

**PRODUCTION OF PLASTIC FROM MARINE ALGAE**

**PAVESWARI A/P SITHAMBARANATHAN**

**UNIVERSITI MALAYSIA PAHANG**

UNIVERSITI MALAYSIA PAHANG

**BORANG PENGESAHAN STATUS TESIS ♦**

**JUDUL: PRODUCTION OF PLASTIC FROM MARINE ALGAE**

**SESI PENGAJIAN : 2010/2011**

Saya

**PAVESWARI A/P SITHAMBARANATHAN**

**(HURUF BESAR)**

mengaku membenarkan tesis (PSM/~~Sarjana/Doktor Falsafah~~)\* ini disimpan di Perpustakaan Universiti Malaysia Pahang dengan syarat-syarat kegunaan seperti berikut :

1. Tesis adalah hakmilik Universiti Malaysia Pahang
2. Perpustakaan Universiti Malaysia Pahang dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.

4. \*\*Sila tandakan ( ✓ )

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh

\_\_\_\_\_  
(TANDATANGAN PENULIS)

\_\_\_\_\_  
(TANDATANGAN PENYELIA)

Alamat Tetap: Lot 5084, Jln. Shell Gate,

**DR.MOHAMMAD DALOUR**

Kampung Arab, 71000,

**HOSSEN BEG**

Nama Penyelia

Port Dickson, Negeri Sembilan

Tarikh : 20 APRIL 2011

Tarikh 20 APRIL 2011

CATATAN : \*

Potong yang tidak berkenaan.

\*\*

Jika tesis ini **SULIT** atau **TERHAD**, sila lampirkan surat daripada pihak berkuasa/organisasiberkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai **SULIT** atau **TERHAD**.

♦

Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

**“I hereby declare that I have read this thesis and in my opinion this thesis has fulfilled the qualities and requirements for the award of Degree of Bachelor of Chemical Engineering (Chemical)”**

**Signature :**

**Name of Supervisor : DR.MOHAMMAD DALOUR HOSSEN BEG**

**Date :**

**PRODUCTION OF PLASTIC FROM MARINE ALGAE**

**PAVESWARI A/P SITHAMBARANATHAN**

**A thesis submitted to the Faculty of Chemical and Natural Resources  
Engineering in Partial Fulfillment of the Requirement for the  
Degree of Bachelor Engineering in Chemical Engineering**

**Faculty of Chemical & Natural Resources Engineering  
Universiti Malaysia Pahang**

**APRIL 2011**

I declare that this thesis entitled “Production of Plastic from Marine Algae” is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.”

Signature :

Name : PAVESWARI A/P SITHAMBARANATHAN

Date : APRIL 2011

*To my beloved mother and father*

## ACKNOWLEDGEMENT

I would like to express my thanks towards God for the strength and encouragement that was given to me throughout the research and also with the completion of this thesis. I have also gained a lot of experiences and ideas in order to finish this thesis.

I offer my sincerest gratitude to my supervisor, Dr. Mohammad Dalour Hossen Beg who has supported me throughout my thesis with his patience and knowledge whilst allowing me the room to work in my own way. Moreover, endless guidance and support from him has made me to finish this research as well as the thesis. One simply could not wish for a better or friendlier supervisor.

I also would like to thank my parents who deserve to be given a token of appreciation for advises and critics that enabled me to complete my thesis. Not forgetting my family members and friends that had given me the support and encouragement to complete this thesis.

Once again, I would like to thank everybody who was important to the successful realization of thesis who involved directly or indirectly for assisting me to complete the thesis.

## ABSTRACT

The two objectives of this research are to produce plastic that is environmental friendly whereby the plastic produced can be at least slightly decomposed to smaller substances by the living organisms from marine algae and also to characterize the plastic that have been produced from the marine algae via mechanical and physical testing. In this study, algae which are Red *Eucheuma cottonii* are the raw material whereby Low Density Poly Ethylene (LDPE) is the additional plasticizer which aids in the plastic production. Chemical pretreatment was carried out on samples. The samples were then extruded by using twin screw extruder at temperature of 150 °C and 50 RPM. The extruded samples are then inject molded and characterize by using Fourier Transform Infrared Spectroscopy (FTIR), melt flow index (MFI), tensile testing and density test. From the results obtained, it was found out that this species of algae is not suitable to be the raw material due to the weak properties of intermediate product which is the product after the extrusion process. During the experiments, those algae were difficult to extrude due to easier moisture absorbance from the environment that lead to failure in injection molding during the sample preparation. Hence it can be concluded that the formulation using this species are not suitable for injection molding purpose.



## ABSTRAK

Terdapat dua objektif utama dalam kajian ini iaitu untuk memproses plastic yang tidak mencemarkan alam sekitar di mana plastik tersebut mempunyai kebolehan untuk biodegradasi oleh kehidupan organisma di samping menyifatkan plastik yang telah dihasilkan melalui kajian mekanikal dan fizik. Red Eucheuma cottonii merupakan bahan mentah untuk kajian ini manakala LDPE merupakan bahan tambahan yang membantu dalam penghasilan plastik. Rawatan kimia telah dijalankan atas sampel. Sampel tersebut disediakan untuk proses pengusiran pada suhu 150 °C dan 50 RPM. Sampel kemudian dibentuk melalui suntikan dan disifatkan melalui FTIR, MFI, ujian untuk menguji kekuatan plastic yang telah dihasilkan dan juga ujian ketumpatan.. Hasil kajian didapati spesies ini tidak sesuai untuk kajian ini. disebabkan penyerapan wap air dari sekeliling yang menyebabkan susah untuk proses pengusiran. Dengan ini boleh disimpulkan bahawa komposisi yang digunakan bagi spesies ini tidak sesuai untuk proses suntikan yang akan menghasilkan bentuk yang khas.

## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	<b>DECLARATION</b>	
	<b>DEDICATION</b>	
	<b>ACKNOWLEDGEMENT</b>	i
	<b>ABSTRACT</b>	ii
	<b>ABSTRAK</b>	iii
	<b>TABLE OF CONTENTS</b>	iv
	<b>LIST OF TABLES</b>	vii
	<b>LIST OF FIGURES</b>	viii
	<b>LIST OF ABBREVIATIONS</b>	ix
	<b>LIST OF SYMBOLS</b>	x
<b>1.0</b>	<b>INTRODUCTION</b>	<b>1</b>
	1.1 Background of the study	1
	1.2 Problem Statement	3
	1.3 Objective	3
	1.4 Scope of research	3
<b>2.0</b>	<b>LITERATURE REVIEW</b>	<b>4</b>
	2.1 Introduction	4
	2.2 Classification of Seaweeds	5
	2.3 Proteins in Red Algae	6
	2.3.1 Amino Acids in <i>Eucheumacottonii</i>	6
	2.3.2 Experimental Absorption Frequencies of few Amino Acids using FTIR (Fourier Transform Infrared Spectroscopy)	8

2.3.3 Protein Denaturation and Denaturants	9
2.4 Additives for Algal based Plastics	10
2.5 Latest Discoveries	11
<b>3.0 MATERIALS AND METHODS</b>	<b>12</b>
3.1 Introduction	12
3.2 Materials	12
3.2.1 Denaturants	12
3.2.1.1 Urea	13
3.2.1.2 Sodium Dodecyl Sulfate (SDS)	14
3.2.1.3 Sodium Sulfite ((Na <sub>2</sub> SO <sub>3</sub> )	14
3.2.1.4 Starch	15
3.2.2 Plasticizers	16
3.2.2.1 Glycerol	16
3.2.2.2 Di-ethylene glycol (DEG)	17
3.2.3 Additives	18
3.2.3.1 Low Density Poly Ethylene (LDPE)	18
3.3 Equipment	19
3.3.1 Extruder	19
3.3.2 Injection Molding	20
3.3.3 Hot Press	20
3.3.4 Fourier Transform Infrared Spectroscopy (FTIR)	20
3.3.5 Melt Flow Indexer (MFI)	20
3.3.6 Tensile Tester	20
3.3.7 Pycnometer	21
3.4 Method of Research	21
3.4.1 Sample Preparation and Procedures	21
3.4.1.1 Compounding and Protein	

	Denaturization	21
	3.4.1.2 Extrusion	21
	3.4.1.3 Injection Molding	22
	3.4.1.4 Hot Press	22
	3.4.2 Fourier Transform Infrared Spectroscopy (FTIR)	22
	3.4.3 Melt Flow Index (MFI) Testing	23
	3.4.4 Tensile Testing	23
	3.4.5 Density Testing	23
<b>4.0</b>	<b>RESULTS AND DISCUSSION</b>	<b>25</b>
	4.1 Introduction	25
	4.2 Extrusion Process	26
	4.3 Injection Molding	26
	4.4 Hot Press	28
	4.5 Fourier Transform Infrared Spectroscopy (FTIR)	29
	4.6 Melt Flow Index (MFI)	32
	4.7 Tensile Test	33
	4.8 Density	36
<b>5.0</b>	<b>CONCLUSIONS AND RECOMMENDATIONS</b>	<b>38</b>
	<b>REFERENCES</b>	<b>40</b>
	<b>APPENDIX A</b>	<b>42</b>

## LIST OF TABLES

TABLE NO	TITLE	PAGE
2.1	Amino acid concentration and total nitrogen content in <i>Eucheuma cottonii</i>	7
2.2	Experimental absorption frequencies (cm <sup>-1</sup> ) of glycine (Gly), alanine (Ala), threonine (Thr), cysteine (Cys) and methionine (Met)	9
3.1	Properties of Urea	13
3.2	Properties of Sodium Dodecyl Sulfate	14
3.3	Properties of Sodium Sulfite	15
3.4	Properties of Starch	16
3.5	Properties of glycerol	17
3.6	Properties of Diethylene glycol	18
3.7	Properties of Low Density Poly Ethylene	19
4.1	Functional Groups in Pure Algae	31
4.2	Functional Groups in Modified Alginate and LDPE	31
4.3	Melt Flow Index for percentage composition of LDPE and modified alginate	32
4.4	Tensile Strength of percentage composition of LDPE and modified alginate	33
4.5	Percent Elongation at Break between the Composition	36
4.6	Densities for Different Percentage Compositions of LDPE and Modified Alginate	36

