A), van't Hoff plot at three different temperatures for binding of SA-ctDNA system (B) and bar diagram plot to visualize the thermodynamic parameters of SA and ct-DNA at 298 K (C)	51
Fig. 3A.5. Fluorescence emission spectra of native EB and EB-ctDNA complex with increasing concentration of SA (0-240 $\mu$ M)	52
Fig. 3A.6. Stern-Volmer quenching plot of SA (30 $\mu$ M) by KI concentration in the absence and presence of ct-DNA	53

Fig. 3A.7.	Thermal decomposition curve of free ct-DNA and SA-ctDNA complex at pH 7.4. [ct-DNA]= $25 \times 10^{-6}$ (M) and [SA]= $40 \times 10^{-6}$ (M)	55
Fig. 3A.8.	Viscosity measurement plot of ct-DNA (50 $\mu$ M) with increasing concentration of SA	56
Fig. 3A.9.	Far-UV CD spectra of ct-DNA on the addition of varying concentration of SA	57
Fig. 3A.10.	Fluorescence anisotropy plot of SA (30 $\mu$ M) and ct-DNA ( $0-2 \times 10^{-4}$ M)	58
Fig. 3A.11.	Agarose gel electrophoretic pattern of ct-DNA in the absence and presence of varying concentrations of SA; Lane 1, free ct-DNA without UVB radiation; lane 2, free ct-DNA with UVB radiation; lane 3, ct-DNA+ 25 $\mu$ M SA with UVB radiation; lane 4, ct-DNA+ 50 $\mu$ M SA with UVB radiation; lane 5, ct-DNA+ 75 $\mu$ M SA with UVB radiation; lane 6, ct-DNA+ 100 $\mu$ M SA with UVB radiation. Where (A) corresponds to the image of the gel, (B) and (C) corresponds to agarose gel electrophoresis intensity plot of the band part and the smearish part respectively	59
Fig. 3A.12.	Binding of sinapate (green) in the minor groove of DNA as obtained by molecular docking simulation. Two possible binding conformations are shown superimposed and separately	60
Fig. 3A.13.	(A): Hydrogen bonds between SA and the bases of DNA as obtained from molecular docking. Donor acceptor distances are shown. Two most favourable binding conformations of SA are shown. (B): Binding energy of SA with DNA and the H bonding over the period of simulation. Point of dissociation of SA from DNA is marked with an arrow. (C): Distance between C1 of SA and the -NH <sub>2</sub> group of three adjacent three guanine bases viz. G10 of chain A (blue) G14 of chain B (red) and G16 of Chain B (yellow). Point of dissociation of SA from DNA is marked	61-62

## Chapter 3B

- Fig. 3B.1. Fluorescence quenching spectra of plasma protein (albumin) in the presence of varying concentrations of SA at 298 K;  $\lambda_{ex} = 280$  nm, pH = 7.4 (0.1M PBS). Excitation band pass = 5 nm and Emission band pass = 5 nm. (a) alcohol/buffer medium; (b) DMSO/buffer medium 79
- Fig. 3B.2. The double-logarithm plot of  $\log[(F_0-F)/F]$  vs.  $\log[Q]$  for the interaction between human blood plasma with SA in two different media 80
- Fig. 3B.3. Comparative analysis of percent viable cells (analyzed by MTT assay) after administration of different concentrations of SA in three different solvent systems, on UVB exposed human peripheral blood mononuclear cells 82
- Fig. 3B.4. Assay of Cell growth and cell death by flow cytometric analysis using human blood peripheral mononuclear cells and immortalized keratinocytes (HaCat) after UVB exposure with and without SA administration, (A) PBMC cell culture with UVB and SA (B) HaCat culture with UVB and SA 83
- Fig. 3B.5. LDH Assay (mean  $\pm$  SD) for % cytotoxicity of human PBMC exposed to UVB after prior administration of SA in DMSO/buffer, alcohol/buffer media and PEG 4000 in buffer medium 84
- Fig. 3B.6. Sialic Acid Assay for evaluation of cell death (O.D<sub>630</sub> nm) of human PBMC exposed to UVB with prior administration of SA in DMSO/buffer and alcohol/buffer media and SA in PEG/buffer medium 85
- Fig. 3B.7. (A) ROS scavenging activity of SA before and after exposure of UVB measured by DPPH activity. (B) ROS scavenging activity of SA measured by Trolox equivalent through ABTS activity after UVB exposure 85
- Fig. 3B.8. Serum amyloid A (SAA) level in UVB exposed human peripheral blood before and after administration of sinapic acid. The bar diagram shows the mean  $\pm$ SD value of SAA before and after SA administration on UVB exposed blood cells 86



Fig. 3B.9.	(A) represents the pmole concentration of nitrate evolved against OD level at 540 nm. (B) represents the concentration of nitrate evolved in cells after UVB exposure with and without SA administration	87
------------	--	----

