THE EFFECT OF DIFFERENT DRYING METHODS ON THE QUALITY CHARACTERISTICS OF *KAPPAPHYCUS ALVAREZII SP.* SEAWEED POWDER

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Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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FACULTY OF MANUFACTURING ENGINEERING

2021

DECLARATION

I hereby, declared this report entitled "The Effect of Different Drying Methods on The Quality Characteristics of *Kappaphycus alvarezii sp.* Seaweed Powder" is the results of my own research except as cited in references.

Signature : ……………………………………

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Date : 15 SEPTEMBER 2021

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Kaedah pengeringan memainkan peranan penting dalam mengekalkan nutrien semula jadi dalam rumpai laut. Penyelidikan ini bertujuan untuk menentukan jangka masa optimum untuk kaedah pengeringan ketuhar berdasarkan kualiti *Kappaphycus alvarezii sp*. serbuk rumput laut. Untuk memberikan pengeringan yang baik, ia tidak boleh menghilangkan kandungan mineral dalam *Kappaphycus alvarezii sp.* selepas pengeringan rawatan kerana mineral bertindak menjaga kualiti makanan. Walau bagaimanapun, kajian sebelumnya menunjukkan bahawa kandungan mineral dalam rumpai laut banyak hilang setelah rawatan pengeringan melalui kaedah pengeringan matahari. Kaedah pengeringan matahari menyebabkan tempoh pengeringan yang lama kerana suhu yang tidak menentu. Oleh itu, pengeringan ketuhar boleh menjadi penyelesaian kerana dapat mengurangkan jangka masa pengeringan kerana melibatkan suhu tertentu, tetap dan konsisten. Oleh kerana itu, ia dapat mengelakkan pencemaran luar yang tidak diingini yang dapat menghilangkan komponen kimia penting tertentu. Walaupun begitu hingga kini, kajian yang terhad dilakukan terhadap rumpai laut *Kappaphycus alvarezii sp.* melalui kaedah pengeringan ketuhar kerana banyak penyelidik memfokuskan pada kaedah konvensional, iaitu kaedah pengeringan matahari. Untuk memperoleh dan menganalisis kandungan kelembapan dan mineral untuk kedua kaedah pengeringan berdasarkan parameter yang telah ditetapkan, analisis kandungan kelembapan dan analisis mineral telah dipilih. Tempoh pengeringan optimum untuk kaedah pengeringan ketuhar adalah 10 jam kerana kandungan lembapan yang lebih rendah dan nilai kandungan mineral yang lebih tinggi. Selama 10 jam pengeringan ketuhar, rumpai laut dapat menjaga dan mengawal kehilangan kandungan mineral serta menurunkan kadar kelembapan untuk mengekalkan kualiti rumput laut Kappaphycus alvarezii sp. setelah melalui rawatan pengeringan. Oleh itu, pengguna akan mendapat faedah dari produk berasaskan rumput laut ini sekiranya kualiti rumpai laut dapat dikekalkan kerana nilai pemakanan tinggi rumpai laut menyumbang kepada nutrien manusia seperti vitamin, mineral dan semua asid amino penting.

ABSTRACT

Drying methods play a significant role in preserving the natural nutrients found in seaweed. This research aims to determine the optimum duration for oven-drying method based on the quality characteristics of *Kappaphycus alvarezii sp.* seaweed powder. In order to provide excellent drying behaviour, it should not eliminate the mineral content in *Kappaphycus alvarezii sp.* after drying treatment as minerals acts in maintaining the quality of the food. However, the previous studies show that the mineral contents in seaweed are heavily lost after the drying treatment by the conventional drying method, i.e., direct sun-drying method. Sun-drying method causes a long period of drying duration due to unpredictable and uncertain temperatures. Therefore, oven-drying may offer a solution as it can reduce the duration of drying since it utilizes a specific temperature, fixed and consistent. Moreover, it can avoid unwanted outside contamination which could possibly eliminate certain important chemical components. Nevertheless to date, there is a limited number of studies that have been done on the seaweed *Kappaphycus alvarezii sp.* using oven-drying method since many researchers still focusing on the conventional method, which is the sun-drying method. In order to obtain and analyze the moisture and mineral contents for both drying methods based on the parameter that has been set, the tools such as moisture content analysis and mineral analysis have been selected. The optimum drying duration for oven-drying method is 10 hours as it provides low moisture content and high mineral content values. At 10 hours of oven-drying, *Kappaphycus alvarezii sp.* seaweed is able to keep and control the loss of the mineral content while lower the moisture content to retain the quality of *Kappaphycus alvarezii sp.* seaweed after going through the drying treatment. Thus, consumers will get benefits from this seaweed-based products if the quality of seaweed can be retained as the high nutritional value of *Kappaphycus alvarezii sp.* contributes to human nutrients such as vitamins, minerals and all the essential amino acids.

DEDICATION

Only

my beloved father, Sulaiman bin Bachik

my appreciated mother, Nina Kurniawati binti A. Wahab

my sister, Nur Hasanah binti Sulaiman

my kindhearted supervisor, Ts. Dr. Rose Farahiyan binti Munawar

my friends

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

SEM	-	Scanning Electron Microscopy
ICP-AES	-	Inductively Coupled Plasma-Atomic Emission Spectrometry
EDX	-	Energy Dispersive X-Ray

LIST OF SYMBOLS

%	-	Percent
wt%	-	Weight Percent
°C	-	Degree Celsius
kg	-	Kilogram
mg/g DW	-	Milligram per gram of dry weight
mg mL^{-1}	-	Milligram per milliliter
nm	-	Nanometer
µm	-	Micrometer
cm	-	Centimeter
min	-	Minute
g	-	Gram
ml	-	Milliliter
mg/ml	-	Milligram per millilter
kV	-	Kilovolt
Ca	-	Calcium
Mg	-	Magnesium

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter describes the background of the study, problem statement, objectives, research scopes and the significance of this research. The *Kappaphycus alvarezii sp.* seaweed was used throughout the study as a representative of the investigated seaweed species, as demanded by the respective industry (Saanen Sdn. Bhd.).

1.1 Background of Study

Seaweed or marine algae are a group of organisms that either lives in ocean or swamps waters. Similar to the land plants, seaweed contains photosynthesis pigmentation and photosynthesizes and produces food with the aid of sunlight and nutrients provided by the ocean water. Seaweeds are discovered between high to low tide in the coastal area and up to a level in the sub-tidal region whereby only 0.01% photosynthetic light is reachable. In order to create different circumstances, plant pigments, visibility, light, temperature, depth, tides and shore behaviours merge to specify the classification and variation of seaweed. Seaweed is essentially divided into three main categories, which including green (Chlorophyta), brown (Phaeophyta) and red (Rhodophyta) (Brownlee *et al.*, 2012). Seaweed is low in calories, high in fibre and minerals, and contain a substantial quantity of protein, vitamins and essential minerals. In addition, seaweeds are able to generate important oxidation immune defences. Seaweed is indeed an essential source of natural antioxidants which can protect the human body toward free radicals (Mohamed *et al.*, 2018).