**LIST OF FIGURES**

<b>FIGURE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
3.1	Extruder	19
3.2	Flow Chart of Research Methodology	24
4.1	Failure injection molding	27
4.2	LDPE (41.18 %)	27
4.3	LDPE (33.33 %)	28
4.4	LDPE (37.5 %)	29
4.5	FTIR for Pure Algae	30
4.6	FTIR for Modified Alginate and LDPE	30
4.7	Stress versus Strain curve for the percentage composition of 33.33 % LDPE and modified alginate	33
4.8	Stress versus Strain curve for the percentage composition of 37.5 % LDPE and modified alginate	34
4.9	Stress versus Strain curve for the percentage composition of 41.18 % LDPE and modified alginate	34
4.10	Tensile Strength versus Percentage Composition of LDPE and Modified Alginate	35

**LIST OF ABBREVIATIONS**

Gly	: Glycine
Ala	: Alanine
Thr	: Thyrosine
Met	: Methionine
RPM	: Rotations Per Minute
LDPE	: Low Density Poly-Ethylene
HDPE	: High Density Poly-Ethylene
FTIR	: Fourier Transform Infrared Spectroscopy
MFI	: Melt Flow Index
SDDS	: Sodium Dodecyl Sulfate
EL	: Elongation at Break

## **LIST OF SYMBOLS**

lf: Distance between the marks at or as close as possible to failure

lo: Distance between the marks inked on the specimen before stretching



## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background of the Study**

Marine algae are a type of phytoplankton (plant life), seaweeds in corals or anemones that is flower without petals. There are three common groups of marine algae that are green algae, brown algae and red algae. Sources of marine algae depend on the climate. For instance, green algae are largely aquatic or marine which can be found on the trunks of the trees, while brown algae can be found in colder oceans of the world and red algae commonly grown in warm-temperature and tropical climates. Marine algae is used in the production of plastic due to its advantage as a biodegradable plastic where it can be decomposed into smaller substance by living organisms. Basically biodegradability is defined as a process where all material fragments is consumed by microorganisms as a food and energy source. In this case, majority of the plastics fall into the category of petro-plastics and this petroleum based plastics are considered to be non-biodegradable or at best only biodegrade slowly which would end up as litter or in landfills. Therefore, algae based plastics is considered to be environmental- friendly as a biodegradable plastic. This is because marine algae undergoes photosynthesis process like other plants to harness sunlight and carbon dioxide and the energy produced is stored in the cell as lipids and form of carbohydrates. On the basis of these findings, it can be inferred that plastic produced from marine algae can solve two major problems that are air pollution resulting from carbon dioxide evolution and the second one is that solving future crises due to a shortage of energy resources which eventually make them an important innovation of sustainable development. Marine algae are being used due to

its unique characteristics that can contribute to the production of plastic. Marine algae also have been reported to contain more unusual substances, such as low molecular-weight sulfides and amines as well as industrial precursor molecules, such as acrylic acid used in the production of plastics. Besides that, for several years there were studies in producing plastics from vegetable materials such as corn and other starches. However, these largely starch-based materials are often not well suited for many applications of solid packing foams because of their relatively rapid breakdown under wet conditions, and their inherently low breaking strengths. If we turn that food into plastic, it becomes more expensive-too expensive for the poor peoples in the third world ((WO/1994/017132) ALGAL PLASTICS). Moreover, algae can grow extremely fast in very large quantities at a very low price. When people talk about “seaweed” they are actually talking about one form of algae. Thus when talking about in the context of bioplastics, red algae also known as “red seaweed”. Since there are many types of algae, only one specific type of algae is taken into consideration for the production of plastic. Red algae are chosen for this research due to high level of protein as compared to green and brown algae which is more feasible to produce plastic. This is because plastic is a polymer and red algae consists of protein chains that are also one type of natural polymer that can be processed to produce plastic. The organisms specified for use of this research are red algae of the species *Red Eucheuma Seaweed* of the Division (Rhodophyta) and Class (Rhodophyceae) ( Kathleen M.Cole et al.,1990). *Eucheuma* is a genus of tropical red seaweed that grows on limestone-rich substrates, especially coral reefs. Basically, the plastic is produced by breaking off the peptide links that connects the amino acids to form the protein by a process called protein denaturizing. This can be done by adding plasticizer and undergoes extrusion process together with some tensile tests for the strength of the plastic being produced. Thus, like all other plastics, bioplastics are composed of three basic parts which are one or more polymers, one or more plasticizers and finally plus one or more additives. Roughly speaking, polymers basically give plastic its strength; plasticizers give it its bendable and moldable qualities,

and additives give the plastic produced other properties such as color, durability and so on.

## **1.2 Problem Statement**

This research is being conducted in order to identify whether or not the species of algae used is ideal for the production of plastic.

Besides that, this research is to determine the optimum percentage composition of algae and additional plasticizer that gives the satisfactory strength of the plastic produced.

## **1.3 Objective**

There are two main objectives in this research of producing plastic from marine algae.

The first objective is to produce plastic that is environmental friendly whereby the plastic produced can be at least slightly decomposed to smaller substances by the living organisms from marine algae.

The second objective is to characterize the plastic that have been produced from the marine algae via mechanical and physical testing.

## **1.4 Scope of Research**

The scopes of study in this research are about the description and the characteristics of marine algae that help in the production of plastic. Moreover, the precise scope regarding the protein denaturizing of the marine algae by chemical treatment by using sodium dodecyl sulfate (SDS) and also conducting tests such as tensile tests in order to determine the strength of the plastics being produced from the marine algae.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

When the question arises the differences between bio plastics and biopolymers, this is how both of it are defined. As said in the portal of BioBasics (BioBasics, [www.biotech.gc.ca](http://www.biotech.gc.ca)), biopolymers were defined as polymers which are present in, or created by, living organisms. These include polymers from renewable resources that can be polymerized to create bio plastics. On the other hand, the portal also said that bio plastics are plastics manufactured using biopolymers, and are biodegradable. Today, bio plastics are gaining popularity once again as new manufacturing techniques developed through biotechnology are being applied to their production. Basically, there are two types of biopolymers which are those that come from living organisms; and, those which need to be polymerized but come from renewable resources. Both types are used in the production of bio plastics. Besides that from the website of Wikipedia , bio plastics or organic plastics are forms of plastics derived from renewable biomass sources such as vegetable oil, corn starch, and pea starch unlike fossil-fuel plastics derived from petroleum. Bio plastics provide the twin advantages of conservation of fossil resources and reduction in CO<sub>2</sub> emissions, which make them an important innovation of sustainable development. Algae serve as an excellent feedstock for plastic production owing to its many advantages such as high yield and the ability to grow in a range of environments. Algae bioplastics mainly evolved as a byproduct of algae bio fuel production, where companies were exploring alternative sources of revenues along with those from bio

fuels. In addition, the use of algae opens up the possibility of utilizing carbon, neutralizing greenhouse gas emissions from factories or power plants. Algae based plastics have been a recent trend in the era of bio plastics compared to traditional methods of utilizing feedstock of corn and potatoes as plastics. While algae-based plastics are in their infancy, once they are into commercialization they are likely to find applications in a wide range of industries.

## 2.2 Classification of Seaweeds

Seaweeds can be classified into three broad groups based on pigmentation: brown, red and green reported from the thesis by Khaled (1999). From the website ([marinelife.about.com](http://marinelife.about.com)), red algae have its often brilliant color due to the pigment phycoerythrin. These facts regarding red algae were obtained from (<http://www.lenntech.com/eutrophication-water>) noting that Rhodophyta, phylum of the kingdom protista consisting of the photosynthetic organisms commonly known as red algae. In most algae the primary pigment is *chlorophyll*, the same green pigment used in plants. Many algae also contain secondary pigments, including the *carotenoids*, which are brown or yellow, and the *phycobilins*, which are red or blue. Secondary pigments give algae their colorful hues. The red algae are multicellular and are characterized by a great deal of branching, but without differentiation into complex tissues. Most of the world's seaweeds belong to this group. Although red algae are found in all oceans, they are most common in warm-temperate and tropical climates, where they may occur at greater depths than any other photosynthetic organisms. Most of the coralline algae, which secrete calcium carbonate and play a major role in building reefs, belong here. Red algae are a traditional part of oriental cuisine. There are 4000 known marine species of red algae where a few species occur in fresh water. These algae can live at greater depths than brown and green algae because it absorbs blue light.

Besides that, red algae are most common in warm-temperature and tropical climates, where they may occur at greater depths than any other photosynthetic

organisms. Red algae are chosen as the species to be used as the raw material for the production of plastics from marine algae. This is because red algae have the high amount of amino acids which act as the building blocks for the formation of protein which makes it also a natural polymer was found in the species belonged to Rhodophyta (red algae) as compared to Phaeophyta and Chlorophyta reported by Nirmal *et al.*, 2010. Besides that an article from BioBasics said that there are also growing plants in plastic. In this era, plants have eventually become the factories for the production of plastics and this is proven by researches creating bacteria known as *Arabidopsis thaliana* plant through genetic engineering. Basically, this plant contains specifically the enzymes which are used by the bacteria to create the plastic. Through the conversion of sunlight into energy the bacteria create the plastic. Moreover, the researches have transferred the gene that codes for this enzyme into the plant and via its cellular processes the plant produces plastic. The plant is then harvested and later the plastic is extracted from it using solvent. Separation involving between the solvent from the plastic are done in order to remove the liquids resulting from the process.

## **2.3 Proteins in Red Algae**

### **2.3.1 Amino Acids in *Eucheuma cottonii***

There are many types of amino acids present in red algae and all the protein contents are used in this research field in order to achieve a substantial dimensional stability of the plastics produced similar to the synthetic plastics. The table below can be used as a tool to identify the types of protein that can contribute to the production of plastics from marine algae. Table 2.1 shows the amino acid concentration and total nitrogen content in *Eucheuma cottonii* reported by Patricia Matanjun *et al.* 2007.

**Table 2.1** Amino acid concentration and total nitrogen content in *Eucheuma cottonii*

Amino Acids	(mg g <sup>-1</sup> dry weight)
Aspartic acid (Asp)	2.65±0.15
Glutamic acid (Glu)	5.17±0.13
Serine (Ser)	1.92±0.04
Glycine (Gly)	2.27±0.32
Histidine (His)	0.25±0.10
Arginine (Arg)	2.60±0.14
Threonine (Thr)	2.09±0.01
Alanine (Ala)	3.14±0.11
Proline (Pro)	2.02±0.09
Thyrosine (Tyr)	1.01±0.12
Valine (Val)	2.61±0.07
Methionine (Met)	0.83±0.17
Isoleucine (Ile)	2.41±0.04
Leucine (Leu)	3.37±0.06
Phenylalanine (Phe)	19.07±2.48
Lysine (Lys)	1.45±0.48
Chemical score (%)	25.6
Most limiting amino acid	lysine
Total amount	52.86±3.37 <sup>c</sup>
Essential amino acid (EAA)	32.07±3.13 <sup>b</sup>
EAA (%)	60.59±1.36 <sup>a</sup>
Protein (%)	9.76±1.33 <sup>a</sup>

Values are expressed as mean  $\pm$  standard deviation, n=3

Values in the same row with different superscripts letters are significantly different (p<0.05)

Chemical score % =  $\frac{(\text{mg limiting amino acid per g of test protein} \times 100)}{(\text{mg limiting amino acid per g of reference protein})}$

(No. based on FAO/WHO/UNU amino acid requirement pattern)

@ limiting amino acids

Based on the Table 2.1, I have found out that phenylalanine has the highest content in this species.

