PRODUCTION OF PLASTIC FROM SEA ALGAE

SAODAH BINTI ALI

A thesis submitted in partial fulfillment of the requirement for the degree of Bachelor in Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
Universiti Malaysia Pahang

APRIL 2010

ABSTRACT

This research provides the information that related to a production of plastic from sea algae. The aim of this research was to produce the plastic from sea algae. Basically, the sea algae contain a large quantity of polymer protein and carbohydrates which is about 50 to 70 percent of its composition. Algae can be produced as a plastic by manipulating or doing structural changes to the polymer structure of the algae which is called as protein denaturation process. In a protein denaturation, the chemical agents; the combination of sodium dodecyl sulfate, SDS, sodium sulfite and urea were used to unfold the complex structure of protein polymer of algae. The procedures that involved in this production of plastic from sea algae were cutting, compounding, drying, and hot pressing. During compounding, the additives were added such as starch, fiber and plasticizer. The plastic was produced by using hot press machine at different temperature ranging from 110^{o}C to 80^{o}C and pressure is less than 10MPa. As the result obtained, formulation of sample with starch addition shows best performance which shows almost like a plastic characteristic. As a conclusion, a lot of works need to be done in order to produce better result, so that the plastic with the best characteristic can be produced. For further research, it is recommended that the extrusion process is used because it would be easier; in fact, it is most applicable in plastic production industry.

ABSTRAK

Kajian ini menyediakan maklumat yang berkaitan dengan pengeluaran plastik dari rumpai laut. Tujuan dari penelitian ini adalah untuk menghasilkan plastik dari rumpai laut. Pada dasarnya, rumpai laut mempunyai kandungan protein dan karbohidrat yang tinggi yang mana hampir 50 hingga 70 peratus daripada komposisinya. Alga atau rumpai laut boleh dihasilkan sebagai plastik dengan memanipulasi atau melakukan perubahan ke atas struktur protein rumpai yang disebut sebagai proses "*denaturation protein*". Dalam proses ini, bahan kimia yang merupakan gabungan sodium dodecyl sulfit, SDS, natrium sulfit dan urea akan digunakan untuk mengubah struktur kompleks protein rumpai laut. Prosedur yang akan terlibat dalam pengeluaran plastik dari rumpai laut ini adalah proses pemotongan, pecampuran, pengeringan, dan "*hot pressing*". Semasa proses percampuran, beberapa bahan seperti kanji, serat dan "*plasticizer*" ditambah. Plastik ini dihasilkan dengan menggunakan mesin "*hot press*" pada suhu yang berbeza bermula dari 110^{o}C kepada 80^{o}C dan tekanan yang dikenakan adalah kurang dari 10MPa. Hasil yang diperolehi daripada eksperimen, campuran sampel dengan kanji menunjukkan prestasi terbaik yang menunjukkan hampir seperti ciri-ciri plastik. Sebagai kesimpulan, masih banyak yang perlu dilakukan untuk mendapatkan hasil yang lebih baik, sehingga plastik dengan karakteristik terbaik dapat dihasilkan. Untuk kajian lebih lanjut, disarankan agar proses "*extrusion*" digunakan kerana ianya lebih mudah, bahkan, proses ini merupakan proses yang digunakan oleh kebanyakan industri penghasilan plastik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Biodegradable plastics are plastics that will be decompose in natural aerobic composting and anaerobic landfill environments. They may be composed of eiter bioplastics, which are plastics whose components are derived from renewable raw materials, or petroleum-based plastic which utilize an additive. Fukuda (1992) stated that biodegradable plastic are polymeric materials which change into lower molecular weight compounds at least one step in degradation process is through metabolism in the presence of naturally occurring organisms. There are continuous interests in the development of plastic materials that biodegradable and that come from renewable source. There are some research of biodegradable plastic had been developed especially from plant-based such as starch corn, potato, activated sludge from wastewater treatment, chickpea and some others.