In Malaysia, the most significant and widely cultivated seaweed species is *Kappaphycus alvarezii sp*. *Kappaphycus alvarezii sp.* is a red seaweed species (Rhodophyta) and can be found in reddish, yellowish, green and brown in colour based on the presence of the water-soluble pigments, the blue phycocyanin and red phycoerythrin pigments. (Rudke *et al.*, 2020). The red *Kappaphycus alvarezii sp.* seaweed is abundantly found in Semporna, Sabah. Resulting in the high market value of *Kappaphycus alvarezii sp.*, the seaweed variation from Sabah was relocated and cultivated in Langkawi and Kedah. The red *Kappaphycus alvarezii sp.* seaweed, commercially recognized as *Eucheuma cottonii* is an economically valuable tropical Rhodophyta that is highly sought after for its polysaccharide cell wall and carrageenan properties, making it the most important carrageenophyte for industrial purposes in the world (Ilias *et al.*, 2017). Over the last four decades, *Kappaphycus alvarezii* has become the most crucial element of kappacarrageenan, a vital source in different applications and products. Carrageenan is most often used in the food industry due to its functional and physical characteristics including such thickening, stabilizing, gelling, water-binding and texturing a range of dairy and instant items like ice cream, frozen desserts, chocolate, milk, yoghurt, cheese, pie, puddings and sauces.

The drying process is one of the most important post-harvest treatment of seaweed. The main priority of the drying process is to conserve and increase the lifespan of the seaweed. However, the drying process can also adversely affect seaweed based on certain factors such as drying temperature, drying conditions and drying period. It may lead to unwanted changes in the colour, quality, nutritional, phytochemical content and aroma of seaweed (Badmus *et al.*, 2019). The quality of the seaweed, such as mineral content value will deteriorate after undergoing a drying process. Besides, the conventional drying method, which is the sun-drying process, offers a more negative impact on the seaweed as it not only reduces the quality of the seaweed, it also caused the seaweed exposed to dirt and dust contamination, insect infestation, uncertain drying temperature (uncontrollable weather), direct exposure overheating and long drying duration (Maisnam *et al.*, 2017). After reading several previous research paper, the perfect and suitable alternative method to replace the conventional drying method is by conducting the oven-drying method. Besides counter all the problem facing by the conventional method, the oven-drying method also is the easiest drying method (Babu *et al.*, 2018).

Hence, the aim of this research study is to plan the preparation and characterization of *Kappaphycus alvarezii sp.* seaweed powder by using the different drying method, which is the sun-drying and oven-drying method based on the different drying duration. Due to the shortcomings of the previous study, the effect of oven-drying method on the *Kappaphycus alvarezii sp.* seaweed powder quality compare to the conventional method, which is sun-drying, with a complete characterization were analyzed and discussed. For both drying methods, the moisture content and mineral content after the formation of *Kappaphycus alvarezii sp.* seaweed powder have been further determined and evaluated using the moisture content analysis and mineral analysis. In addition, the surface morphology of the dried samples of *Kappaphycus alvarezii sp.* seaweed for both drying method also has been analyzed by using Scanning Electron Microscope.

1.2 Problem Statement

This study emphasises the preparation and the characterization of *Kappaphycus alvarezii sp.* seaweed powder on how different drying method, which are sun-drying and oven-drying method would affect the seaweed powder. Seaweed contains natural minerals and antioxidants which contribute significantly in retaining the quality of food as well as protecting the health of the body (Sehwag and Das, 2013). To produce a seaweed powder, there are several processes involved starting with the cleaning the seaweed, soaking process, cutting process, drying process and lastly is grinding process. Drying process is a major process that might affects the moisture content and mineral content in the seaweed.

There are several drawbacks on the drying process of seaweed using conventional methods, which is sun-drying method. In order to produce a quality seaweed powder, the quality characteristics such as minerals should be maintained as much as possible after going through the drying process. The sun-drying method is carried out in an open environment, which may degrade the quality of the food. It is due to exposure to contamination of dirt and dust, infestation of insects, direct overheating of exposure, long drying duration and low heat transmission rates (Naseer Ahmed *et al.,* 2013). In addition, sun-drying method offers the drying process using the sunlight. Meaning that this method relying 100% on the weather condition. Since the weather is uncontrollable, the temperature could vary significantly and be unpredictable. This will lead the food to dry slowly and increase the risk of contaminating the food.

To provide high demand and huge potential market of *Kappaphycus alvarezii sp.* seaweed powder, it needs to maintain the quality of the seaweed powder as well as speed up the drying process. Therefore, to overcome the limitations of conventional drying method, the method of oven-drying was conducted in this study. By conducting oven-drying method, many problems encountered during the implementation of the sun drying process can be fixed. Oven-drying method offer fixed and consistent temperature, short duration of drying and protect seaweed from outside contamination. Moreover, based on Çoklar and Akbulu's (2017) study on black grapes, oven-dried sample indicates a lower loss of antioxidant activity compared to sun-dried sample. It follows that the minerals will exhibit the same results. In fact, some of the antioxidants are minerals as well such as zinc, copper and manganese (Muhammad *et al.*, 2012). Other than that, fixed and higher temperature of oven-drying will provide faster duration to achieve the suitable moisture content. With low mineral content loss and quickly to achieve perfect moisture content, oven-drying method will produce the higher quality of *Kappaphycus alvarezii sp.* seaweed powder compared to sun-drying method. Figure 1.1 shows the summarization of problem statement and research gap of seaweed powder.

Market Issue

- To provide high demand and huge potential market of seaweed powder, it needs to maintain the quality of the seaweed powder as well as speed up the drying process. As the drying duration decrease, the production of seaweed powder increase.
- To maximize the application of seaweed in any field, especially in food pharmaceutical products.

Limitation

- The use of conventional drying process method which is sun-drying process.
- Nowadays, not so many researchers study about how drying methods and drying duration affected the quality and mineral content value of the seaweed, specifically *Kappaphycus alvarezii sp*.

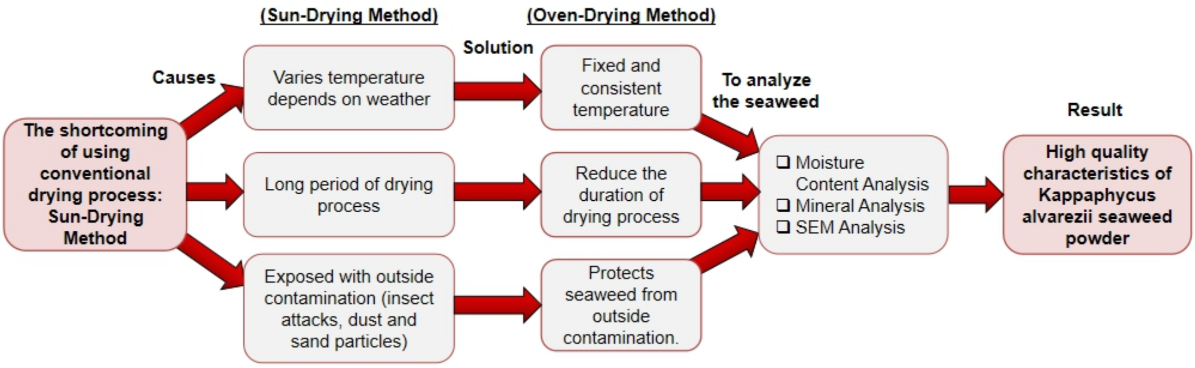

Figure 1.1: The summarization of problem statement and research gap

1.3 Objectives

1. To prepare the *Kappaphycus alvarezii sp.* seaweed powder by focusing on different drying method specifically the method of oven and sun-drying based on the drying duration as parameter.
2. To determine the moisture content and mineral content of the *Kappaphycus alvarezii sp.* seaweed after drying treatment using Moisture Content Analysis and Mineral Analysis.
3. To characterize the surface morphology and structure of *Kappaphycus alvarezii sp.* seaweed by using Scanning Electron Microscopy (SEM) Analysis.

