Contents

S. No.	Title	Page No.
I.	Abstract	i-iii
II.	Declaration	iv
III.	Certificate of the supervisor	v
IV.	Acknowledgment	vi - viii
V.	Contents	ix-xiv
VI.	List of Tables	xv
VII.	List of Figures	xvi – xxii
VIII.	Abbreviations	xxiii-xxv
	CONTENTS	
1.	**Chapter I**	
	Introduction	1-4
2.	**Chapter II**	
	Review of Literature	5-64
2.1.	Fish and its Composition	5-7
2.2.	Causes of fish spoilage	7-9
2.3.	Method of detection of fish spoilage	10-48
2.3.1.	Conventional techniques	10-15
2.3.1.1.	Sensory method	10-13
2.3.1.1.1.	European Union (EU) scheme	10-11
2.3.1.1.2.	Quality Index Method (QIM)	12
2.3.1.1.3.	The Torry Scoring System	13
2.3.1.2.	Instrumental or biochemical methods	13
2.3.1.2.1.	Total Volatile Basic Nitrogen (TVB-N)	13
2.3.1.2.2.	Trimethyl Amine (TMA)	14
2.3.1.2.3.	Thiobarbituric Acid (TBA)	14
2.3.1.2.4.	Peroxide Value (PV)	14-15
2.3.1.2.5.	Free Fatty Acid (FFA)	15
2.3.1.3.	Biological method	15
2.3.2.	Innovative techniques	16
2.3.2.1.	Polyaniline-based sensor	16-18
2.3.2.2.	Dye-based sensor	18-19

2.3.2.3.	Smartphone-based sensor	19-31
2.3.2.3.1.	Optical-Based Sensor	20-24
2.3.2.3.1.1.	Colorimetric analysis	21-22
2.3.2.3.1.2.	Optical imaging and Spectroscopy techniques	22-24
2.3.2.3.2.	Fluorescence-based sensor	24-26
2.3.2.3.3.	Electrochemical sensor	27-29
2.3.2.3.4.	Label-free smartphone sensor	29-31
2.3.2.4.	Application of smartphone-based sensor in fish freshness analysis	32-43
2.3.2.4.1.	Colorimetric method of fish spoilage detection using SPBS	32-36
2.3.2.4.2.	Electrochemical method of fish spoilage detection using SPBS	37
2.3.2.4.3.	Fluorescent method of fish spoilage detection using SPBS	37-43
2.3.2.5.	Keyword network analysis (KNA) of smartphone-based sensors application in fish spoilage	44
2.3.2.6.	Advantages and limitations of smartphone-based sensors over analytical instruments	45-47
2.3.2.7.	Challenges and Future Trends	48
2.4.	Conclusion	49
2.5.	References	50-64
3.	**Chapter III**	
	To develop and characterize the polyaniline-based sensor for monitoring the freshness of fish during storage	65-86
3.1.	Introduction	65-66
3.2.	Materials and Methods	66-70
3.2.1.	Preparation of polyaniline (PANI) label	66-67
3.2.2.	Characterization of polyaniline (PANI)	67
3.2.3.	Response time	67-68
3.2.4.	Calibration of the PANI label using UV-visible spectrophotometer	68

3.2.5.	Sample preparation	69
3.4.6.	Performance evaluation of the label	70
3.4.7.	Measurement of TVB-N and pH	70
3.2.8.	Microbial analysis of fish	70
3.2.9.	Statistical analysis	70
3.3.	Results and discussion	71-81
3.3.1.	Polymerization and characterization of polyaniline	71-74
3.3.2.	Response time and calibration of PANI label	75-76
3.3.3.	Performance evaluation of the developed PANI label	76-78
3.3.4.	Measurement of TVB-N, pH, and microbial count	78-81
3.4.	Conclusion	82
3.5.	References	83-86
4.	**Chapter IV**	
	To develop the dye-based sensor for monitoring the freshness of fish during storage	87-102
4.1.	Introduction	87-88
4.2.	Material and Methods	88-91
4.2.1.	Preparation of bromocresol purple dye (BPD) label	88-89
4.2.2.	BPD label response time	89
4.2.3.	Sensor calibration	89-90
4.2.3.	Sample preparation and performance evaluation of the developed BPD label	89-90
4.2.4.	Measurement of TVB-N and pH	90
4.2.5.	Microbial analysis of fish	91
4.2.6.	Statistical analysis	91
4.3.	Results and discussion	91
4.3.1.	Response time and calibration of the BPD label	91-92
4.3.2.	Performance evaluation of the developed BPD label	93-94
4.3.3.	Measurement of TVB-N, pH, and microbial count	94-96
4.3.4.	Leaching test of the developed labels	96-97
4.4.	Conclusion	98