Salmoral et al (2000), reported that the use of renewable natural polymers in the manufacture of plastic grows in impulse and importance in the last years of the 20th century, many major chemical companies are becoming increasingly in developing technologies for manufacturing of products from crops. The truly biodegradable plastics are those that can be consumed by micro-organism and reduced to simple compounds and one way to produce biodegradable plastics is by using natural polymers based on starch proteins and cellulose. Ren (2003) stated that biodegradable plastic of renewable resources origin also helps preserve the non-renewable resources and contribute to sustainable development. Several polysaccharide-based biopolymers are being used as possible coating material or packaging films. The degradation of synthetic polymer film can be accelerated by incorporating starch as filler (Chandra et al, 1998).

In this research, the production of plastic from sea algae will be studied. The possibility of processing algae to a plastic is high because generally, algae contain very high composition of protein which is 50-70 percent of its overall content. Algae have been recognized as a new source that already applied in a wide variety of industries and application. Many newer applications are being discovered from the same feedstock of algae in order to produce such a wide range of end-uses of fuels and non-fuels product. Algae research also provides an environmentally friendly solution for serious global threat like green house gas emissions. The previous researches that have been done are focusing on its potential to be a major source of biofuels in order to find other alternative fuel to replacing petroleum. The composition of algae show that they are contain in large amount of protein polymer which can be modify to the plastic structure by some chemical treatment for denaturation of protein. Proteins are composed of different amino acids and hence the nutritional quality of a protein is determined basically by the content, proportion and availability of its amino acids (Becker, 2004). Many analyses of gross chemical composition of different algae have been published in the literature.

1.2 Problem statement

The purpose of this study is to do research on sea algae in order to produce biodegradable plastic as it has a large amount of protein polymer in their structure. According to current situation, world is running out of petroleum source within a few years which is cannot be renewable. So, world will finishing the source for making plastic especially for packaging industrial which plays a very important thing in our daily life. Beside that, the petroleum-based plastics create visual pollution problems and can have harmful effects on aquatic and terrestrial animals. A non-biodegradable plastic are particularly noticeable components of the litter stream due to their size and it is take along time to fully decompose. In addition, these plastics can produce toxic when a decompose in which as consequent it is can cause land pollution, river pollution, water source pollution and some other pollution. However, due to limitation of new resources create the difficulties in searching renewable source that replaced the petroleum in many applications especially in packaging material. Recently, algae had been explored as a new renewable source for the diesel production by extraction of algae oil process. Hence, there are possibilities to make algae as new source in plastic production due to high protein content in most of the algae. By doing this research, it is hoped that the biodegradable plastic from algae can be produce and can contribute to environment control.

1.3 Objectives

There is one objective that has been determined in order to realize the purpose of this research. The objective is:

a) To produce biodegradable plastic from sea algae

1.4 Scope of study

The scopes of study in this research are:

a) Description of algae composition and characteristic.
b) De-naturation of protein from the sea algae by chemical treatment of sodium di-sulfite (SDS).
c) Formulation of sample to produce plastic by hot pressing process using different additives.
d) Production of plastic using hot pressing.
e) Effect of different temperatures on product structure.

1.5 Rationale and significance

This study is deemed significant for the reasons that it would provide valuable information about the production of biodegradable plastic from sea algae. Since the production of plastic from sea algae is still new in research and development, thus, it is hope that some beneficial information can be used and well developed so that we could have a renewable source for plastic production. Furthermore, it is also hoped that steps will be taken to help the environment to overcome the pollution that cause by non-biodegradable plastic and the short of petroleum source by replacing with a renewable source of algae. The results obtained from this research can be beneficial to many ports especially society and environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The most recent research and interest into using algae are producing biodiesel as a renewable source in order to cover the short of petroleum source in a few years. Algae have the potential to be explored for wide variety uses and application purpose other than production of biodiesel. However, there are not many research have been done on exploring algae as new source for plastic production; the researches on it just start to grow up. Meanwhile, there are many researches that have been done on biodegradable plastic from different raw material such as corn starch, potato starch, chick pea and etc. Moreover, there are also a lot of researches that had been done on chemical composition in different type of algae and have been published in the literature. Hopefully, those studies can be beneficial in order to study the production of biodegradable plastic from algae.