1.4 Research Scopes

This study concentrates on the drying process of *Kappaphycus alvarezii sp.* seaweed in order to form the seaweed powder by utilizing different drying methods based on the drying duration to investigate the effect of drying process on the quality of the seaweed powder. The main purpose is to determine the optimum duration for the oven-drying method in order to replace the sun-drying method based on the moisture content and mineral content of the *Kappaphycus alvarezii sp.* seaweed powder and surface structure of the dried *Kappaphycus alvarezii sp.* Seaweed. The research was carried out on the basis of a variety of scopes in order to perform out this study.

In this research study, the first objective is to prepare the *Kappaphycus alvarezii sp.* seaweed powder by focusing on different drying method specifically the method of oven and sun-drying based on the drying duration as parameter. The drying methods involved are sun-drying and oven-drying methods. This drying process was carried out based on the predetermined parameter, which is under a different drying duration. The second objective is to determine the moisture content and mineral content of the *Kappaphycus alvarezii sp.* seaweed after going through the drying treatment. In order to achieve this objective, moisture content analysis and mineral analysis were performed.

The purpose of doing moisture content analysis is to study the amount of water in *Kappaphycus alvarezii sp.* seaweed powder after going through all the processes in the formation of seaweed powder. Mineral analysis is to study the mineral content value that remain in the seaweed powder after going through the processes to form the seaweed powder. However, due to Covid19's pandemic constraint, the mineral analysis study was conducted through postulating the critical review analysis. The last objective is to characterize the surface morphology and structure of the *Kappaphycus alvarezii sp.* seaweed. To accomplish this final objective, Scanning Electron Microscopy (SEM) analysis was performed to study the surface morphology and structure of *Kappaphycus alvarezii sp.* seaweed after the drying process. Figure 1.2 shows the mapping matrix for the scopes and objectives.

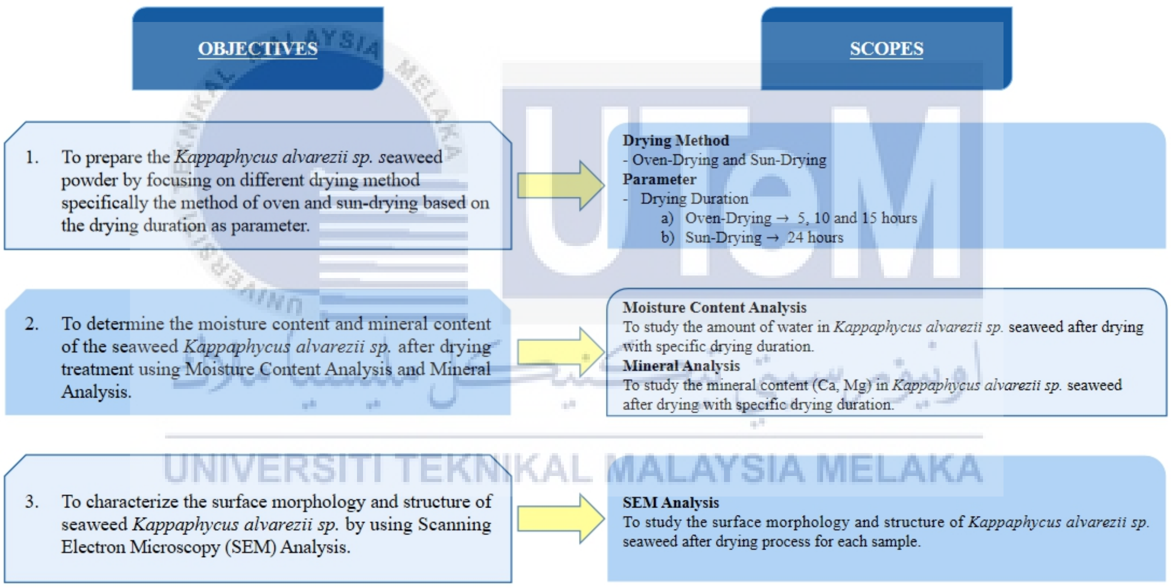

Figure 1.2: The mapping matrix of the scopes and objectives

1.5 Significant of Research

Seaweed has a high nutritional value such as protein, vitamin and mineral content that can be beneficial to the human body. Apart from using it in human products, seaweed has also been used in pet food due to its high mineral and nutritional value. (Kumar *et al.*, 2014). Minerals are elements of chemical that are needed for proper metabolic activity. Some minerals are required by human's body system to work effectively, and they can have an impact on various aspects of human health, such as overweight (Munoz and Dias, 2020). Besides, the consumption of certain minerals is also linked to better cardiovascular system. Undoubtedly, it has been proposed that adequate mineral consumption may lower blood pressure by acting as a calcium antagonist on smooth muscle tone, resulting in vasorelaxation (Circuncisao *et al.*, 2018). In addition, seaweed's mineral content could be in the range from 10 to 100 times greater than those of land vegetables.

Limited comprehensive studies on the impact of drying methods on the quality of seaweed powder have been conducted so far. Most research uses conventional drying methods due to their availability, convenience and does not require high expertise and expense. By using sun-drying methods, low-quality seaweed powder will be formed as a result of the loss of too many nutrients and minerals. Consumers would not benefit from the lack of these many nutrients and minerals that they deserved.

In addition, this research study proposed the solution to the issue that arises from the conventional drying method. Instead of offering the consumers low quality of seaweed products, it provides a higher quality of seaweed products in a short period of time. It is claimed by Coklar and Akbulut (2017) that oven-drying also results in loss of minerals and antioxidants but not as much as the conventional drying method. Moreover, this method seems to be the perfect alternatives to the conventional method as it also does not require high expertise and cost compare to other methods such as freeze drying (Badmus *et al.*, 2019) (Coklar and Akbulut, 2017). Finally, this oven-drying method could reduce the loss of minerals and produce a more beneficial product to the consumers.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter contains a review of previous research that is related to the study. Related information of previous studies are extracted as references and discussion based on their research about seaweed, *Kappaphycus alvarezii sp*. seaweed, properties and composition of *Kappaphycus alvarezii sp.* seaweed, benefits and application of *Kappaphycus alvarezii sp.* seaweed, drying method and the characterization and analysis of *Kappaphycus alvarezii sp.* seaweed.

2.1 Seaweed

Seaweed is a marine plant or macroalgae that live in waterways. Seaweed can usually be found in the ocean but also have certain types that grow in either lakes or rivers. Seaweeds are members or algae family, which exists in various sizes from single microscopic cells to some of the most significant plants known to man like giant seaweeds and able to create forested areas in coastal waters (Raj *et al.*, 2018). Marine algae, which is known as seaweed, contains nearly 10,000 species and contributes to approximately 10% of the global marine productivity.

According to Brownlee *et al.* (2012), seaweed is an easily obtainable source of food probably to have been eaten by coastal communities since the beginning of time, especially in South-East Asia countries. However, it does not consider to be a part of Western diets as a whole meal. In western countries, seaweed is isolated (such as agar or carrageenan from red algae) and used industrially. Seaweed contains quite unique molecules, such as proteins, polysaccharides, phenols, pigments and bioactive peptides (Rudke *et al.*, 2020).