### **2.3.2 Experimental Absorption Frequencies of few Amino Acids using FTIR (Fourier Transform Infrared Spectroscopy)**

As discussed by the researches such as Rolf *et al.*, 2007, they have identified the absorption frequencies for non aromatic amino acids. They have presented on the first gas phase Fourier Transform Infrared Spectroscopy (FTIR) spectra of the natural amino acids glycine, alanine, threonine, cysteine and methionine. It is revealed that matrix isolation spectroscopy has OH stretch, C=O stretch, NH<sub>2</sub> bend and COH bend vibration frequencies of glycine at 3560, 1790-1800, 1622-1630 and 1100 cm<sup>-1</sup> which was in good agreement with their research which show acceptable values which are 3577,1787,1620 and 1114 cm<sup>-1</sup>. Based on the table 2.2, it shows the absorption frequencies of few selected amino acids such as glycine (Gly), alanine (Ala), threonine (Thr), cysteine (Cys) and methionine (Met). This would help in my research as I could identify the presence of amino acids by determining the functional groups.



**Table 2.2** Experimental absorption frequencies ( $\text{cm}^{-1}$ ) of glycine (Gly), alanine (Ala), threonine (Thr), cysteine (Cys) and methionine (Met)

Functional Groups	Gly	Ala	Thr	Cys	Met
OH ipb(COOH)	1114	1114	1114	1118	1117
CH/NH bend	1620	-	1282 1377 - - 1614	- 1364 - - 1627	- 1369 1442 - 1630
C=O	1787	- 1372 - 1590 1627	1779	1782	1777
CH	2937/2868 2951	1785	- 2928 2981	- 2952 -	2860 2930 -
OH (COOH)	3577	- 2924 2991	3570	3572	3572
OH	-	3575	3652	-	-

### 2.3.3 Protein Denaturation and Denaturants

The researches Gonzalez *et al.*, 2009, found out that the in order for the formation of protein based bioplastics; there are three most essential steps for it to occur. The three steps are the stabilized intermolecular bonds are break off, mobile polymer chains are oriented in the desired shape and finally allowing the formation of new intermolecular bonds that strengthen the three –dimensional network. Besides that, denaturation of protein which is caused by heat results whereby in this case they used albumen. This is due to exposure of these sulfhydryl groups which accompanied by a decrease in its total content due to oxidation to disulfide bonds reported by Van der Placken *et al.*, 2005. Thus according Gonzalez *et al.*, 2009 proteins chains unfold and entangle with other proteins, and new bonds arise, causing the texture to change.

In order to denature the proteins in the algae few researches such as Rakesh *et al.*, 2002, certain reagents such as urea and sodium disulphide are added to denature

protein as well as improve the gluing strength and their water resistance of the protein structure. However, in this journal they did research on soybean plastics that are protein based plastics. This research is almost similar to my undergraduate research since they are using the protein chains and I can use this as a reference to conduct my project. It was also discussed in this journal that the concentration urea had a significant effect on the extent of protein unfolding and ultimately on the adhesive properties (Plasticsnews.com/headlines).

## **2.4 Additives for Algal based Plastics**

In my research I will be using LDPE (Low Density Poly Ethylene) as a form of additives to enhance the sample preparation as well as to improve the final product. From the book Additives can be categorized into 5 factors such as:

- a) processing aids as to improve the process ability
- b) antioxidants or stabilizers
- c) mineral fillers as in to bulk out of the polymer
- d) impact modifiers for example glass fibres to increase the strength
- e) compatibilisers as in to improve mixing of two or more polymers (Polymers, The Environment and Sustainable Development)

LDPE has a better chance to act as impact modifiers or plasticizers at the same time in order to increase the strength of the algal plastics produced. These are the following characteristics of LDPE. LDPE is light and it has a good impact resistance besides having a good flexibility which would improvise the properties of the algal plastics to be produced. Most importantly, LDPE has a thermoforming performance that will assist in the extrusion process of the modified alginate that is added with the chemical composition. Moreover LDPE also has no moisture absorption since algae itself has a higher water content whereby the addition of LDPE is hoped to reduce the water content (Menasha Corporation).

## **2.5 Latest Discoveries**

It is found out that a company called Cereplast has come with some invention to improvise the algal based bio plastics. Currently they have inject molded the algal based biomass together with polypropylene. Besides that, they have also tried with materials like corn, starch and tapioca in order to produce bio plastics. However, algae have a better demand in terms of producing bio plastics as compared to corn, starch and so on due to the food spikes. This is because algae would have less potential impact on the food chain and on any food that could be consumed by humans. In addition, Cereplast also believes that algae help in the process of greening the plastics as well as to ensure for longer term sustainability.

## **CHAPTER 3**

### **MATERIALS AND METHODS**

#### **3.1 Introduction**

This research is being conducted based on the experimental work. In this research species of red algae *Eucheuma cottonii* is used. This algae is being collected from Semporna, Sabah.

During this study, thermo-plastic as well as thermo-mechanical processing will be used to produce plastic. In thermo-plastic processing, the proteins from the red algae are mixed with the plasticizers by using the extruder in order to obtain a homogeneous phase in a dough-like material. Meanwhile thermo-mechanical processing is used further for the application of both heat and pressure. These methods would enable to produce bioplastics which is environmental friendly and to reduce the consumption of petrochemical products.

#### **3.2 Materials**

##### **3.2.1 Denaturants**

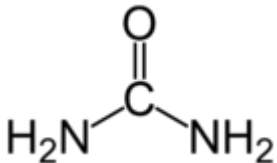
Denaturants basically cause a chemical reaction, whereby protein unfolds when it comes into contact with denaturant chemical.

### 3.2.1.1 Urea

Urea is classified under the group of chaotropes which are one form of denaturants which eventually disrupt water interactions and assist to solubilize hydrophobic proteins and peptides. Moreover it also act as general protein denaturants whereby they unfold proteins and altering their three dimensional structure. Besides that, urea is also known as a low ultraviolet (UV) absorbing protein denaturant.

Urea or carbamide is an organic compound with the chemical formula  $(\text{NH}_2)_2\text{CO}$ . The molecule has two amine ( $-\text{NH}_2$ ) groups which is joined by a carbonyl ( $\text{C}=\text{O}$ ) functional group. Properties of urea are stated as below in the table below:

**Table 3.1** Properties of Urea

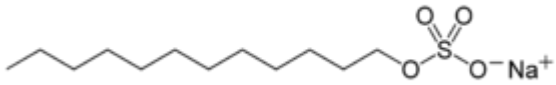
Other names	Carbamide, carbonyl diamide, carbonyldiamine, diaminomethanal, diaminomethanone
Molecular Structure	
CAS Number	57-13-6
Molecular formula	$\text{CH}_4\text{N}_2\text{O}$
Molar mass	$60.06 \text{ g mol}^{-1}$
Appearance	White solid
Density	$1.32 \text{ g/cm}^3$
Melting point	$133\text{--}135 \text{ }^\circ\text{C}$

### 3.2.1.2 Sodium Dodecyl Sulfate (SDS)

Sodium lauryl sulfate (SLS), sodium laurilsulfate or sodium dodecyl sulfate (SDS or NaDS) ( $C_{12}H_{25}SO_4Na$ ) is an anionic surfactant used in many cleaning and hygiene products. Basically, the molecule has a tail of 12 carbon atoms, attached to a sulfate group, giving the molecule the amphiphilic properties required of a detergent.

Properties of Sodium Dodecyl Sulfate are listed in the table below:

**Table 3.2** Properties of Sodium Dodecyl Sulfate

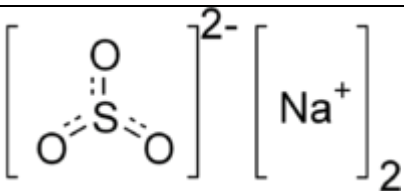
Other names	Sodium monododecyl sulfate; Sodium lauryl sulfate; Sodium monolauryl sulfate; Sodium dodecanesulfate; dodecyl alcohol, hydrogen sulfate, sodium salt; n-dodecyl sulfate sodium; Sulfuric acid monododecyl ester sodium salt;
Molecular Structure	
CAS Number	151-21-3
Molecular formula	$NaC_{12}H_{25}SO_4$
Molar mass	$288.38 \text{ g mol}^{-1}$
Density	$1.01 \text{ g/cm}^3$
Melting Point	$206 \text{ }^\circ\text{C}$

### 3.2.1.3 Sodium Sulfite ( $Na_2SO_3$ )

Sodium sulfite (sodium sulphite) is a soluble sodium salt of sulfurous acid. A part of the flue gas desulphurization process which produces sodium sulfite resulting

from sulfur dioxide scrubbing. Sodium sulfite is primarily used in the pulp and paper industry. It is used in water treatment as an oxygen scavenger agent, in the photographic industry to protect developer solutions from oxidation and (as hypo clear solution) to wash fixer (sodium thiosulfate) from film and photo-paper emulsions, in the textile industry as a bleaching, desulfurizing and chlorinating agent and in the leather trade for the sulfurization of tanning extracts. Properties of sodium sulfite are tabulated as follows:


**Table 3.3** Properties of Sodium Sulfite

Other names	Hypo clear (photography)
Molecular Structure	
CAS Number	7757-83-7
Molecular formula	Na <sub>2</sub> SO <sub>3</sub>
Molar mass	126.043 g/mol
Density	2.633 g/cm <sup>3</sup> (anhydrous) 1.561 g/cm <sup>3</sup> (heptahydrate)
Melting Point	33.4 °C (dehydration of heptahydrate) 500°C (anhydrous)
Appearance	White Solid

#### 3.2.1.4 Starch

Starch is being added in order to improve the gluing strength. Starch or amyllum is a carbohydrate consisting of a large number of glucose units joined together by glycosidic bonds. This polysaccharide is produced by all green plants as an energy store. It is the most important carbohydrate in the human diet and is contained in such staple foods as potatoes, wheat, maize (corn), rice, and cassava. Properties of starch are listed as follows:

**Table 3.4** Properties of Starch

Starch	
CAS Number	9005-25-8
Molecular formula	$(C_6H_{10}O_5)_n$
Density	1.5 g/cm <sup>3</sup>
Melting Point	Decomposed
Appearance	White Powder

### 3.2.2 Plasticizers

Basically, plasticizers are molecules with low molecular weight and low volatility which eventually reduce the intermolecular forces and increase the polymer chains mobility. The less plasticizer, the stronger the plastic but the presence of too much plasticizer would also because plastic becomes too tacky.