2.2 Biodegradable plastic

For several years there has existed interest in developing biodegradable plastic from vegetable materials which are generally made from corn starch, potato starch, chickpea and other starches. These biodegradable plastic generally include the addition of other materials which act to enhance polymerization, chemical cross-linking, or flexibility. The demand of biodegradable plastic product has been increased especially in packaging industry. According to Arvanitoyannis (1999), the continuous increasing extent of pollution of the environment has recently give raised to demands for novel biodegradable polymers, mainly for applications relates to food packaging and agriculture. Many things have been proposed as biodegradable alternative such as starch film, blood-meal and etc. However, these largely starch-based materials are often not well-suited for many applications of solid packing foam because of their relatively rapid break down under wet conditions, and their inherently low breaking strength (Tarrant et al, 1994).

The majority plastic produced nowadays, fall into petro-plastic category, which is non-energy product of petroleum chemicals. This type of plastic is considered as non-biodegradable or takes a long times to be decomposed to nature. Gluszynski (1997) reported that the conventional plastics, manufactured from fossil-fuels such as oil, coal and natural gas, not only consume non-renewable and finite resources, but also contribute heavily to the global problem of waste disposal. Thus it take at least 50 years for them to break down and there is a limit on developing biodegradable materials to alleviate the plastic waste disposal problems (Fang et al, 2004). Replacement of petrochemically based plastic by biological derived plastics would reduce petroleum usage.

The application of additives can be also include in the production of algal plastic such as chemical agent for denaturation of protein, plasticizer, antioxidants, antistatic agents, compactibilitizers, flame retardance, heat stabilizers, water repellents, impact modifiers, lubricants, fillers, viscosity modifiers and combination of thereof. It has been discovered that algae are well-suited as raw materials for molded foams and other plastic as raw materials for molded foams and other plastic applications as they contain polysaccharides such as cellulose, as inherent structural components of the cell walls. The algal plastic foams can be rigid, semi-rigid or flexible (Tarrant et al, 1994).

The application of additives can be mixed into an algal pulp before or concurrently with the generation of the algal fiber matrix. For instance, a high gluten starch, such as starch isolated from sticky rice, can be added to the algal pulp and incorporated into the algal fiber matrix of the plastic. These loose packing have been formed by a variety of standard foaming and extrusion methods derived from polystyrene foam production, or the extrusion or explosive popping of cereal foods. In addition to being affected by the composition of the algal plastic, the properties of the end product can also be affected by the type of process used such as casting, extrusion or injection moulding. The production of cellular foams depends upon the degree of polymeric rigidity, the foaming agent, and the techniques used. In general, there are many techniques in producing the algal plastic such as air or other gases are mechanically mixed into algal plastic suspension, gases dissolved in the algal plastic suspension, foaming methods using isocyanate and wet-pupled algal resin, extrusion process using screw extruder, microwave popped algal foams and injection moulding (Tarrant et all, 1994).

2.3 Algae

Algae (singular *alga*) are a term that encompasses many different groups of living organisms. Algae have been traditionally regarded as simple plants, and some more closely related to the higher plant (www.science.jrank). Algae are large and diverse group paraphyletic group of simple, typically autotrophic organisms, ranging from unicellular to multicellular forms. The largest and most complex marine forms are called seaweeds. They are photosynthetic, like plants, and 'simple' because they lack the many distinct organs found in land plants. Algae also are extremely important species because they produce more oxygen than all plants in the world. Hans Garffron (1939), stated that algae sometimes will switch from production of oxygen to the production of hydrogen.