Based on the research paper prepared by Joshi *et al.* (2015), seaweed consists of three subclassifications which are red (Rhodophyta), brown (Phaeophyta) and green (Chlorophyta). The classification depends on seaweed colour, cell structure and several other factors. According to Raj *et al.* (2018), the characteristics of the red colour of Rhodophyta is due to phycoerythrin pigment. The brown pigments in Phaeophytes are because of the dominance of fucoxanthin and xanthophylls pigments, and the green colour of Chlorophyta is due to the presence of chlorophyll as in higher plants. Table 2.1 shows the classification of seaweed.

Table 2.1: Classification of seaweed (Joshi *et al.*, 2015)

Red algae (Rhodophyta)	**Brown algae (Phaeophyta)**	**Green algae (Chlorophyta)**
● Red algae are either epiphytes, grows on rocks or shells like large fleshy, branched or blade like thalli. ● The red algae coloration (reddish, yellowish, green and brown) is caused by water-soluble pigments, the blue phycocyanin and red phycoerythrin. ● Most red algae are used in food products and scientific research.	● The fastest growing seaweed species in the word. ● Consists of variety forms from simple, freely branched filaments to highly differentiated forms. ● Range of colour from olive-yellow to deep brown due to the accessory carotenoid and fuxoxanthin (photosynthetic) pigment.	● Can be found in fresh and marine habitats. ● Green due to chlorophyll involvement. ● Require sufficient amount of sunlight to live, accessible only in shallow water (edge of the sea).

Figure 2.1 shows the red algae (Rhodophyta) species image. Figure 2.2 shows the image of brown algae (Phaeophyta) and Figure 2.3 shows green algae (Chlorophyta) image.

Figure 2.1: Red algae species (Rhodophyta) (Joshi et al., 2015)

Figure 2.2: Brown algae species (Phaeophyta) (Joshi et al., 2015)

Figure 2.3: Green algae species (Chlorophyta) (Joshi et al., 2015)

2.1.1 Red Algae *S*eaweed (Rhodophyta)

Rhodophyta or red algae may be grown in temperate and sub- or tropical areas. The major concern in red algae species is due to their simple cultivation and high content of polysaccharides (40–50% of dry weight), in specific, carrageenan and agar (Rudke *et al.*, 2020). They have been used as the primary industrial sources of carrageenan. Some types of red algae species that have been used in industry including *Kappaphycus alvarezii, Euchema denticulatum, Sarchothalia crispate and Chondrus crispus.* In 2016, it is said that the production of of red algae has reached nearly 60% of the total production of aquatic plants (macroalgae and microalgae), which was over 30 million tons. As mentioned above, industrial interests in red algae are significantly related to the extraction of agar and carrageen, as they are commonly used for various industries, especially in the food industry.

2.1.2 *Kappaphycus alvarezii sp.* Seaweed

Figure 2.4: *Kappaphycus alvarezii sp.* seaweed (Rudke *et al.*, 2020)

Kappaphycus alvarezii sp. is a red species of algae (Rhodophyta) that grow abundantly in the ocean. This type of algae found in reddish, yellowish, green and brown in colour based on the composition of phycoerythrin pigments. It can be found in coastal area of Sabah, Malaysia. It is easily cultivated and grows quickly, with a growth of nearly 4.5% daily. Based on the research paper from Rudke *et al.* (2020), *Kappaphycus alvarezii sp.* is the main industrial source of kappa-carrageenan because of this polysaccharide provides for up to 37 wt% of algae in a dry base. Due to k-carrageenan's physicochemical properties such as gelling, thickening, stabilizing and emulsifying, it has a variety of applications including a thickening agent for milk-based products, assisting in drug delivery systems, skin lotions, toothpaste and shaving foams.

Kappaphycus alvarezii sp. is one of the essential commercial sources of carrageenan sources for food, pharmaceutical industries and cosmetic. According to Mohammad *et al.* (2019), *Kappaphycus alvarezii sp.* is one of the largest tropical red macroalgae and able to grow up to two meters long. *Kappaphycus alverazii sp.* become favourable for food and pharmaceutical applications due to its highest growth rate among the other *Kappaphycus* seaweeds. Malaysia has produced over 118,298 tonnes of seaweed with a market value of 97.3% from 2007 to 2008.

2.1.3 Properties and Composition of *Kappaphycus alvarezii sp.* Seaweed

Kappaphycus alvarezii sp. (red seaweed species) has been widely used in the food and pharmaceutical industries all around the world. This is because of its properties such as carrageenans, agar and alginate that can be formed into sources of polysaccharide. Besides, red seaweed also contain high nutritional properties such as protein, vitamin and mineral contents (Kumar *et al.*, 2014). Aside from being used in human products, red seaweed were also used in animal food due to their high mineral content and nutritional value. Kumar *et al.* (2014) also state that *Kappaphycus alvarezii sp.* contain functional properties such as nitrogen solubility, water-holding capacity (WHC), fat absorption capacities (FAC), emulsifying and surface-active properties and foaming capacity and stability.

According to Chang *et al.* (2017), *Kappaphycus alvarezii sp.* is a vital source of carrageenans, which is a hydrocolloid, that used as a food additive, emulsifying, acting as a gelling, thickening and stabilizing agent in both nutraceutical and pharmaceutical products. Seaweed also found low in calories, high fibre and mineral content, high protein, vitamins, trace elements and a wide variety of second metabolites not found in other species. In addition, it also rich in phytochemicals, such as phenolic substances and macro and micronutrients (Mohammad *et al.*, 2019).

Rudke *et al.* (2020) state that the chemical composition and concentrations in *Kappaphycus alvarezii sp.* are highly unpredictable and depends on growing conditions such as water temperature, sunlight, water salinity, light intensity, wave power, water depth, climatic conditions and others. Generally, *Kappaphycus alvarezii sp.* contains 50.8% of carbohydrates, 3.3% of proteins, 3.3% of lipid, 15.6% of ash, 12.4% of sulphated groups and 3.0% of insoluble aromatic substances on average. The lipid fraction consists mainly of saturated fatty acids (64.28%), specifically C16:0 (46.51%). *Kappaphycus alvarezii sp.* also has essential amino acids, up to 43% of the total amino acid content, particularly leucine, phenylalanine and threonine. Table 2.2 shows the chemical composition of *Kappaphycus alvarezii sp.* seaweed.

Table 2.2: Chemical composition of *Kappaphycus alvarezii sp.* seaweed (Rudke *et al.*, (2020)

Components	**Average compositions**
Carbohydrates	50.8%
Proteins	3.3%
Lipid	3.3%
Ash	15.6%
Sulphated groups	12.4%
Insoluble aromatic substances	3.0%

2.1.4 Benefits of *Kappaphycus alvarezii sp.* Seaweed

It is proposed that *Kappaphycus alvarezii sp.* may potentially be used as cholesterol reducer, dietary fibre, antiviral and anticancer compounds, antioxidant sources and hemagglutination activity (Chang *et al.*, 2017). In addition, the presence of dietary fibre in *Kappaphycus alvarezii sp.* help to increase blood glucose level, serum lipid concentration, improve immune system activity, weight-loss support and blood pressure reduction. Based on the research that have been done by Mohammad *et al.* (2019), phytochemical components in *Kappaphycus alvarezii sp.* provide a wide variety of physiological roles such as antioxidant, antiallergenic, antiatherogenic, antiinflammatory, antimicrobial, antithrombic, vasodilatory effects and cardioprotective. Figure 2. 5 shows the benefits of *Kappaphycus alvarezii sp.* seaweed.