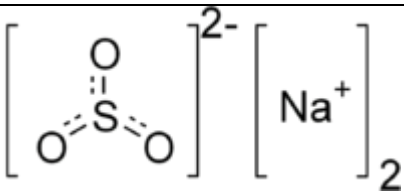
#### 3.2.2.1 Glycerol

Glycerol (or glycerin, glycerine) is a simple polyol compound. It is a colourless, odorless, viscous liquid that is widely used in pharmaceutical formulations. Basically, glycerol has three hydrophilic hydroxyl groups that are responsible for its solubility in water and its hygroscopic nature. In addition, the glycerol backbone is central to all lipids known as triglycerides. Glycerol form cross links with proteins, the protein



mobility is decreased but clusters of a glycerol molecules increase the film plasticity. Glycerol is sweet-tasting and of low toxicity. Properties of glycerol are listed as follows:

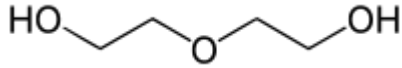
**Table 3.5** Properties of glycerol

Other names	Hypo clear (photography)
Molecular Structure	
CAS Number	7757-83-7
Molecular formula	Na <sub>2</sub> SO <sub>3</sub>
Molar mass	126.043 g/mol
Density	2.633 g/cm <sup>3</sup> (anhydrous) 1.561 g/cm <sup>3</sup> (heptahydrate)
Melting Point	33.4 °C (dehydration of heptahydrate) 500°C (anhydrous)
Appearance	White Solid

### 3.2.2.2 Di-ethylene glycol (DEG)

Diethylene glycol (DEG) is an organic compound with the formula (HOCH<sub>2</sub>CH<sub>2</sub>)<sub>2</sub>O. It is miscible in water, alcohol, ether, acetone and ethylene glycol. DEG is a widely used solvent. It is a colorless, practically odorless, poisonous, viscous, and hygroscopic liquid with a sweetish taste. In terms of hazardous effects it is harmful if swallowed and may cause irritation to eyes as well to skin. Properties of diethylene glycol are tabulated as follows:

**Table 3.6** Properties of Diethylene glycol

Other names	diethylene glycol; ethylene diglycol; diglycol; 2,2'-oxybisethanol; 3-oxa-1,5-pentanediol; dihydroxy diethyl ether
Molecular Structure	
CAS Number	111-46-6
Molecular formula	C <sub>4</sub> H <sub>10</sub> O <sub>3</sub>
Molar mass	106.12 g/mol
Density	1.118 g/mL
Melting Point	-10.45 °C
Appearance	Colorless liquid
Boiling Point	244–245 °C

### 3.2.3 Additives

Additives basically give colour and durability of the material or in this case the plastic being produced.

#### 3.2.3.1 Low Density Poly Ethylene (LDPE)

LDPE is more flexible than HDPE, which makes it a good choice for prosthetic devices, most of which are either drape formed or vacuum formed. Its impact resistance makes it a natural for impact pads, while its easy machinability makes it a good choice for fabricated parts where chemical and corrosion resistance is demanded.

**Table 3.7** Properties of Low Density Poly Ethylene

Melt Index	1.25 g/10 min
Density	920 kg/m <sup>3</sup>
Yield Point	9.4 MPa
Tensile Break	13.4 MPa
Elongation at Break	515 %
Tensile Modulus	287 MPa
Water Absorption	Slight %

### 3.3 Equipment

#### 3.3.1 Extruder

In this research, a twin screw extruder branded Thermo Scientific will be used. The extrusion is accomplished by the twin screw extruder in a cylindrical barrel. An extruder is required for this experiment which forcing molten material through a shaped die by means of pressure. In this case, screws are used to progress the polymer in the molten or rubbery state along the barrel of the machine and twin extruder enhances for a superior mixing.

**Figure 3.1** Extruder

### **3.3.2 Injection Molding**

The injection pressure is (25 %) and the mold temperature to be used (150°C). This type of molding is used where it cools and hardens to the required configuration of the mold cavity. The pelletized material is then injecting molded into specimens by using injection molder for tensile testing. The equipment's brand is Nissei.

### **3.3.3 Hot Press**

Hot press is an equipment to get mold shapes by the application of heat and pressure. The samples are pressed for a preset period of time with a mould shape.

### **3.3.4 Fourier Transform Infrared Spectroscopy (FTIR)**

FTIR enables to identify the unknown materials, determine the quality or consistency of a sample and also can determine the amount of components in a mixture. In infrared spectroscopy, IR radiation is passed through a sample. Some of the infrared radiation is absorbed by the sample and some of it is passed through (transmitted). The resulting spectrum represents the molecular absorption and transmission.

### **3.3.5 Melt Flow Indexer (MFI)**

For this research, Melt Flow Indexer Dynisco will be used. Besides that, it utilizes 32-bit microprocessor to provide test parameter control, self-diagnostics and digital calibration. The onboard computer controls and displays temperature to  $\pm 0.1^\circ\text{C}$  using a unique PID control algorithm

### **3.3.6 Tensile Tester**

This experimental will require Instron Tensile Tester with a load of 50 kN. This equipment will be needed in order to determine the tensile strength of the sample specimens as well as for the determination of elongation at break in percentages.

### 3.3.7 Pycnometer

Pycnometer modeled **The AccuPyc<sup>®</sup> II 1340 Series** will be used for this research whereby using a gas displacement technique to measure volume, the AccuPyc II 1340 completes most sample analyses in less than three minutes. This equipment uses gas helium to conduct this experiment in order to identify the densities of the samples to be measured. Besides that, there is a method to include direct sample mass input from a balance and cycle-based displacement volume reporting.

## 3.4 Method of Research

### 3.4.1 Sample Preparation and Procedures

#### 3.4.1.1 Compounding and Protein Denaturation

200 g of *Eucheuma cottonii* algae will be weighed and cut into small pieces for blending purpose with the denaturants using a blender. The denaturants such as urea, sodium dodecyl sulfate, sodium sulfite and starch will be added to the algae with the percentages of 16.5 %, 1.5 %, 1.5% and 21.5 % of the total algae respectively. Plasticizers such as glycerol and di-ethylene glycol will be added in the percentage of both 25 % of the total algae. The balance 9 % is water to be added in order for easier blending.

#### 3.4.1.2 Extrusion

Extrusion was carried out in the Thermo Scientific using the blended compounds together with LDPE composition of 33.33 %, 37.5% and 41.18 % into the extruder. A

mechanical screw extruder is used within the range of temperature( 80°C-150°C) as process variable that are 80°C,100°C,120°C, 140°C,150°C with the range 5 wt%-20 wt%. The speed of the extruder also plays a vital role in producing a smooth modified alginate. Thus, speed of 40-50 m/s is used to extrude the specimens. The material is pelletized into a length of less than 5 mm.

#### 3.4.1.3 Injection Molding

The three modified alginate with three different compositions will be inject molded at the temperature of 120 °C and a pressure of 25 %.

#### 3.4.1.4 Hot Press

The unsuccessful samples in injection molding process will be using hot press as an alternative to get mould shapes and heat pressed at the temperature of 150 °C. The heat press is conducted for a time period of 15 minutes and removed it and cools it for about 2 to 3 minutes.

#### 3.4.2 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR is used for recognizing and comparing the presence of amino acids between modified alginate and pure algae. Besides the respective peaks are identified in order to determine the functional groups of amino acids as well as low density poly ethylene.

### 3.4.3 Melt Flow Index (MFI) Testing

A standard weight of 2.16 kg and a melt temperature of 150 °C will be used. The sample is left in the barrel of the melt indexer apparatus for an extended period that is 10 minutes. The weight is then applied and 3 “cut-offs” are taken in the normal way that follows ASTM 1238. Later, the average melt flow is taken and comparison will be done between the three percentages.