In 'Algae and their characteristics, types of algae' (science.jrank.org) states that algae are not uniform group of organism but consist of seven divisions of distantly related organisms which are *euglenophyta, chrysophyta, pyrrophyta, chlorophyta, rhodophyta, paeophyta and xanthophyta*. Each of division has their own characteristics. For *euglenophyta*, or euglenoids are 800 species of unicellular, protozoan-like algae, most of which occur in fresh water and lack a true cell wall, and are bounded by a proteinaceous cell covering known as pellicle. This type of algae has one or three flagella for locomotion, and they store carbohydrate reserves as paramylon. Then, *chrysophyta* are the golden-brown algae and diatoms, which respectively account for 1,100 and 40,000 -100,000 species of unicellular and can occur in both marine and fresh waters. The golden-brown algae store energy as carbohydrate called leucosin, and also in oil droplet. Meanwhile, for the *pyrrophyta* type, they are fire algae which occur in marine ecosystems and also fresh water and they store energy as starch. *Chlorophyta* or green algae occur in fresh water and some in marine, most of this type of algae are microscopic. The food reserves of green algae are starch. Examples of green algae are *chlamydomonas* and *chlorella*. Other type of algae is *rhodophyta* or red algae which mostly marine and this species is range from microscopic to macroscopic in size. This red algae store energy as specialized polysaccharide, known as floridean starch. Next, *paeophyta* or brown algae occur in marine environments. This species are macroscopic in size, including the giant kelps that can routinely achieve lengths of tens of meters. Examples of this species are the rockweeds (*Fucus spp. and Ascophyllum spp.)* and the kelps (*Laminaria spp.*). The last one is *xanthophyta* or green-green algae primarily occur in fresh waters and they store carbohydrate as leucosin.

Algae are made up of eukaryotic cells which are cells with nuclei and organelles and do not develop multicellular sex organ. All algae can carry out photosynthesis process because all of algae have plastids, the bodies with chlorophyll. Algae present very strong concentration in mineral elements of an iodine, calcium, phosphorus, potassium, magnesium, copper, zinc, cobalt, iron, fluorine and etc. In addition they also contain almost all vitamins and acid amino (Mollah et al, 2007) .

There are many researches that have been done about the chemical composition in different type of algae and have been published in the literature. Large-scale production of algae which are the chlorophyceae type; *Chlorella* sp. and *Scenedesmus obliquus*, cyanobacteria *Spirulina* sp. and *Athrospira* sp. (Becker, 2007), have a large quantity of polymer which are contain large amount of protein and carbohydrate composition which is make it possible to be process in order to produce as a plastic as shown in Table 2.1. The chlorophyceae, which is green algae, *Scenedesmus obliquus* contains about 50 to 56 percent of protein in its composition meanwhile *Chlorella vulgaris* and *Chlorella pyrenoidosa* contain about 51 to 58 percent and 57 percent of protein composition respectively. Algae can be varying in proportions of proteins, carbohydrates, fats and nucleic acids as table 2.1 below:

Table 2.1: General composition of different algae (% of dry matter)

Strain	Protein	Carbohydrates	Lipids
Scenedesmus obliquus	50-60	10-17	12-14
Scenedesmus quadricuada	47	-	1.9
Scenedesmus dimorphus	8-18	21-52	16-40
Chlamydomonas rheinhardii	48	17	21
Chlorella vulgaris	51-58	12-17	14-22
Chlorella pyrenoidosa	57	26	2
Spirogyra sp.	6-20	33-64	11-21
Dunaliella bioculata	49	4	8
Dunaliella salina	57	32	6
Euglena gracilis	39-61	14-18	14-20
Prymnesium parvum	28-45	25-33	22-38
Tetraselmis maculate	52	15	3
Porphyridium cruentum	28-39	40-57	9-14
Spirulina platenis	46-63	8-14	4-9
Spirulina maxima	60-71	13-16	6-7
Synechoccus sp.	63	15	11
Anabaena cylindrical	43-56	25-30	4-7

(Source: Becker, 1994)

There are many researches that have been done about the chemical composition in different type of algae and have been published in the literature. Large-scale production of algae which are the chlorophyceae type; *Chlorella* sp. and *Scenedesmus obliquus*, cyanobacteria *Spirulina* sp. and *Athrospira* sp. (Becker, 2007), have a large quantity of polymer which are contain large amount of protein and carbohydrate composition which is make it possible to be process in order to produce as a plastic as shown in Table 2.1. The chlorophyceae, which is green algae, *Scenedesmus obliquus* contains about 50 to 56 percent of protein in its composition meanwhile *Chlorella vulgaris* and *Chlorella pyrenoidosa* contain about 51 to 58 percent and 57 percent of protein composition respectively.