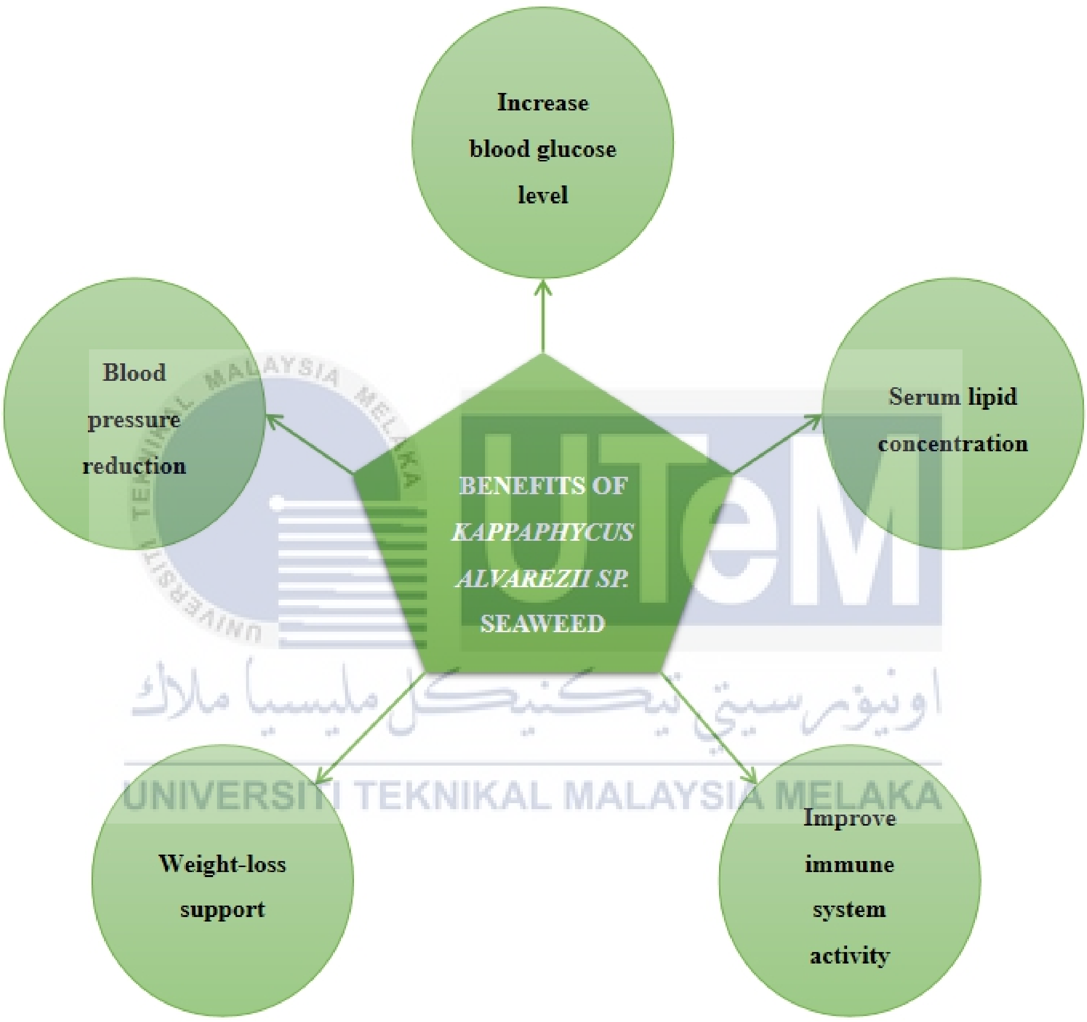

Figure 2.5: Benefits of *Kappaphycus alvarezii sp.* seaweed (Mohammad *et al.*, 2019)

2.1.5 Applications of *Kappaphycus alvarezii sp.* Seaweed

Kappaphycus alvarezii sp. have become favourable in the food and pharmaceutical industries due to its highest growth rate. In the food industry, it is used as an agent of thickening and stabilizing. In the research paper prepared by Mohammad *et al.* (2019), it has been claimed that this kind of seaweed has been commonly used as a food ingredient in the making of pasta, yoghurt, ice-cream, cookies, bread, cheeses, beef patties and frankfurters. It has also been proposed that *Kappaphycus alvarezii sp.* might be used to replace wheat flour in the making of yellow alkaline noodles (*Mi Kuning*) and flat rice noodles (*Kuetiau*) since Malaysia was very famous with that kind of foods. Due to low fibre content in wheat flour, red species seaweed may be the most suitable material to replace it in noodles making process. Due to its physicochemical properties, which including thickening, gelling, stabilizing and emulsifying, it has a wide variety of uses, such as thickening agents for milk-based desserts and sausages, providing better drug delivery systems, toothpaste, skin lotions and shaving foams (Rudke *et al.*, 2020). Figure 2.6 shows the applications of *Kappaphycus alvarezii sp.* seaweed.

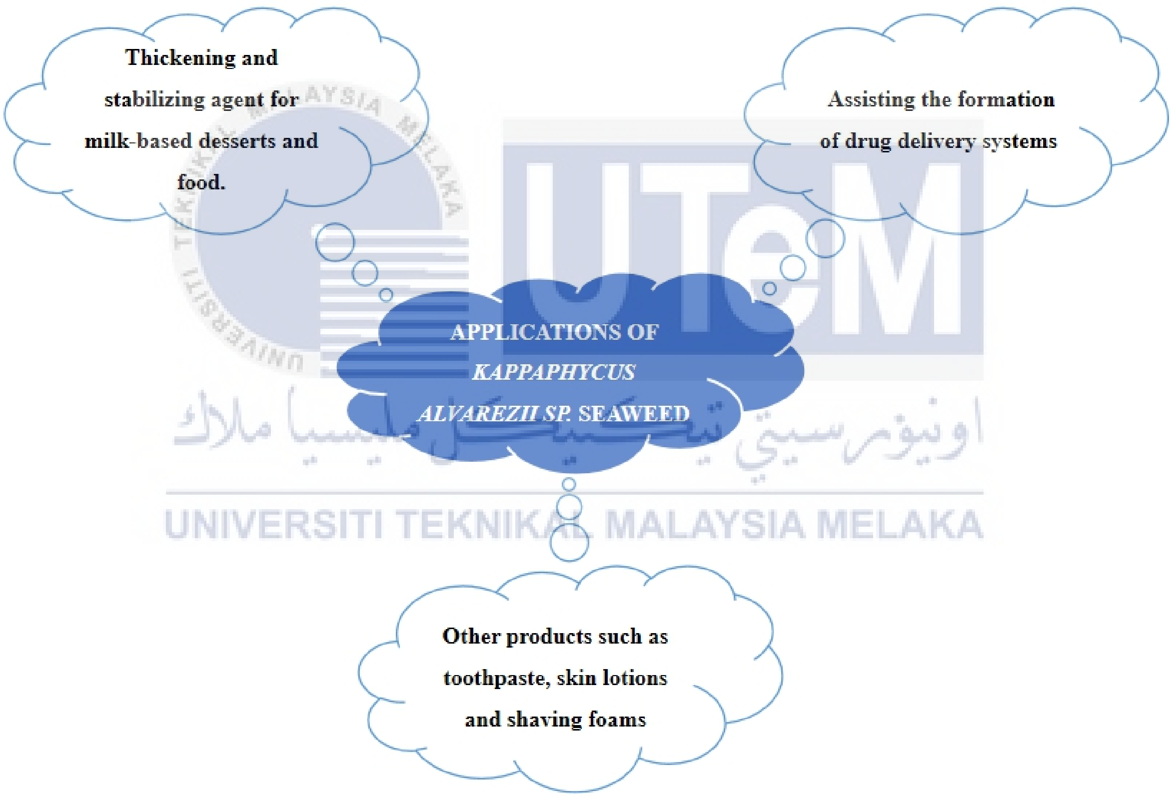

Figure 2.6:Applications of *Kappaphycus alvarezii sp.* seaweed (Rudke *et al.*, 2020)