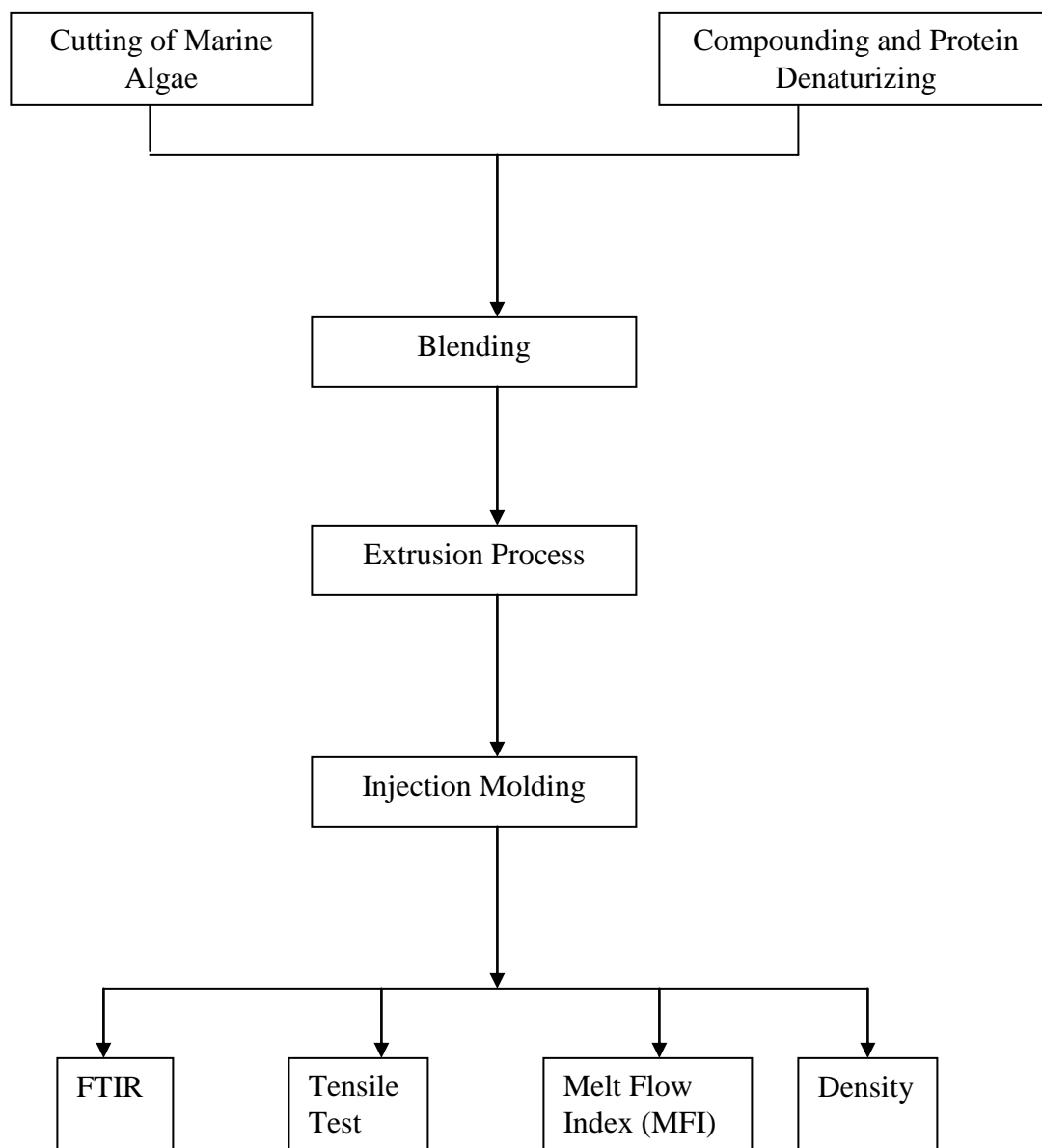
### 3.4.4 Tensile Testing

Instron tensile tester will be used at the cross head of 3 mm/min and a load of 50 kN will be applied to the sample. Tensile results will be taken and stress versus strain curve will be plotted in order to determine the tensile strength and elongation at break (%). Tensile strength is determined from the stress versus strain curve whereby the stress at the maximum on the engineering stress-strain curves. Percent elongation at break is calculated by using the formula:

$$\%EL = \frac{(l_f - l_o)}{l_o} \times 100 \% \quad (\text{Eq .1})$$

### 3.4.5 Density Testing

The samples were prepared for the density measurement by using gas helium pycnometer branded Micromeritics. This method is based on knowledge of the mass and volume displacement by the sample that has been palletized. Mass of the samples are recorded and inserted in the screen.



**Figure 3.2** Flow Chart of Research Methodology



## **CHAPTER 4**

### **RESULTS AND DISCUSSION**

#### **4.1 Introduction**

The results are discussed between three different compositions of LDPE and modified alginate which are 33.33 %, 37.5 % and 41.18 % together with chemically modified alginate. However, there were few trials and errors were carried out in order to determine the suitable temperature and rotational speed per minute (RPM) for the samples to be extruded. Besides that, determination between the samples was also determined to see which the samples that could be injected molded are. The cause for the unsuccessful injection molding was also determine to improvise and at the same time heat press was used as an alternative to substitute the injection molding step in order to get mould shape. On the other hand, the palletized three samples of compositions were used to study of characterization of modified alginate and raw algae were studied using FTIR. Each type of bond in a molecule will absorb IR light at a specific frequency, sometimes more than one. Since most molecules have several different types of bonds, a given compound will show multiple absorbances. So, each peak is not one molecule, its part of a molecule. If several molecules in a formulation have the same type of bond, each peak may be part of several molecules, with each one of them having various other absorbances that create the "signature" for a given molecule. Besides that, tensile strength between the

three percentage compositions are compared based from the stress versus strain curve. Tensile strength can be determined by applying force to the specific specimens until it breaks off. Besides that, tensile strength would be able to measure the ability of the polymer to withstand the pulling stress whereby the specimen is prepared in a dumbbell or dog bone shaped. The most important properties which characterize a polymer are its molecular weight and this can be achieved by measuring the melt flow index of the specimens. Theoretically it is said that melt flow index is inversely proportional to the polymer's molecular weight. MFI test eventually uses a capillary rheometer. For the density measurements gas helium pycnometry is used whereby mass and volume displacement to calculate density.

#### **4.2 Extrusion Process**

After several trials and runs, the optimum temperature was found to be 150 °C and the rotational speed was 45-50 RPM with a feed ratio of 5 wt% - 20 wt%. Besides that, it was also found that as the RPM increases, the retention time of the samples in the extruder eventually decreases. This will cause fewer samples in the extruder to be burnt.

#### **4.3 Injection Moulding**

Based on the results of the injection molding, it shows unsatisfactory results as due to failure of the three type of composition. The unsuccessful composition that is failed is shown in the **Figure 4.1** below when the samples supposed to come out as in a pair and not separately as shown in the image. However, only modified algae which contained 41.18 % of LDPE and modified alginate can be injected to become samples for tensile test but with brittle appearance as shown in the **Figure 4.2**. There

are few reasons due to the failure in injection molding such as the particular species are very soft and then this particular species of *Eucheuma cottonii* tend to easily absorb moisture from the surrounding. Thus, these species are strongly not recommended for this process even with the addition of LDPE.



**Figure 4.1** Failure injection molding



**Figure 4.2** LDPE 41.18 %

#### 4.4 Hot Press

Hot press was conducted as an alternative experiment for the other two percentage composition of LDPE and modified alginate which are 33.33 % and 37.5 % respectively to get mould shapes. In this experiment a temperature of 150 °C was used to heat up the samples for about 10 minutes and at the same time compressed the sample. Somehow the dumbbell shapes obtained for both the percentages but the samples were very brittle and it was slightly out of shape. As shown in the Figure 4.3 is the molded shape for LDPE composition of 33.33 % and modified alginate. On the other hand, **Figure 4.4** shows the molded shape for LDPE composition of 37.5 % and modified alginate. This may be due to the samples in the mould experiencing excessive orientation that cause the samples fracture prematurely. In this stage the polymer chains tend to become elongated and frozen along the axis of the part thus leaving little chain to entangle around the particular perimeter of the part.

Furthermore, the inappropriate melting and moulding temperatures would have caused the mechanical failure of these samples. The molded samples are then used for further tests.



**Figure 4.3** LDPE (33.33 %)



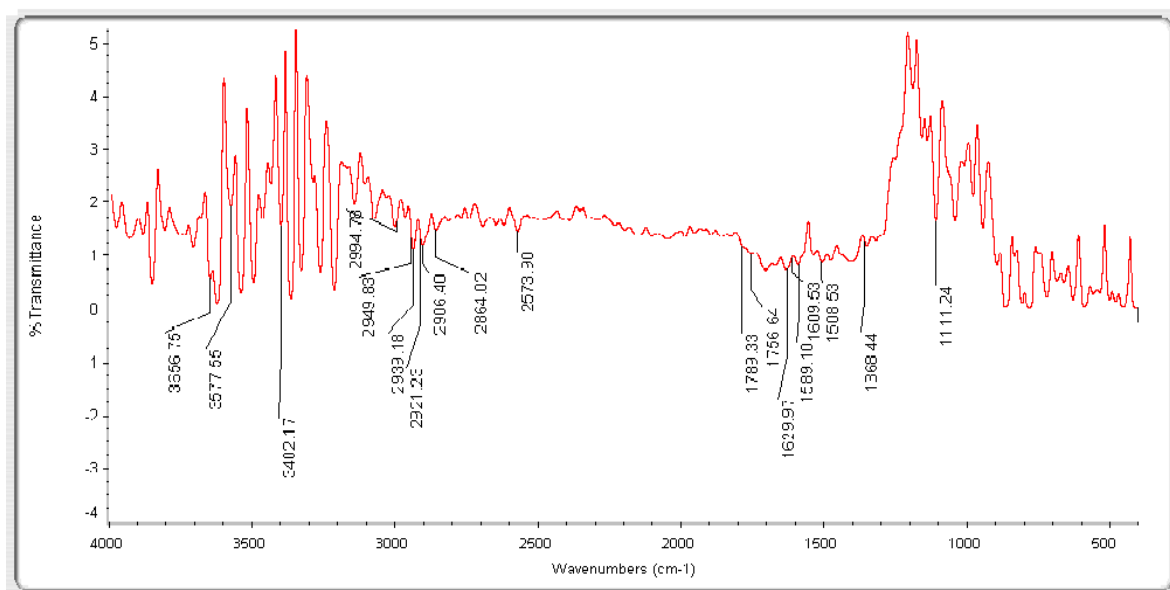
**Figure 4.4** LDPE (37.5 %)

#### **4.5 Fourier Transform Infrared Spectroscopy (FTIR)**

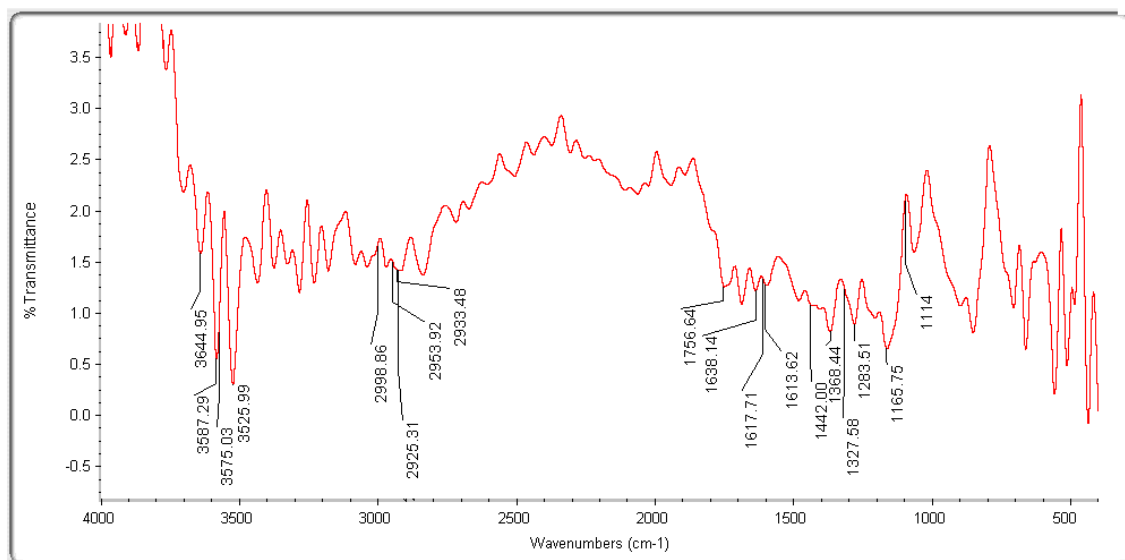
As shown in the both **Figure** of **4.5** and **4.6** show the peaks that are used to make comparison of the presence of functional groups of LDPE as well as the amino acids content between the modified alginate and LDPE. Since there are 16 amino acids found in the species of *Eucheuma cottoni*, but only 4 types of amino acids are considered here to make an easier comparison. The amino acids that are considered here for the FTIR test are glycine (Gly), alanine (Ala), tyrosine (Tyr) and methionine (Met). As the technique works on the fact that bonds and groups of bonds vibrate at characteristic frequencies, the wave number are displayed in the table below. A molecule that is exposed to infrared rays absorbs infrared energy at frequencies which are characteristic to that molecule.

