

TABLE OF CONTENTS

Contents	Page No.
<i>Abstract</i>	i-iv
<i>Declaration</i>	v
<i>Certificate</i>	vi
<i>Acknowledgement</i>	vii-viii
<i>Table of Contents</i>	ix-xvi
<i>List of Table</i>	xvii-xix
<i>List of Figure</i>	xx-xxiv
<i>List of Abbreviations</i>	xxv-xxvi
<i>List of Symbols</i>	xxvii-xxviii
 CHAPTER 1	 1-11
INTRODUCTION	
1.1 Sustainable nanocellulose from food waste	1
1.2 Sources of cellulose and nanocellulose	2
1.3 Extraction of nanocellulose	3
1.4 Pickering emulsion	3
1.4.1 Pickering emulsions as a carrier of bioactive compounds	4
1.4.2 Importance of lipid digestion	4
1.5 Role of hydrogel in food system	5
1.5.1 Nanocellulose and protein as hydrogel components	6
1.5.2 Hydrogel-based bioactive compound encapsulation	7
1.6 Aerogels: Properties and Applications	7
1.6.1 Nanocellulose-based aerogels	8
1.6.2 Incorporation of bioactive compounds in aerogels	8
1.7 Research Gap	9
1.8 The objectives of the present investigation	10

CHAPTER 2	12-35
REVIEW OF LITERATURE	
2.1 Cellulose	12
2.2 Nanocellulose	12
2.3 Mechanical treatment applied to nanocellulose	13
2.3.1 Ultrasonication	13
2.3.2 High pressure homogenization	14
2.4 Characterization of nanocellulose	15
2.5 Food application of nanocellulose	15
2.6 Pickering emulsion	16
2.6.1 Stabilization mechanisms of nanocellulose	17
2.6.2 Impact of Pickering emulsion on β -carotene bioaccessibility	19
2.6.3 Health benefits and nutraceutical applications of β -carotene	19
2.6.4 Application of Pickering emulsion in mayonnaise	20
2.7 Hydrogel	21
2.7.1 Polysaccharide /protein-based hydrogels	22
2.7.2 Influence of formulation on hydrogel	23
2.7.3 Entrapment of β -carotene in hydrogels	24
2.7.4 Functional properties of nanocellulose/protein hydrogels	26
2.7.5 Hydrogel and its application in ice-cream	27
2.8. Aerogels	28
2.8.1 Nanocellulose aerogels as sustainable packaging materials	29
2.8.2 Novel aerogel delivery systems for improved food packaging application	31
2.8.3 Enhancing food preservation with bioactive compounds in aerogels	32
2.8.4 Application of aerogel in food freshness indicator	33
CHAPTER 3	36-91
PROPERTIES OF NANOCELLULOSE OBTAINED FROM BANANA RACHIS AND PINEAPPLE PEEL USING DIFFERENT TREATMENTS	
3.1. Introduction	36

3.2	Materials and methods	39
3.2.1	Materials	39
3.2.2	Methods	39
3.2.2.1	Ultrasonication	39
3.2.2.2	High pressure homogenisation	39
3.2.3	Isolation of cellulose and nanocellulose	40
3.2.4.	Experimental design	40
3.2.5.	Characterization of powdered banana rachis (BR), cellulose fibre (CF) and nanocellulose (NC)	42
3.2.6.	Data analysis	43
3.3	Results and discussion	43
3.3.1	Stages of nanocellulose isolation from banana rachis	43
3.3.2	Modelling and fitting using ultrasonication (US) for banana rachis	45
3.3.3	Modelling and fitting using high-pressure homogenisation (HPH) for banana rachis	51
3.3.4.	Characterisation of nanocellulose obtained from banana rachis	58
3.3.4.1.	Comparative analysis of the morphology of nanocellulose obtained by ultrasonication and high-pressure homogenization	58
3.3.4.2	FT-IR spectroscopic analysis of ultrasonicated samples	59
3.3.4.3	XRD analysis of ultrasonicated samples	60
3.3.4.4	Thermogravimetric analysis (TGA) and 1 st order derivatives (DTG)	61
3.3.4.5	Differential scanning calorimetry (DSC) of ultrasonicated samples	62
3.3.4.6	Morphological analysis of nanocellulose obtained by ultrasonication	65
3.3.4.7	TEM analysis of ultrasonicated nanocellulose samples	66