#### Chapter 4

Fig. 4.1.	The photograph of synthesis of Ni-SA NPs	101
Fig. 4.2.	UV-Vis spectra of SA and Ni-SA NPs	101
Fig. 4.3.	FTIR spectra of pure sinapic acid and Ni-SA NPs	103
Fig. 4.4.	(a) and (b) represent the TEM images of Ni-SA NPs and (c) histogram showing particle size distribution of Ni-SA NPs (d) SAED pattern of the Ni-SA NPs	105-106
Fig. 4.5.	PXRD pattern of the Ni-SA NPs	107
Fig. 4.6.	Ni(2p) core-level spectrum from the Ni-SA NPs	108
Fig. 4.7.	Spectral change of nano particle solution in presence of permanganate ion (0-3 $\mu\text{M}$ )	109
Fig. 4.8.	Spectral change of Ni-SA NPs upon addition of respective ions, (A) arsenate ion (0 to 4.67 $\mu\text{M}$ ), (B) arsenite ion (0 to 3.77 $\mu\text{M}$ ), (C) molybdate ion (0 to 4.67 $\mu\text{M}$ ), (D) dichromate ion (0 to 4.67 $\mu\text{M}$ ), (E) chloride ion (0 to 4.69 $\mu\text{M}$ ), (F) fluoride ion (0 to 4.71 $\mu\text{M}$ ), (G) iodide ion (0 to 4.67 $\mu\text{M}$ ), (H) persulphate ion (0 to 4.67 $\mu\text{M}$ ), (I) selenate ion (0 to 4.67 $\mu\text{M}$ ), (J) selenite ion (0 to 4.71 $\mu\text{M}$ ), (K) sulphate ion (0 to 4.67 $\mu\text{M}$ ), (L) sulphite ion (0 to 4.67 $\mu\text{M}$ ), (M) thiosulphate ion (0 to 4.72 $\mu\text{M}$ )	110-113
Fig. 4.9.	Selectivity of the Ni-SA NPs towards permanganate ion	114
Fig. 4.10.	ITC data for binding isotherm between $\text{KMnO}_4$ with the NPs at 298 K	115
Fig. 4.11.	(a) Ni(2p) core-level spectrum from the $\text{KMnO}_4$ treated Ni-SA NPs (a) and (b) normalised overlay of the Ni(2p) spectra from the two materials	116
Fig. 4.12.	Interference study for the sensing of permanganate ion	117

#### Chapter 5

Fig. 5.1.	(A) Stern-Volmer plots of the fluorescence quenching of the $\beta\text{-CN}$ by	128-129
-----------	--	---------

	SA and (B) for the binding parameter evaluation with $\beta$ -CN at three different temperatures	
Fig. 5.2.	van't Hoff plot at three different temperatures for binding of $\beta$ -CN-SA system (A) and bar diagram plot to visualize the thermodynamic parameters of SA and $\beta$ -CN (B)	131-132
Fig. 5.3.	ROS scavenging activity of SA in presence and absence of $\beta$ -CN was measured by DPPH activity	133
<b>Chapter 6</b>		
Str. 6.1.	The chemical structure of GA	138
Fig. 6.1.	Fluorescence titration spectra of GA (25 $\mu$ M) with various concentration of ct-DNA (0-100 $\mu$ M). (inset: absorption spectra of free gallic acid)	143
Fig. 6.2.	Stern-Volmer quenching plot of GA (20 $\mu$ M) by varying KI (0-0.009 M) concentration in the absence and presence of ct-DNA	144
Fig. 6.3.	Viscosity measurement plot of ct-DNA (50 $\mu$ M) with increasing concentration of GA	145
Fig. 6.4.	Far-UV CD spectra of ct-DNA on the addition of varying concentration of GA	146
Fig. 6.5.	Fluorescence emission spectra of native EB and EB-ct-DNA complex with increasing concentration of GA (0-140 $\mu$ M)	147
Fig. 6.6.	Thermal melting curve of free ct-DNA and GA-ct-DNA complex at pH 7.4	148
Fig. 6.7.	Fluorescence anisotropy plot of GA (30 $\mu$ M) and ct-DNA (0-100 $\mu$ M)	149
Fig. 6.8.	Molecular docking of GA with DNA: (A) GA binds at the groove of DNA as seen from the docked structure; (B) Possible hydrogen bonding between GA and base pairs of DNA; (C) Two different conformations of GA are shown superimposed over one another (GA1 shown in yellow: before docking and GA1 shown in blue: after docking) with RMSD value of 3.17 $\text{\AA}$ .	150

## List of Tables

<b>Chapter 2</b>	<b>Page No.</b>
Table 2.1. List of chemicals, including formulas and company names	24
 <b>Chapter 3A</b>	
Table 3A.1. Variation of Stern-Volmer quenching constant ( $K_{SV}$ ) and bimolecular quenching constant ( $k_q$ ) and modified Stern-Volmer quenching constant at three different temperatures for SA-ct-DNA system	49
Table 3A.2. Binding constant and other thermodynamic parameters at three different temperatures for SA-ctDNA system	51
Table 3A.3. $K_{SV}$ values obtained in KI quenching of SA in the absence and presence of ct-DNA	54
 <b>Chapter 3B</b>	
Table 3B.1. List of binding constant ( $k_b$ ) and binding sites ( $n$ ) for the interaction of SA in different media with human blood plasma at 298K	81
 <b>Chapter 4</b>	
Table 4.1. FTIR spectral data of pure sinapic acid and synthesized Ni-SA NPs, along with their potential functionalities	103-105
Table 4.2. PXRD data of the prepared nanoparticle and possible assignment of JCPDS no.	107
Table 4.3. Atomic percentage of C, O, N and Ni in Ni-SA NPs as obtained from XPS	108
Table 4.4. Different analytical parameters for the detection of the $KMnO_4$	110
Table 4.5. Atomic percentage (at %) of C, O, Ni, K and Mn in $KMnO_4$ treated Ni-SA NPs as obtained from XPS	116
Table 4.6. Recovery percentage of $KMnO_4$ in tap water	118

## **Chapter 5**

Table 5.1.	Variation of Stern-Volmer quenching constant ( $K_{SV}$ ) and biomolecular quenching constant ( $k_q$ ) and modified Stern-Volmer quenching constant at three different temperatures for $\beta$ -CN-SA system	129
Table 5.2.	The binding constant and other thermodynamic parameters for the $\beta$ -CN-SA system are listed below for three different temperatures	132

## **Chapter 6**

Table 6.1.	Hydrogen bonding distance between GA and nearby DNA bases pairs.	151
------------	--	-----