On the other hand, **Table 4.1** shows functional groups in the pure algae while **Table 4.2** shows the functional groups in the modified alginate and LDPE as additives with their respective frequencies. As for comparison, the amino acids were not present in the modified alginate which proves that the proteins inside the algae have been

denaturated already. These can be viewed from the graph that there are no peaks that represents the  $\text{NH}_2$  the amino group and the carboxyl group ( $-\text{COOH}$ ).



**Figure 4.5** FTIR for Pure Algae



**Figure 4.6** FTIR for Modified Alginate and LDPE

**Table 4.1** Functional Groups in Pure Algae

Functional Groups	Wave number (cm <sup>-1</sup> )			
	Gly	Ala	Thr	Met
NH <sub>2</sub> bend	1617.71	Absent	1283.51	1442
C=O	1756.64	1638.14	-	-
CH	2933.48	-	-	2925.31
OH	3587.29	3575.03	3644.95	Absent

**Table 4.2** Functional Groups in Modified Alginate and LDPE

Functional Groups	Wave number (cm <sup>-1</sup> )				
	Gly	Ala	Thr	Met	LDPE
NH <sub>2</sub> bend	-	Absent	-	-	
C=O	-	-	-	-	
CH	2953.92	-	2928.52	2864.02	2908.97
OH	Absent	3575.03	3652.67	-	3342.11
Aromatic C-H	-	-	-	-	3084.68
Symmetric methyl	-	-	-	-	2843.59
Aliphatic C-C	-	-	-	-	2345.06
Aromatic C=C	-	-	-	-	1646.31
CH <sub>2</sub>	-	-	-	-	747.33
Carboxylic Acid	-	-	-	-	1360.27

#### 4.6 Melt Flow Index (MFI)

**Table 4.3** Melt Flow Index for percentage composition of LDPE and modified alginate

MATERIALS	MELT FLOW INDEX (g/10 min)
LDPE (33.33 %) +Algae	14.222
LDPE ( 37.5 %) + Algae	9.636
LDPE (41.18 %) +Algae	7
LDPE only	1.8

From the results displayed on the **Table 4.3**, LDPE with (33.33%) as additives have a higher melt flow index. This is because a higher MFI shows that the more polymer flows under test conditions. Thus, LDPE with (33.33 %) flows more under the temperature of 150°C. As LDPE composition increases, the MFI also decreases and is proven as the MFI for LDPE is 1.8 where the value for (41.18%) nears this value.

The MFI can be regarded as being inversely proportional to the polymer's molecular weight. Thus, higher MFI shows a decrease in melt viscosity and eventually shows a decrease in the molecular weight of the material. Therefore, it can be concluded that low molecular weight shows high melting point.

A decrease in the MFI of the polymer can also be an indicative of cross linking and is observed as the result during melt operations such as extrusion.



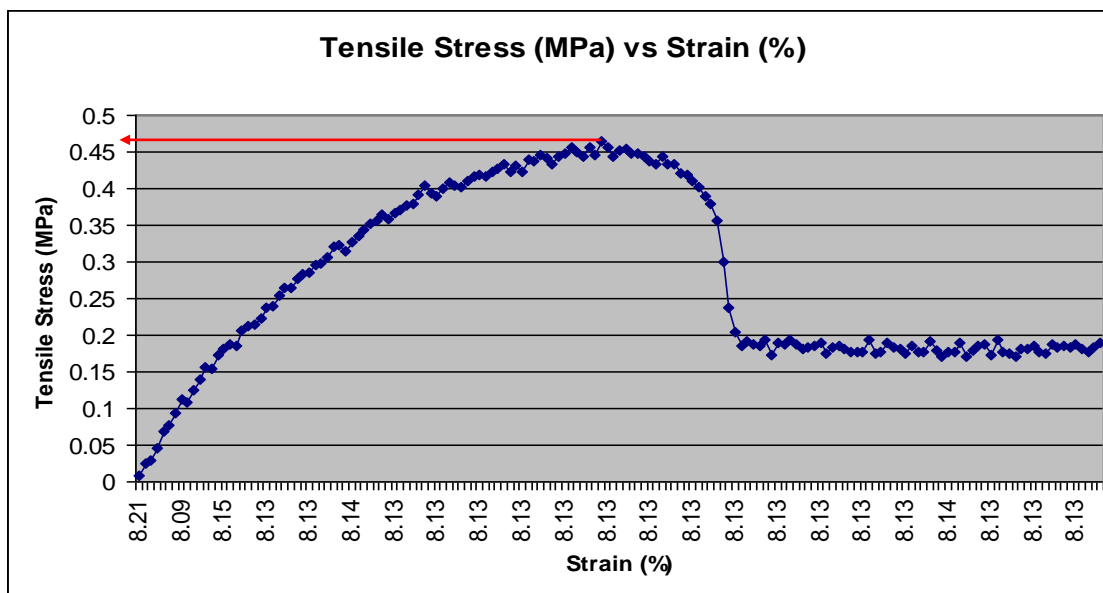
## 4.7 Tensile Test

These are the results obtained for tensile test for 33.33%, 37.5 % and 41.18 % of LDPE. From the results obtained percentage composition of 41.18 % LDPE and modified alginate shows the highest tensile strength due to the presence of higher LDPE amount. As shown in the **Figure 4.7, 4.8 and 4.9** show the stress versus strain curve for percentages composition of 33.33 %, 37.5 % and 41.18 % LDPE and modified alginate.

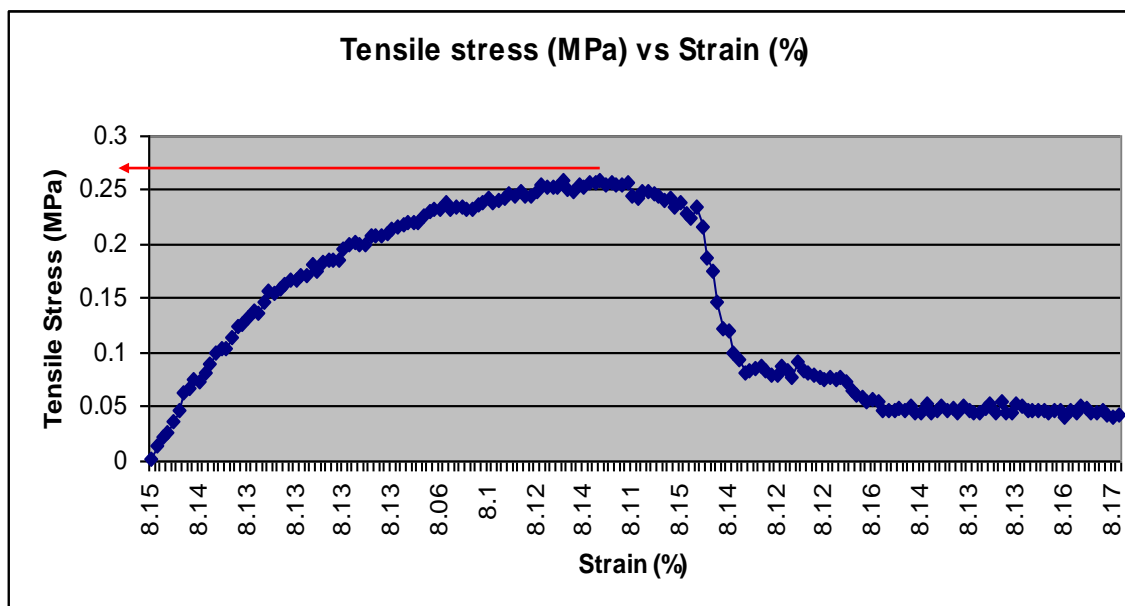
From the three graphs, tensile strength for each composition can be determined whereby the stress at the maximum on the engineering stress-strain curves. The results are displayed in the **Table 4.4**.

**Table 4.4** Tensile Strength of percentage composition of LDPE and modified alginate

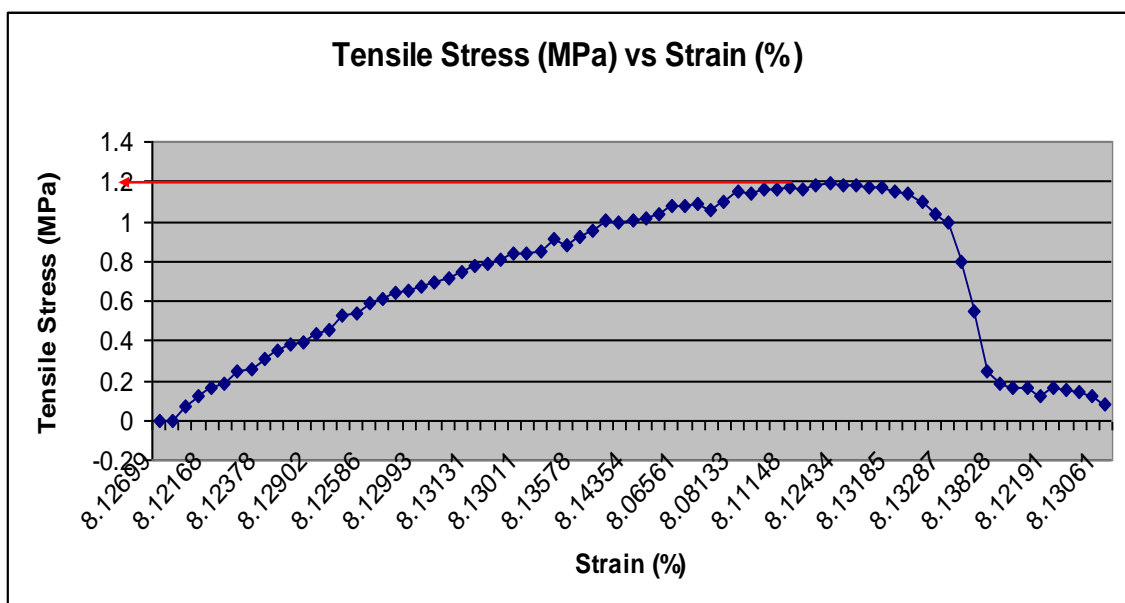
Percentage composition of LDPE and modified alginate (%)	Tensile Strength (MPa)
33.33	0.46
37.5	0.26
41.18	1.2