3.3.4.8. AFM analysis of ultrasonicated nanocellulose samples	67
3.3.5. Isolation of nanocellulose from pineapple peel	68
3.3.6. Modelling and fitting using ultrasonication (US) for pineapple peel	69
3.3.7. Modelling and fitting using high-pressure homogenisation (HPH) for pineapple peel	76
3.3.8. Characterisation of nanocellulose obtained from pineapple peel	82
3.3.8.1. Comparative analysis of the morphology of nanocellulose obtained by ultrasonication and high-pressure homogenisation	82
3.3.8.2. FTIR analysis of ultrasonicated samples	83
3.3.8.3. Relative crystallinity of ultrasonicated samples	84
3.3.8.4. Thermogravimetric Analysis (TGA) and 1st order derivatives (DTG)	85
3.3.8.5. Differential scanning calorimetry (DSC) analysis of ultrasonicated samples	86
3.3.8.6. TEM analysis of ultrasonicated nanocellulose	89
3.3.8.7. AFM analysis of ultrasonicated nanocellulose	90
3.3.8.8. Component content comparison of banana rachis and pineapple peel	90
3.4. Conclusion	91
CHAPTER 4	92-132
EFFECT OF NANOCELLULOSE-STABILIZED PICKERING NANOEMULSION IN A FOOD SYSTEM ON B-CAROTENE BIOACCESSIBILITY	
4.1. Introduction	92
4.2. Materials and methods	94
4.2.1. Materials	94
4.2.2. Preparation and characterization of Pickering nanoemulsion	94
4.2.2.1. Optimization design	94

4.2.2.2	Pickering nanoemulsion formulation	96
4.2.2.3	Evaluation of Pickering nanoemulsion stability	96
4.2.2.4	Particle size analysis of Pickering nanoemulsion	96
4.2.2.5	4.2.2.1.Morphology of Pickering nanoemulsion	96
4.2.3	Encapsulation of β -carotene in Pickering nanoemulsion	97
4.2.4	Chemical stability of β -carotene in Pickering nanoemulsion	97
4.2.5	Preparation of β -carotene-enriched functional mayonnaise	98
4.2.6	Functional mayonnaise characterization	98
4.2.6.1	Color analysis	98
4.2.6.2	Morphological analysis	98
4.2.6.3	Texture analysis	100
4.2.6.4	Rheological properties	100
4.2.6.5	Oxidative stability analysis	100
4.2.6.6	RP-HPLC analysis	101
4.2.6.7	In-vitro lipid digestion	101
4.2.6.8	β -carotene bioaccessibility	102
4.2.7	Statistical analysis	102
4.3	Results and discussion	102
4.3.1	Experimental design and optimization of oil phase composition	102
4.3.2	Characterisation of Pickering nanoemulsion	110
4.3.2.1	Emulsion stability during storage	110
4.3.2.2	Particle size analysis	112
4.3.2.3	Morphological analysis	113
4.3.3.	Chemical stability of β -carotene encapsulated Pickering nanoemulsion	115
4.3.4.	Characterisation of functional mayonnaise	116
4.3.4.1	Color analysis, stability, and visual appearance of functional mayonnaise	116
4.3.4.2	Optical microscopic analysis of functional mayonnaise	120
4.3.4.3	Texture analysis of functional mayonnaise	122
4.3.4.4	Oxidative stability of functional mayonnaise	123