4.5.	References	99-102
5.	**Chapter V**	
	To design and develop a cradle (smartphone sensing system) for determination of spoilage	103-116
5.1.	Introduction	103-104
5.2.	Materials and Methods	104-109
5.2.1.	Design and development of cradle for sensing using a smartphone	104
5.2.2.	Wavelength calibration for the developed smartphone sensor	104-106
5.2.3.	Calibration of the sensor, and Measurement of Uncertainty (MOU) of the developed	107
5.2.4.	Performance evaluation of the developed sensor	107-108
5.2.4.1.	Limit of detection, Limit of quantification, Accuracy and Precision, and % Recovery	109
5.3.	Results and discussion	110-113
5.3.1.	Wavelength calibration for the developed smartphone sensor	110-111
5.3.2.	Calibration of the developed sensor	111-113
5.4.	Conclusion	113
5.5.	References	114-116
6.	**Chapter VI**	
	To calibrate and validate the developed cradle for development of a mobile application for monitoring of chemical spoilage of fish during storage	117-141
6.1.	Introduction	117-118
6.2.	Materials and Methods	118
6.2.1.	Response of PANI label using the developed smartphone sensor	118
6.2.2.	Sample preparation and performance evaluation of the developed sensor	118-120
6.2.3.	Sensor validation	120-121

6.2.3.1.	Using UV-Vis's spectrophotometer	120
6.2.3.2.	Measurement of TVB-N and pH	120-121
6.2.3.3.	Microbial analysis of fish	121
6.2.3.4.	Texture Analysis	121
6.2.4.	Stability and reproducibility test of polyaniline label	121-122
6.2.5.	Statistical analysis	122
6.3.	Results and discussion	123-124
6.3.1.	Response of PANI label using smartphone sensor	123
6.3.2.	Performance evaluation of sensor using fish sample	123-124
6.3.3.	Sensor validation	124-135
6.3.3.1.	Using UV-Vis's spectrophotometer	124-128
6.3.3.2.	Using TVB-N and pH	129
6.3.3.3.	Microbial analysis of stored fish	129-132
6.3.3.4.	Texture analysis	132-135
6.3.4.	Stability and reproducibility test of polyaniline label	135-136
6.4.	Development of web application	137
6.5.	Conclusion	138
6.6.	References	139-142
7.	**Chapter VII**	
	To study the effect of extracted essential oil from pomelo peel on storage stability using developed sensor	143-174
7.1.	Introduction	142-144
7.2.	Materials and methods	144-149
7.2.1.	Extraction of essential oil	144
7.2.2.	Characterization of extracted essential oil	144
7.2.3.	Total phenolic content	145
7.2.4.	DPPH* radical scavenging activity	145
7.2.5.	Antimicrobial activity of essential oil	145
7.2.6.	Preparation of samples	145-148

7.2.7.	Performance evaluation using developed smartphone sensor	148
7.2.8.	Measurement of TVB-N and pH	148
7.2.9.	Microbial Analysis	148-149
7.2.10	Texture Analysis	149
7.2.11.	Statistical analysis	149
7.3.	Results and discussion	150-163
7.3.1.	Extraction yield of pomelo peel essential oil	150
7.3.2.	Characterization of pomelo peel essential oil	150-151
7.3.3.	DPPH* scavenging activity and total phenolic content of pomelo peel essential oil	151
7.3.4.	Antimicrobial activity of pomelo peel essential oil	152-155
7.3.5.	Study of the effect of essential oil as a preservative using the developed smartphone sensor	155-156
7.3.6.	Validation of the finding of smartphone senor using UV-visible spectrophotometer	156-157
7.3.7.	Measurement of TVB-N and pH values	157-159
7.3.8.	Microbial analysis	159-162
7.3.9.	Texture analysis	162-163
7.4.	Conclusion	164
7.5.	References	165-174
8.	**Chapter VIII**	
	Summary and Conclusion	175-178
	Appendix	i-v