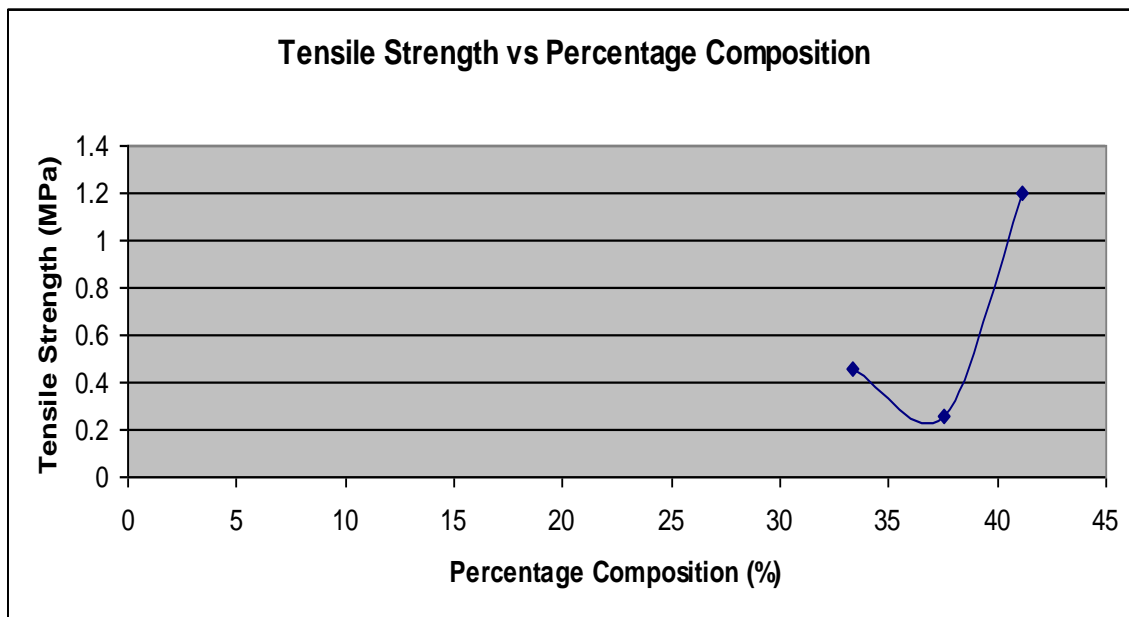
**Figure 4.7** Stress versus Strain curve for percentage composition of 33.33 % LDPE and modified alginate



**Figure 4.8** Stress versus Strain curve for the percentage composition of 37.5 % LDPE and modified alginate



**Figure 4.9** Stress versus Strain curve for the percentage composition of 41.8 % LDPE and modified alginate



**Figure 4.10** Tensile Strength versus Percentage Composition of LDPE and Modified Alginate

Tensile strength decreases for the percentage composition of 37.5 % LDPE and modified alginate. This may be influenced by the test temperature, the sample's loading history and the strain rate that is crosshead speed. Perhaps, the strain rate that is 3 mm/min is not suitable and load 50 KN is too big for this particular composition. Moreover, this may also be due to characteristics of 37.5 % LDPE which did not match with the algae.

Furthermore, percent elongation at break was also calculated by removing the fractured specimen from the grips; fitting the broken ends together and measuring the distance between gage marks. **Table 4.5** below shows the percent elongation at break obtained for the three different types of LDPE compositions and modified alginate. Based on the results obtained, percent elongation at break is the highest for the percentage composition for 33.33% LDPE and modified alginate. From here can be concluded that the shorter the original gauge length,  $l_0$ , the greater the fraction of total elongation and consequently increases the percent elongation at break. Thus, the

percentage composition of 33.33 % LDPE and modified alginate shows that the material is ductile and less brittle.

**Table 4.5** Percent Elongation at Break between the Compositions

Composition of LDPE and modified alginate (%)	Fracture Length, $l_f$ (cm)	Original Gauge Length, $l_o$ (cm)	Percent Elongation at Break (%)
33.33	2.03458	5.0	40.69
37.5	2.04139	5.3	38.52
41.18	2.03265	5.4	37.64

#### 4.8 Density

**Table 4.6** Densities for Different Percentage Compositions of LDPE and Modified Alginate

Composition of LDPE and modified alginate (%)	Density ( $\text{g/cm}^3$ )
33.33	1.0063
37.5	1.1217
41.18	0.927

From the **Table 4.6**, 37.5 % has the highest density as compared to other percentages. Perhaps, may be the additives in LDPE has distorted the density result especially when present at a higher amount. Moreover, density measurements are unfortunately of little value in polymer analysis because in most cases compounded and

formulated polymers have quite different densities to their pure parent polymers. The density of 41.18 % shows the lowest density however a comparable value with the density of pure LDPE which is  $0.92 \text{ g/cm}^3$ . This proves that higher amount of LDPE is present inside the composition which is why the value is nearer to the pure LDPE.

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

The characterization of the material produced has done via physical as well as mechanical testing. Besides the optimum percentage composition that gives the optimum strength has been discovered. However there a lot of improvements that needs to be done to increase the strength of the plastics which are far from commercialization. Red *Eucheuma cottonii* should be substituted with some other species that are relevant to the research due to the fast absorbance of moisture from the surroundings that inhibits the production of plastic. Algae alone cannot withstand to produce plastics due to a lot of constraints and thus LDPE should be added in order to produce algal plastics. Following are few recommendations in order to improve this research.

In this research, suitable algae for the production of plastic should be cultivated. Thus a lot of trials and runs with different species should be conducted in the extruder to determine the suitable species that comply with the plastic properties and run the experiment. After that, that particular algae species that was chosen should then be cultivated at a certain temperature and conditions to support the specific algal species being grown. Then only that particular species can be used for further test to produce plastic. Besides that, extraction of best protein chains should be determined that could be used for the production of plastic.

Furthermore, it would be beneficial to study about the green algae. Green algae are more suitable instead of red algae. Instead of studying protein chains, cellulosic chains should be considered for the future development of this research. This is because the filamentous algae of the order Cladophorales are especially well suited for making the algal plastics of the present invention. These algae have long macrofibrillar structures made up of cellulosic chains, and the underlying structure of these microfibrillar layers is complex and inherently strong.

On the other hand, chemical agar can be used to see the ability to conduct this research. Chemical agar should be used instead of studying the protein chains for this research. Agar is a biopolymer. Agar seems to slow down the increase in brittleness while the effectiveness of glycerol lasts longer. Besides that, agar also seems to improve resistance to microwave radiation. In addition, agar also helps to improve clarity in sorbitol formulations.

Biotechnology techniques can play a key role in conducting the feasibility and sustainability studies in algae bioplastics. Fermentation and genetic engineering may take the lead in using novel techniques to make algae bioplastics commercially viable.

Moreover the application of antistatic agents could be helpful for this research. Antistatic agents include the hygroscopic compounds that absorb or adsorb water vapour from air. Thus, when this is used the hygroscopic compounds can absorb the moisture in the surrounding from the algae. Anti static agents tend to create a conductive layer of water on the polymer surface that disperses the charge. Besides that, anti static agents are agents which when added to the molding material or applied on the surface of molded object which makes it less conductive. Examples of anti static agents that could be used are polyethylene glycol esters or polyethylene glycols.

## REFERENCES

Gregory M.Glenn, Julie Hsu, Compression-formed starch-based plastic, *Industrial Crops and Products* / (1997) 37-44

Kathleen M.Cole ,Robert G.Sheath , *Biology of the red algae*, Cambridge University Press,1990 (pg 486).

Khaled Mohamed Elsyed AlZaablawy, Utilization Some of Seaweeds in Poultry Diets, *Environmental and Biological Agricultural Sciences*,1999.

M.Johnson, S.Shivkumar, L.Beriowitz-Tarrant from the journal *Structure and properties of filamentous green algae*, *Materials Science and Engineering B38* (1996) 103-108.

Nirmal Kumar, Rita N Kumar, Manmeet K, Anubhuti Bora& Sudeshnachakraborty, Variation of Biochemical Composition of Eighteen Marine Macroalgae Collected From Okha Coast, Gulf Of Kutch, India, *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 9 (2), 2010. [404-410].

Patricia Matanjun , Suhaila Mohamed ,Noordin M. Mustapha & Kharidah Muhammad , Nutrient content of tropical edible seaweeds, *Eucheuma cottonii*, *Caulerpa lentillifera* and *Sargassum polycystum*,2007. [79].

Potatoes, Algae to Replace Petroleum In New Bioplastics-  
[thejakartaglobe.com/.../potatoes-algae-to-replace-petroleum-in-new-bioplastics/349035](http://thejakartaglobe.com/.../potatoes-algae-to-replace-petroleum-in-new-bioplastics/349035)



Rakesh Kumar a, Veena Choudhary a, Saroj Mishra b, I.K. Varma a,Bo Mattiason. Adhesives and plastics based on soy protein products. *Industrial Crops and Products* 16 (2002) 155–172.

(WO/1994/017132) ALGAL PLASTICS,  
[www.wipo.org/pctdb/en/wo.jsp?wo=1994017132](http://www.wipo.org/pctdb/en/wo.jsp?wo=1994017132) (Retrieved on 12 March 2010)

Van der Placken, I., Van Loey, A., Hendrickx, M.E., 2005. Combined effect of high pressure and temperature on selected properties of egg white proteins. *Innov.Food Sci. Emerg. Technol.* 6 (1), 11–20.