Siah *et al.* (2015) also proposed that edible films from *Kappaphycus alvarezii sp.* seaweed show possible applications have been seen in various sectors, including the food industry, the pharmaceutical industry, the cosmetics and toiletries industries and even the agricultural industry. In general, the soup powder, dried vegetables as well as other ingredients are packed with either aluminium laminated plastic or other plastic films for pre-cooked and cup noodles or instant coffee to preserve their qualities. These packs must be ripped to release the contents right before pouring hot water over them. Not only this problematic, but it has also led the packets to end up in landfills, where they might remain for ever and never degrade. Packaging such products with an edible film is one solution to these issues. By boiling or just pouring hot water through it, the packaging can be dissolved, making it unnecessary to rip the packet and the content can be eaten together before mixing the film directly into the solution.

The edible film can also be used to produce face masks and pre-portioned washing powder bags where there is no need to dispose of packaging materials as the films dissolve fully in water. The edible films can be modified into pre-proportioned fertilizer bags primarily intended for home gardening use. For each pot where the fertilizer dissolves slowly when in contact with damp soil or during watering, a small bag of fertilizer may be added (Siah *et al.*, 2015).

2.1.6 Summary of Literature Review of Seaweed

From the previous research paper, seaweed, specifically *Kappaphycus alvarezii sp.* is marine algae that grow abundantly and can be found in the coastal area in Sabah, Malaysia. Due to the composition of *Kappaphycus alvarezii sp.* seaweed with various properties, it has become a significant source for industry and human use. Besides, it also provides high benefits to the human as it is able to protect humans from chronic diseases. Table 2.3 shows the summary of the literature review in the subchapter of seaweed.

Table 2.3: Summary of literature review of seaweed

References	**Sub-topic**	**Findings**
Raj *et al. (*2018)	Seaweed	● Seaweed exists in various size. ● Contains nearly 10,000 species globally.
Brownlee *et al.* (2012)		● Seaweed is a source of food eaten by the coastal communities, especially in South-East Asia countries. ● Seaweed is isolated and used industrially in western countries.
Rudke *et al.* (2020)		● Seaweed contains unique molecules, such as proteins, polysaccharides, phenols, pigments and

		bioactive peptides.
Joshi *et al.* (2015)		• Seaweed consists of 3 subclassifications which are red (Rhodophyta), brown (Phaephyta) and green (Chlorophyta).
Rudke *et al.* (2020)	Red algae species (Rhodophyta)	Red algae species: • Used as primary industrial sources of carrageenan. • Production of red algae has reached nearly 60% of total production of aquatic plants in the world in 2016.
Rudke *et al.* (2020)	*Kappaphycus alvarezii sp.* seaweed	• Easily cultivated and grows quickly, with growth of 4.5% daily. • Contains physicochemical properties such as gelling, thickening, stabilizing and emulsifying.
Mohammad *et al.* (2019)		• One of largest tropical red macroalgae that can grow up to 2 meters long. • Malaysia produced over 118,298 tonnes of seaweed from 2007 to 2008.
Kumar *et al.* (2014)	Properties and Composition of *Kappaphycus alvarezii sp.* seaweed	*Kappaphycus alvarezii sp.*: • Contain high nutritional properties such as protein, vitamin and mineral contents. • Contain functional properties such as nitrogen solubility, water-holding capacity, fat absorption capacities, emulsifying and surface-active properties and foaming capacity and stability.
Chang *et al.* (2017)		• *Kappaphycus alvarezii sp.* is source of carrageenans, which is hydrocolloid, which used as food additive, emulsifying, acting as gelling, thickening and stabilizing agent.
Mohammad *et al.* (2019)		• Rich in phytochemicals, such as phenolic substances and micronutrients.
Rudke *et al.* (2020)		*Kappaphycus alvarezii sp.* Contains: • Carbohydrates (50.8%) • Proteins (3.3%) • Lipid (3.3%) • Ash (15.6%) • Sulphated groups (12.4%) • Insoluble aromatic substances (3.0%)
Chang *et al.* (2017)	Benefits of *Kappaphycus alvarezii sp.* seaweed	*Kappaphycus alvarezii sp.*: • Used as cholesterol reducer, dietary fibre, antiviral and anticancer compounds, antioxidant sources and hemagglutination activity. • Increase blood glucose level, serum lipid concentration, improve immune system activity, weight-loss support and blood pressure reduction.
Mohammad *et al.* (2019)		• Provides variety of physiological roles such as antioxidant, antiallergenic, antiatherogenic, antiinflammatory, antimicrobial, antithrombic,

		vasodilatory effects and cardioprotective.
Mohammad *et al.* (2019)	Application of *Kappaphycus alvarezii sp.* seaweed	● Used in the making of pasta, yoghurt, ice-cream, cookies, bread, cheeses, beef patties and frankfurters.
Rudke *et al.* (2020)		● Used for milk-based desserts and sausages, provide better drug delivery systems, toothpaste, skin lotions and shaving foams.

2.2 Drying Method

Drying is a process of food dehydration until sufficient moisture is available to promote microbial activity. Drying removes the water necessary for the growth of bacteria, yeasts and moulds. This method can be used to dry most food types including vegetables, meats, herbs and fruits. Dried foods are delicious, lightweight, nutritious, simple to prepare and easy to store (Ahmed *et al.*, 2013). The drying process may affect the nutritional value of food depending on the method or way of drying and the type of nutrients contained in the food itself. There are two types of method of drying that be discussed in this topic which are sun-drying and oven-drying method. When it comes to seaweed especially *Kappaphycus alvarezii sp.*, it is a must to going through drying process due to its high water content. However, the development of seaweed applications is still very limited due to the current use of conventional drying process with the use of sunlight (Suherman *et al.*, 2018). Depending on weather conditions, this drying process is done for 2-3 days. This drying method also allows dirt from the outside air to contaminate the product.

2.2.1 Sun-Drying Method

Sun-drying is a method of traditional drying which has been used since immemorial time. Basically, this method utilizes the presence of sun and wind to carry out the drying and preserving food process. The aim is to remove the water in the sample, thus preventing the growth of bacteria, fungi or yeast. In order to achieve the desired moisture content, food is left and exposed to the sun for several days due to the uncontrollable weather condition. It can be risky to the dried sample. By referring to the research paper prepared by Naseer Ahmed *et al.* (2013), sun-drying is not recommended for meats and vegetables. This is because it raises risk of spoilage of food as vegetables contain low acid and sugar. Meats rich in protein making it suitable for microbial growth if it is difficult to control temperature and humidity. Sun-drying are safe and highly recommended to dry fruits, which has high sugar and acid content. Open sun-drying causes food to be exposed to dirt and dust contamination, insect infestation, direct exposure overheating, long drying period, degradation in efficiency and low heat transmission rates due to some significant problems encountered during open-air drying (Maisnam *et al.*, 2017). Figure 2.7 shows the drawbacks of using sun-drying method.