For the use of proteins in non food applications such as surfactants, adhesives, coatings or plastics, it is discussed that a certain degree of denaturation must occur in order to make proteins processable, and to reach the required product properties such as strength, water resistance or adhesion. By adjusting the processing parameters (temperature, water content, chemicals) conditions can be created to allow structural changes in the protein (De Graaf, 2000).

In this research, the type of algae used is *Gracilaria sp*. which can be categorized in Red algae or scientifically named as *Rhodophyta* group. These kinds of algae are mostly from marine, which are most diverse in tropical waters. Species of red algae range from microscopic to macroscopic in size. The cell walls of red algae are constructed of cellulose and polysaccharide, such as agar and carrageenin. These algae lack flagellae, and they store energy as a specialized polysaccharide known as floridean starch. The photosynthetic pigments of red algae are chlorophylls *a* and *d*, and their accessory pigments are carotenoids, xanthophylls, and phycobilins. Red algae such as Gracilaria changii mainly serve as a raw material from which agar and carrageenan are extracted out for use in the food industries or in the production of tissue culture media (Glickman, 1987; Jahara & Phang, 1990).

It is one of the more abundant agarophytic seaweeds found in Malaysia and is now cultured mainly for agar production (Phang, Shaharuddin, Noraishah & Sasekumer, 1996). Reports on certain edible seaweed showed that many contain significant amounts of protein, vitamins and mineral essential for human nutrition (Jensen, 1993; Noda, 1993; Oohusa, 1993). Fresh and dried seaweeds are extensively consumed especially by people living in the coastal areas where it is occasionally eaten as a salad dish especially along the east coast of Peninsula Malaysia and in East Malaysia. The nutrients composition of seaweed varies and is affected by species, geographic area, season of the year and the temperature of water (Jensen).

Many studies on *Gracilaria* sp have been reported especially on its taxonomy and habitat characteristic (Critchley, 1993; Santelices & Doty, 1989) and some of them as shown in Table 2.2 below:

Table 2.2: Properties of Major Algal Taxonomic Groups

S.No	Taxonomic Group	Chlorophyll	Carotenoids	Bilo proteins	Storage products	Flagellation &Cell structure
1.	Bacillariophyta	a, c	β-carotene, ± -carotene rarely fucoxanthin,.		Chrysolaminarin oils	1 apical flagellum in male gametes: cell in two halves with elaborate markings.
2.	Chlorophycophyta (green algae)	a, b	β-carotene, ± -carotene, rarely carotene and lycopene, lutein.		Starch, oils	1,2,4 to many, equal, apical or subapical flagella.
3.	Chrysophycophyta (golden algae)	a, c ,	β-carotene, fucoxanthin		Chrysolaminarin oils	1 or 2 unequal, apical flagella, in some, cell surface covered by characteristic scales.
4.	Cyanobacteria (blue green algae)	a,c	β-carotene, phycobilins			
5.	Phaeco phycophyta (brown algae)	a,c	β-carotene, ± fucoxanthin, violaxanthin		Laminarin, soluble carbohydrates, oils	2 lateral flagella
6.	Dinophyta (dinpflagellates)	a,c	β-carotene, peridinin, neoperididnin dinoxanthin, neodinoxanthin.		Starch, oils	2 lateral, 1 trailing,1 girdling flagellum, in most, there is a longitudinal and transverse furrow and angular plates.
7.	Rhodo phycophyta (red algae)	a, rarely d	β-carotene, zeaxanthin ± β carotene	Phyco erythrin phyco cyanin	Floridean starch oils	Flagella absent

Algae have been recognized as a new source that already applied in a wide variety of industries and application. Many newer applications are being discovered from the same feedstock of algae in order to produce such a wide range of end-uses of fuels and non-fuels product. Algae research also provides an environmentally friendly solution for serious global threat like green house gas emissions. The previous researches that have been done are focusing on its potential to be a major source of biofuels in order to find other alternative fuel to replacing petroleum.