3 Types of Marine Algae Seaweeds Come in Brown, Green and Red By Jennifer Kennedy, [marinelife.about.com/od/ plants/tp/typesofalgae.htm](http://marinelife.about.com/od/plants/tp/typesofalgae.htm). (Retrieved on 18 July 2010)

[www.biotech.gc.ca](http://www.biotech.gc.ca) (Retrieved on 20 September 2010)

[www.wikipedia.org](http://www.wikipedia.org) (Retrieved on 17 October 2010)

<http://www.lenntech.com/eutrophication-water> (Retrieved on 19 July 2010)

## APPENDIX A

### Appendix A1: Stress Results for percentage composition of 33.33 % LDPE and modified alginate

Strain (%)	Tensile Stress (MPa)	Strain (%)	Tensile Stress (MPa)
8.208235	0.009315942	8.137522	0.3656082
8.176124	0.02602001	8.130736	0.3588342
8.075639	0.03002944	8.12695	0.3664387
8.084033	0.04520926	8.127008	0.3717397
8.164065	0.0695421	8.130938	0.3781242
8.180206	0.0777601	8.134312	0.3791615
8.120463	0.09477958	8.12941	0.39104
8.088178	0.1126719	8.125304	0.4033399
8.130047	0.1089415	8.130217	0.3929836
8.166959	0.1243362	8.13369	0.3904911
8.143806	0.1397645	8.13146	0.3989907
8.103945	0.1555997	8.131509	0.4081511
8.115366	0.1535415	8.128887	0.4034834
8.150188	0.1722109	8.129632	0.4018212
8.150168	0.1818349	8.131818	0.4102145
8.122928	0.1867681	8.131192	0.4158103
8.11319	0.1845092	8.130204	0.4180738
8.134017	0.2072426	8.135758	0.4172892
8.145581	0.2115495	8.131672	0.4238413
8.130672	0.2152156	8.122757	0.4261778
8.118663	0.2237663	8.128213	0.4332435
8.125534	0.236849	8.137051	0.4233534
8.139098	0.2393535	8.134241	0.4310233
8.136749	0.2550825	8.128417	0.4220053
8.125556	0.2651719	8.128412	0.4399219
8.124667	0.2649802	8.140159	0.4375621
8.134621	0.2775168	8.123573	0.4453149
8.139288	0.2839469	8.128878	0.4426876
8.132917	0.2857809	8.13005	0.4342411
8.121818	0.2966411	8.130639	0.4433106
8.128934	0.2971681	8.132574	0.4482772

Strain (%)	Tensile Stress (MPa)	Strain (%)	Tensile Stress (MPa)
8.138674	0.3200966	8.130772	0.4500644
8.119722	0.3220663	8.134288	0.4438397
8.116961	0.3152219	8.134162	0.4567457
8.138523	0.3279596	8.130419	0.4451691
8.14008	0.3356409	8.132376	0.4647401
8.131415	0.3438648	8.131974	0.4558758
8.12341	0.3524182	8.132581	0.4435638
8.128769	0.3552716	8.130663	0.4527385
8.12992	0.4539095	8.133696	0.1904775
8.131789	0.4471595	8.133402	0.1830776
8.132615	0.4470832	8.133717	0.181791
8.131629	0.4435544	8.129466	0.1743823
8.130064	0.4373838	8.129424	0.1849303
8.130925	0.4343055	8.12933	0.1776395
8.131263	0.4433686	8.13445	0.1778806
8.133985	0.4323316	8.131222	0.1908689
8.134858	0.4328604	8.129782	0.1782178
8.132205	0.4202407	8.132771	0.1714144
8.124533	0.4190537	8.137211	0.1769666
8.132486	0.4106441	8.138823	0.1781227
8.132579	0.4010691	8.132051	0.1905413
8.130177	0.3889389	8.131835	0.1718361
8.130375	0.3789158	8.133484	0.1785941
8.127487	0.3560162	8.136693	0.1860185
8.137831	0.2990996	8.126677	0.1881136
8.135704	0.2382661	8.130205	0.1735044
8.130511	0.2039954	8.132055	0.1939488
8.130296	0.1849085	8.128589	0.1778261
8.134384	0.1918254	8.131472	0.1755728
8.135043	0.1880888	8.131273	0.1714795
8.130152	0.1853431	8.128514	0.1805743
8.129677	0.1946648	8.134694	0.180932
8.132269	0.1731788	8.132639	0.1863492
8.132263	0.1902805	8.135238	0.1778345

**Appendix A2: Stress Results for percentage composition of 37.5 % LDPE and modified alginate**

Strain (%)	Tensile Stress (MPa)	Strain (%)	Tensile Stress (MPa)	Strain (%)	Tensile Stress (MPa)
8.146096	0.001983013	8.132471	0.1996433	8.118374	0.2559568
8.113997	0.01398076	8.129713	0.2079301	8.130449	0.2531803
8.113939	0.02248132	8.134028	0.2084089	8.133806	0.2537274
8.14078	0.02709718	8.130591	0.2073635	8.127614	0.2535108
8.148386	0.03603894	8.130637	0.2107046	8.105795	0.2587003
8.127987	0.04622683	8.129489	0.2152996	8.114818	0.2517743
8.114433	0.06361743	8.12862	0.2157638	8.131432	0.2499999
8.127455	0.06682644	8.129972	0.2177831	8.132805	0.2541858
8.144055	0.07541984	8.129818	0.220612	8.136757	0.2538196
8.135545	0.07252935	8.12831	0.2206282	8.127028	0.2565652
8.120885	0.08175202	8.12786	0.220746	8.126397	0.2568554
8.124134	0.08992571	8.126923	0.226149	8.110522	0.2585242
8.137099	0.09930146	8.126828	0.2305573	8.106581	0.2554217
8.136766	0.1035171	8.125859	0.232959	8.141267	0.2562539
8.126142	0.1147781	8.123466	0.2395636	8.120805	0.2542621
8.133569	0.1248146	8.140463	0.2322411	8.153776	0.2566184
8.137523	0.1266563	8.165686	0.2352481	8.111958	0.2448775
8.12966	0.1329597	8.155645	0.2350615	8.087899	0.2428879
8.124807	0.1389997	8.107339	0.2323918	8.053719	0.2481637
8.129972	0.1361479	8.11209	0.233438	8.090353	0.2484354
8.134731	0.1468818	8.152366	0.2359585	8.10295	0.2475658
8.130728	0.1564924	8.14295	0.2382351	8.176633	0.2440638
8.125903	0.1546104	8.103564	0.2422275	8.163626	0.24159
8.127174	0.1592913	8.100546	0.2388226	8.118846	0.2437863
8.131462	0.1640351	8.139871	0.240091	8.113914	0.2345921
8.13029	0.1674183	8.155917	0.2427767	8.152224	0.2382355
8.131754	0.167434	8.137558	0.2466055	8.150353	0.2294347
8.129816	0.1717097	8.11329	0.2444028	8.11751	0.2253519
8.130609	0.1714932	8.120286	0.2493921	8.1126	0.2338892
8.133729	0.1814241	8.143947	0.244351	8.132317	0.2162229
8.13225	0.1758132	8.140938	0.2453634	8.144156	0.1869395

**Appendix A3: Stress Results for percentage composition of 41.18 % LDPE and modified alginate**

Strain (%)	Tensile Stress (Mpa)	Strain (%)	Tensile Stress (MPa)	Strain (%)	Tensile Stress (MPa)
8.126988	8.126987	8.06561	8.06561	8.123849	8.148866
8.117454	8.117455	8.140864	8.140864	8.121504	8.138631
8.133707	8.133707	8.197192	8.197192	8.080897	
8.132189	8.132189	8.114953	8.114953	8.143538	
8.12168	8.12168	8.081332	8.081332	8.162881	
8.129798	8.129798	8.132931	8.132931		
8.133931	8.133931	8.156014	8.156014		
8.124767	8.124767	8.139566	8.139566		
8.123776	8.123775	8.111484	8.111484		
8.127792	8.127792	8.107569	8.107569		
8.128444	8.128444	8.138984	8.138984		
8.130975	8.130975	8.150855	8.150855		
8.129023	8.129023	8.12434	8.12434		
8.128912	8.128912	8.113611	8.113611		
8.130352	8.130352	8.129261	8.129261		
8.130196	8.130197	8.138239	8.138239		
8.125858	8.125858	8.131849	8.131849		
8.12651	8.12651	8.11941	8.11941		
8.127154	8.127154	8.125631	8.12563		
8.127951	8.127951	8.135048	8.135048		
8.129925	8.129926	8.13287	8.132871		
8.127403	8.127402	8.128204	8.128204		
8.127603	8.127603	8.123318	8.123318		
8.128777	8.128778	8.13235	8.132351		
8.131313	8.131313	8.138277	8.138277		
8.131609	8.131609	8.127817	8.127817		
8.126211	8.126211	8.125918	8.125917		
8.125859	8.125858	8.131473	8.131473		
8.130109	8.13011	8.121906	8.121906		
8.128801	8.128801	8.131061	8.131062		
8.129675	8.129675	8.127414	8.127415		
8.127218	8.127217	8.131153	8.131153		
8.135781	8.13578	8.130606	8.130607		

Date-Time	Sample	MFR/MVR	MeltDensity	X-Mass	FlagTime	ElapsedTime	IV	Temp (C)
Nov-11-10 15:42	PP MAP	8.292		0.415		90.38		149.5
Nov-11-10 15:42	PP MAP	11.636		0.582		120.75		149.5
Nov-11-10 15:42	PP MAP	8.824		0.441		151.13		149.6
Nov-11-10 15:42	PP MAP	9.792		0.49		181.5		149.6
Nov-11-10 15:56	PP MAP	16.262		0.813		90.38		149.9
Nov-11-10 15:56	PP MAP	13.002		0.65		120.75		150
Nov-11-10 15:56	PP MAP	14.124		0.706		151.13		150
▶ 11/11/2010 3:56:22	PP MAP	13.5		0.675		181.5		150

**Appendix A4: Melt Flow Index (MFI) for Percentage Composition of 33.33 % and 37.5 % of LDPE**

Date-Time	Sample	MFR/MVR	MeltDensity	X-Mass	FlagTime	ElapsedTime	IV	Temp (C)
Oct-30-10 11:24	RPP			0		120.4		150
Oct-30-10 11:24	RPP	1.4		0.14		180.77		150
Oct-30-10 11:24	RPP	2.2		0.22		241.15		150.1
Oct-30-10 11:36	RPP	1.1		0.22		180.38		150
Oct-30-10 11:36	RPP	8.75		1.75		300.75		150
Oct-30-10 11:36	RPP	8.45		1.69		421.13		150
Oct-30-10 12:03	RPP	2.3		0.46		180.38		150
Oct-30-10 12:03	RPP	10.8		2.16		300.75		150
Oct-30-10 12:03	RPP	4.05		0.81		421.13		150
Oct-30-10 12:20	RPP	7		1.4		180.38		150
Oct-30-10 12:20	RPP	6.75		1.35		300.75		150
▶ 10/30/2010 12:20:1	RPP	7.25		1.45		421.13		150

**Appendix A5: Melt Flow Index (MFI) for Percentage Composition of 41.18 % of LDPE**