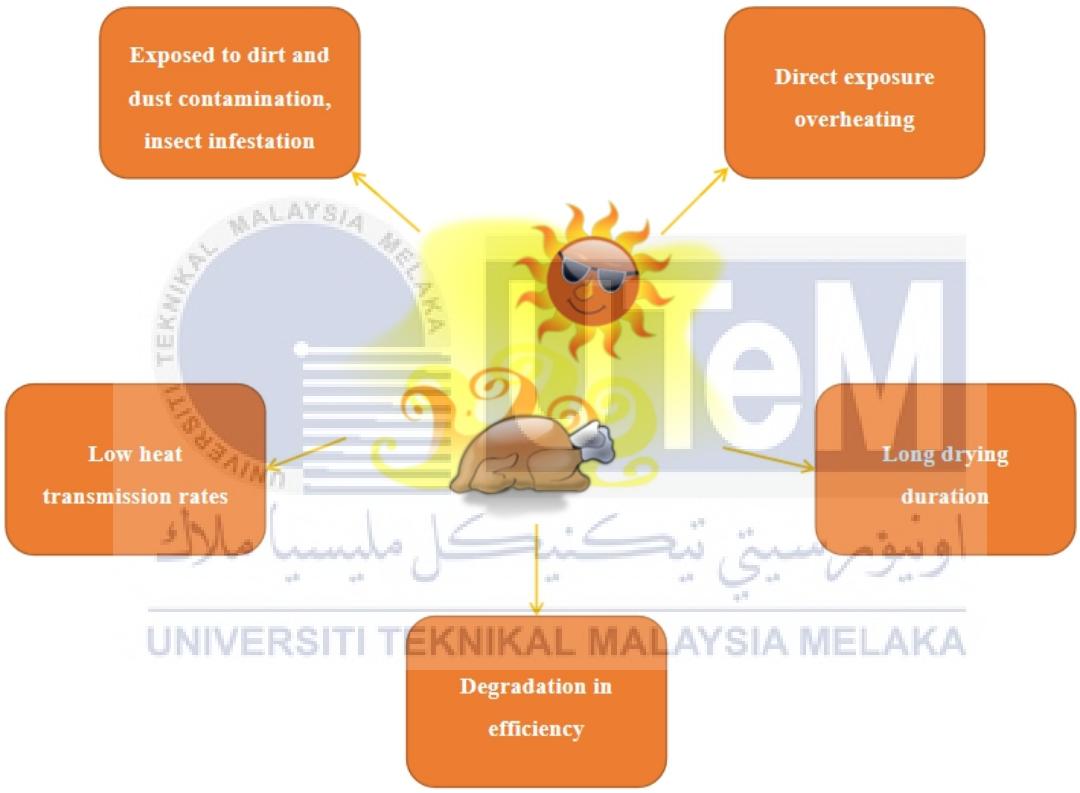

Figure 2.7: The drawbacks of using sun-drying method (Maisnam *et al.*, 2017)

2.2.2 Oven-Drying Method

The oven-drying method is a thermogravimetric method in which the sample is dried at a constant temperature for a specified time. Oven-drying that combines heat, air flow and low humidity. In food drying, usually, the temperature is set as low as 60°C. Higher than 60°C of temperature will cause the food to cook instead of dry or preserve. By referring a journal revised by Flores and Davies (2016), an oven need to have a vent to allow moisture or water to escape. However, the oven which has no vent need to keep the door open for at least one inch, to let the moisture escape. The oven-drying method also avoids dust contamination and insect attacks as it occurs in the oven, with a higher temperature. Moreover, oven-drying is the easiest method to dry food since it requires virtually no specialized equipment. It is rather quicker than open sun-drying, too. But oven drying can only be used on a small scale. However, this also can be considered benefits in using the oven-drying method as the food will go through a complete drying process on its entire surface. Drying ovens can also be configured for batch processing or continuous processing by a conveyor (Babu *et al.*, 2018). Figure 2.8 shows the advantages of using oven-drying.

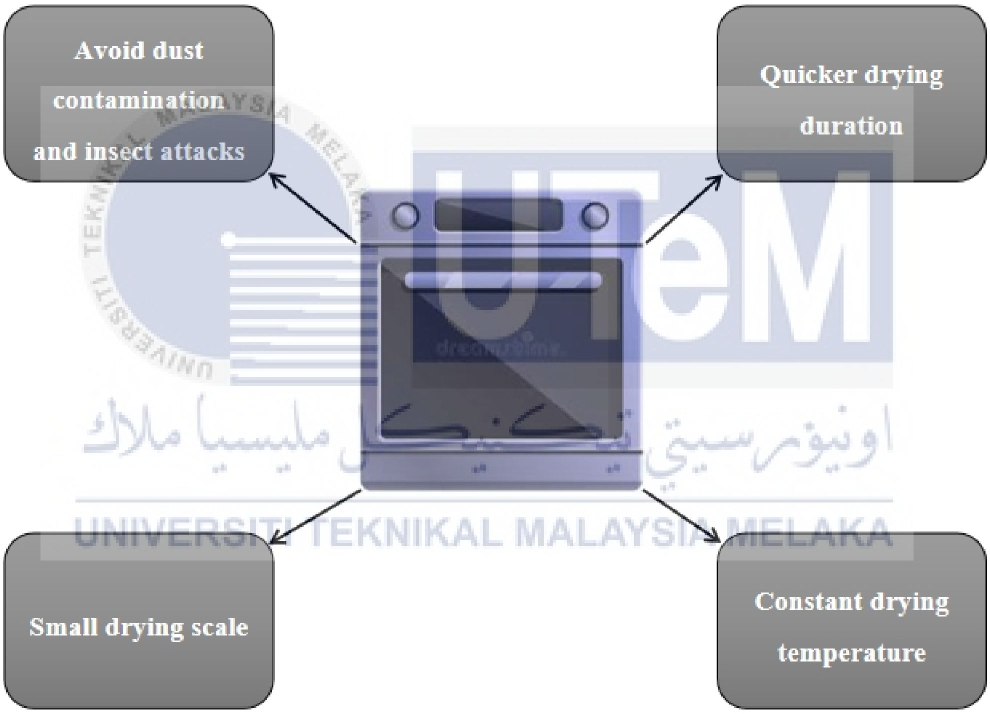

Figure 2.8: The advantages of using oven-drying method (Babu *et al.*, 2018)

2.2.3 Comparison between Sun-Drying and Oven-Drying Method

A research has done by Coklar and Akbulut (2017) to study the effect of drying methods on the antioxidant activity and the phenolic content on black grapes. Table 2.4 shows the comparison between the sun-drying and oven-drying methods.