Brown and red seaweeds are most economic products which can be utilized as food for people, and as resources for the manufacturing of industrial products. These seaweeds are mostly harvested from the wild, although increasing attention is being paid to the cultivation of large algae. Some species of algae can be directly eaten by humans. The red alga is often used as a wrapper for other foods, such as rice or plums, or it may be cooked into a clear soup. Potentially, seaweeds are quite nutritious foods, because about 50 percent of their weight occurs as carbohydrates, with smaller concentrations of proteins and fats, and diverse micronutrients, including iodine. In addition, brown seaweeds, is usually used as a natural resource for the manufacturing of a class of chemicals known as alginates. These chemicals are extracted from algal biomass, and are used as thickening agents and as stabilizers for emulsion in the industrial preparation of foods and pharmaceuticals and for other purposes. Agar is another seaweed product, prepared from mucilaginous components of the cell walls of certain red algae such as *gracilaria* sp. which is used in the manufacturing of pharmaceuticals and cosmetics, as a culture medium for laboratory microorganisms, and for other purpose such as jellied desserts and soup.

Carrageenin is another, agar-like compound obtained from red algae that is widely used to stabilize emulsions in paints, pharmaceuticals, ice cream, and other products. The major source of carrageenin is Irish moss (*Chondrus crispus)* which is purplish alga. Researchers are investigating methods for the economic cultivation of red and brown seaweeds for the production of alginates, agar, and carregeenin and investigating growth rates in dense plantings can be economically increased by enriching the seawater with nitrogen-containing fertilizers. In some places, large quantities of the biomass of brown and red algae wash ashore, especially after severe storms that detach these algae from their substrates. This material, known as wrack, is an excellent substrate for composting into an organic-rich material that can greatly improve soil qualities in terms of aeration and water- and nutrient-holding capacity (science encyclopedia).

Marine algae are important source of dissolved organic carbon in coastal waters. The organic carbon is represented by carbohydrates, polysaccharides, nitrogenous and polyphenolic materials (Craigie and Melachlan 1964; Sieburth and

Jensen 1968). Amino acids and carbohydrates are considered an important group of cell constituents in algae. Composition and calcium binding properties of water soluble polysaccharides in calcareous algae were studied by Bohm (1973) and Liebezeit Dawson (1981). Many investigators made accomplishment to utilize non-traditional source of protein in order to compensate world-wide food protein insufficiency (Bytniewska, 1975). The amino acids of algae have a wide application in human and animal feed nutrition industries (Borowitzka, 1988).

The plastic that will be produce from algae is biodegradable types of plastic in which they can be biodegraded faster by using bacteria. They are can be replaced the petroleum –based plastic that take times to be compose and cause a few problem especially to environment. In current world situation which running out of petroleum source, so algae can be study as a renewable source in order to replacing the petroleum source.

2.4 Protein Denaturation

Protein denaturation can be defined as any modification in conformation not accompanied by rupture of peptide bonds. The ultimate step might correspond to a totally unfolded polypeptide structure. According to De Graaf (2000), Protein denaturation is the unfolding of the protein from a structured native state into an (partially) unstructured state with no or little fixed residual structure, which is not far from a random coil. Denaturation can be induced both by temperature and by denaturants (chemical denaturation). It is generally known that the denaturation temperature of protein may differ due to the protein source, to additives (denaturant such as urea or guanidium HCl) and processing methods. Moreover, denaturation can reversible and irreversible. For the use of the protein in non-food applications such as surfactants, adhevises, coatings or plastics, a certain degree of denaturation must occur in order to make proteins processable, and to reach the required product properties such as strength, water resistance or adhesion. By adjusting the processing parameters (temperature, water content, chemicals) conditions can be created to allow structural changes in the protein.