4.3.4.5	Rheological properties of functional mayonnaise	125
4.3.4.6	RP-HPLC analysis of functional mayonnaise	127
4.3.4.7	In-vitro lipid digestion	129
4.3.4.8	β -carotene bioaccessibility	130
4.4	Conclusion	132
 CHAPTER 5		133-163
DEVELOPMENT OF NANOCELLULOSE/PROTEIN-BASED HYDROGEL WITH ENHANCED GELLING CHARACTERISTICS FOR APPLICATION IN FOOD SYSTEM		
5.1.	Introduction	133
5.2.	Materials and methods	136
5.2.1	Materials	136
5.2.2	Preparation of nanocellulose/protein-based hydrogel	136
5.2.3	Thermal analysis	137
5.2.4	Texture analysis	137
5.2.5	Water Holding Capacity (WHC)	138
5.2.6	Dynamic rheological measurements	138
5.2.7	Application of hydrogels in ice cream	138
5.2.7.1	Preparation of ice cream	138
5.2.7.2	Colour parameters of ice cream	139
5.2.7.3	Texture analysis of ice cream	140
5.2.7.4	Overrun, gas hold-up, and melting behaviour	140
5.2.7.5	Rheological properties of ice cream	141
5.2.7.6	In-vitro gastrointestinal fat digestion of ice cream	141
5.2.7.7	β -carotene bioaccessibility	142
5.2.8	Statistical analysis	142
5.3.	Results and discussion	142
5.3.1.	Morphology of hydrogel	142
5.3.2	Thermal analysis (TGA)	143
5.3.3	Texture analysis	146
5.3.4	Water Holding Capacity	147
5.3.5	Dynamic rheological properties	149

5.3.6	Application of hydrogels in ice cream	152
5.3.6.1.	Colour analysis	152
5.3.6.2.	Texture analysis	153
5.3.6.3.	Overrun, gas hold up, and melting behaviour	155
5.3.6.4	Rheological properties	157
5.3.6.5	In vitro gastrointestinal fat digestion of ice creams	160
5.3.6.6	β -Carotene bioaccessibility	161
5.4.	Conclusion	163
CHAPTER 6		164-192
EVALUATE AEROGELS DEVELOPED FROM NANOCELLULOSE AND INCORPORATE IT WITH BIOACTIVE COMPOUNDS FOR ITS APPLICATION IN PACKAGED FOOD		
6.1.	Introduction	164
6.2.	Materials and methods	166
6.2.1	Materials	166
6.2.2	RP-HPLC analysis	167
6.2.2.1	Extraction	167
6.2.2.2	Purification procedure	167
6.2.2.3	RP-UHPLC operating parameters	167
6.2.3	Development of aerogels using cellulose fibre, nanocellulose, and butterfly pea flower extract	168
6.2.4	Characterization of developed aerogels	169
6.2.5	Antioxidant capacity of bioactive aerogels	171
6.2.6	In-vitro release of bioactive aerogels from cellulose fibre and nanocellulose	171
6.5.7	Colour stability, reversibility, and colour change of bioactive aerogels under different pH conditions	171
6.2.8	Application of developed aerogels in the detection of minced chicken spoilage	172
6.2.8.1	pH measurement	172
6.2.8.2	Total volatile bases-nitrogen (TVB-N) content	172

6.2.8.3	Microbial analysis	173
6.2.9	Statistical analysis	173
6.3	Results and discussion	173
6.3.1	HPLC of anthocyanins present in butterfly pea flower	173
6.3.2	HPLC of phenolic acids present in butterfly pea flower	175
6.3.3	Characterization of bioactive aerogels	176
6.3.3.1	Morphology of the aerogels	176
6.3.3.2	FT-IR spectroscopic analysis	178
6.3.3.3	XRD analysis	180
6.3.3.4	Thermogravimetric analysis (TGA)	181
6.3.3.5	Density, porosity, and water absorption capacity	183
6.3.3.6	Antioxidant activity of the bioactive aerogels	184
6.3.3.7	In-vitro release of butterfly pea flower extract from bioactive aerogels	185
6.3.3.8	Sensitivity, reversibility, and stability of colour change in bioactive aerogel	188
6.3.4	Meat freshness monitoring	189
6.4.	Conclusion	191
CHAPTER 7		193-198
CONCLUSION AND FUTURE SCOPE OF WORK		
7.1	Conclusion	193
7.2.	Chapter 3	194
7.3.	Chapter 4	194
7.4.	Chapter 5	195
7.5.	Chapter 6	196
7.6.	Future scope of work	198
BIBLIOGRAPHY		199-249
LIST OF PUBLICATIONS/CONFERENCES		250-252