Currently a number of industrial applications are based on industrial proteins (Skeist, 1990; Mulder, 1997 and Sonder et al,1997). Non food protein research is currently more driven by a market-pull from consumers than by a technology push from protein producers. It becomes clear that proteins have unique properties that can be exploited for several applications (Kolster et al,1997: De Graaf and Kolster,1998 and Lens et al, 1999). Denaturation is a prerequisite for the processing of proteins into a product and for achieving a good product performance. Protein can be processed in the presence of a high amount of water or under-moisture condition. Generally, protein based coatings and adhesives are produced by dissolving the protein in water at high or low pH and/or using denaturants such as urea (Skeist, 1990, Somanthan et al, 1992; Gennadios et al, 1994 and McHugh et al, 1994).

During common processing procedures of turning materials into coatings (aqueous solutions or dispersion), adhesives (urea-containing solutions) and during extrusion (increased temperature, water added) these conditions generally are met. However, the degree of denaturation or structural changes in general may differ between proteins and processing methods (De Graaf, 200). Though the pathways of thermal and chemical denaturation are different, the final result is the same (Fujita and Noda, 1981). The studies in dilute solution although do not necessarily reflect the structure in solid state (Shewry et al, 1994). The necessary degree of denaturation is very difficult to access, ans the effect of the degree of on the product properties is little investigated. So far denaturation was shown to decrease the water uptake of the protein material.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a key role in carried out this research. The main method that has been used along this research is experimental methodology approach. There are four major parts of experimental work that has being used which are blending, compounding, drying and hot pressing. Due to unavailable of extruder machine for the extrusion process, that method had been replaced with the hot pressing method by using hot press mold. However, there are very limited article that explain on how to make formulation for hot pressing process. It is because the hot pressing was not really applied in the plastic production.

The main part of this research is to produce a plastic from fresh sea algae of *gracilaria* sp by using hot pressing with the best formulation.

3.2 Experiment flow chart

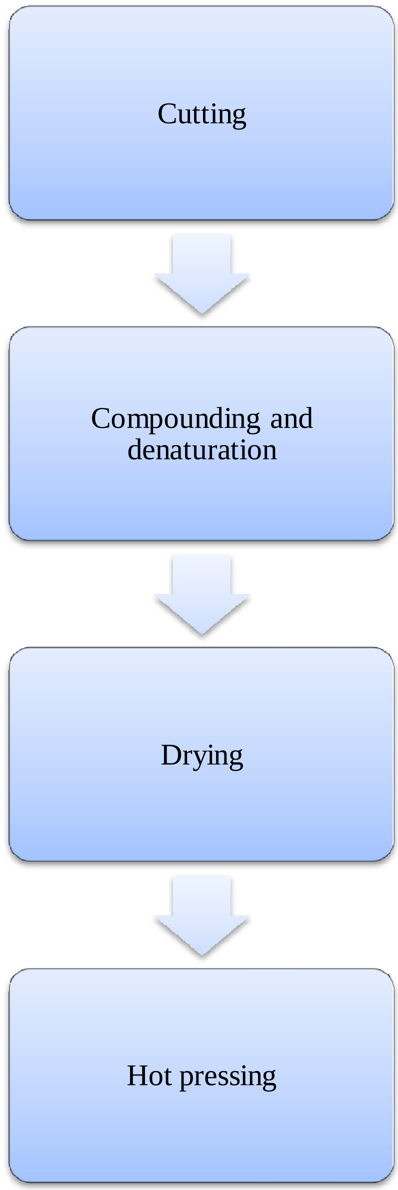

Figure 3.1: Experimental Flow Chart