Table 2.4: Comparison between the sun-drying and oven-drying methods (Coklar and Akbulut, 2017)

Method	Sun-drying	Oven-drying
Sample	Fresh grapes (1 kg)	Fresh grapes (1 kg)
Temperature	Average of 33 °C	60°C
Time taken	7 days	17 hours
Condition	Exposed to rain,dust and insect infestation	Closed and safe from outside contamination
Total Phenolic Content	10.76 mg/g DW	16.12 mg/g DW
Antioxidant Activity	Decreased 50%	Decreased 26%

Johari and Khong (2019) claimed that high total phenolic content provides a high antioxidant activity due to the linear relation between two parameters. Generally, total phenolic content very closely related to antioxidant activity. In addition, the antioxidant activity for oven-drying method higher than the sun-drying method since sun-drying method loss so many DPPH values. From the journal result, it proved that method of oven-drying is better in maintaining the antioxidant properties in food rather than the sun-drying method.

2.2.4 Summary of Literature Review of Drying Method

As a summary, drying process is an important process in order to preserve seaweed for future use and application. Without drying process, seaweed will not last long and are prone to spoilage. The most common and popular method that have been used is sun-drying method. The continuous use of conventional drying methods will have a negative impact on seaweed. The oven-drying method is considered to be the most appropriate method to replace the conventional method. This is because the method of oven-drying could overcome the problems encountered by the method of sun-drying. Table 2.5 shows the summary of literature review in subchapter of drying method.

Table 2.5: Summary of literature review of drying method

References	**Sub-topic**	**Findings**
Ahmed *et al.* (2013)	Drying methods	● Dried foods are delicious, lightweight, nutritious, simple to prepare and easy to store.
Suherman *et al.* (2017)		● Application of seaweed still limited due to the current use of conventional drying, which is sun-drying method.
Ahmed *et al.* (2013)	Sun-drying method	Sun-drying: ● Not recommended for meats and vegetables. ● Highly recommended to dry fruit because of high sugar and acid content.
Maisnam *et al.* (2017)		● Exposed to dirt and dust contamination, insect infestation, direct exposure overheating, long drying period, degradation efficiency and low heat transmission rates.
Flores and Davies (2016)	Oven-drying method	Oven-drying: ● Avoid dust contamination and insect attacks as it occur in oven, with high temperature.
Babu et al. (2018)		● Easiest drying method since not requiring specialized equipment. ● Can be configured for batch processing or continuous processing.

2.3 Characterization of *Kappaphycus alvarezii sp.* Seaweed

2.3.1 Moisture Content Analysis

Moisture content can affect factors such as taste, appearance, texture, weight and shape of the food. Moisture referring to the availability of water molecules for biological reaction in the food. Higher moisture content may cause microbial growth, which can make food unsuitable for human consumption, that may lead to disease or death. Moisture or water content is the most critical factor for microbial growth. The water activity and moisture content must be kept below around 10% and 0.60 - 0.65 respectively, according to the food types, in order to avoid microbial growth (Zambrano *et al.*, 2019). Fresh, moisture-high foods often have a water activity close to 0.99 and are especially likely to develop microbially. Dry food items are also important to minimize spoilage of food. The drying process minimizes the amount of moisture available that support the growth of microbial products and thus increases the durability of the product, which, if not appropriately stored, is an ideal solution.

Many measuring methods, among others, are used for pharmaceutical, agricultural and food industries to ensure the objective humidity content is met. But nevertheless, operations in developing countries frequently lack the regulatory, technical, and financial tools to develop quality control systems similar to those in other industries, in particular small-scale operations like co-operatives or small farmers. Based on the researched paper from Jung *et al.* (2018), moisture content influence the mechanical properties of the material, including elasticity, plasticity, strength and stiffness. In addition, the less amount of moisture content material is more brittle.

According to Pongsuttiyakorn *et al.* (2019), the moisture content is important because it determines dried food quality and storage. Weight of the food material that changes during drying may be used to measure the moisture content. By using a weight sensor, the weight is measured. A sample can be calculated with the equation for moisture content in each period. The equation is

$$M_t = \frac{(W_t - W_s)}{W_s} \qquad \text{Equation 2.1}$$

Where is M_t is the sample moisture in each period at time k (kg water/kg dry solid). W_t is the total weight of sample at each interval (kg) while W_s is the solid weight of sample (kg), which is contant. Figure 2.9 shows the moisture movement during drying process.

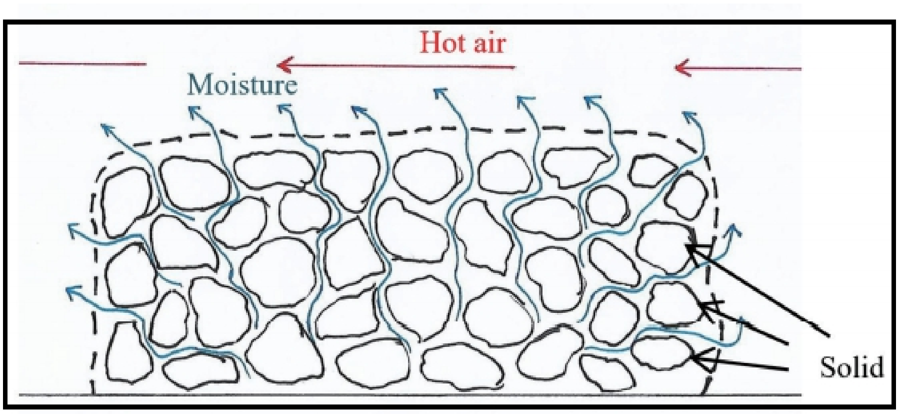

Figure 2.9: Moisture movement during drying process (Pongsuttiyakorn *et al.,* 2019)

2.3.1.1 Classification of Moisture Content Measurements Methods

There are two categories of moisture content measurement method, which are direct and indirect measurement. Direct methods determine moisture content without such an intermediate variable, including the weighing or titration of moisture content pre and post drying and/or filtration. Indirect measurements are known as that because they measure the moisture content by determining the variance of a physical property relative to, or over, the baseline (e.g. temperature, pressure, refractive index) (Zambrano *et al.*, 2019). This characteristic is then correlated to moisture content, transformed into a signal (e.g. wavelength shifting, electric current). In a variety of applications, including laboratories, process lines and fields, both direct and indirect moisture measuring methods can be used. However, for automation and continuous measurement, only indirect methods can be used.

<u>Direct Methods</u>

Direct methods are generally carried out in a lab setting because specific requirements and equipment are generally required. These methods are highly accurate and useful in indirect methods. Their repeatability also helps them to standardize and characterize specific types of samples or equipment. However, direct methods always take some time, were also destructive and need extensive preparation for samples. The direct methods mentioned above are the gravimetric and chemical methods: the Karl Fischer titration, which classified as "quantitative" methods.

The gravimetric method is a common laboratory technology widely used in a wide range of industries (e.g. food, building, fabrics, chemical industry and agriculture). The samples are measured, dried (usually under certain temperature conditions for a specified period of time and sometimes under vacuum) and weighed again. The moisture content is measured in terms of both the initial and final weights, which presupposes that the removal of water is responsible for the loss of weight and the loss of other volatile substances. Zambrano *et al.* (2019) also claimed that the preparations of the sample and drying parameters (such as time, temperature, oven type, humidity and pressure) affect moisture removal efficiency and the drying time needed for a test could change from hours to days.

The Karl Fischer Titration is a common laboratory technique for measuring moisture content in textile, construction and agricultural materials, including solids and liquids. The moisture content is obtained using a calibration curve corresponding to the reagent volume used to titrate the sample water. The sample is dissolved in a solution made up of solvent-like primary alcohol (methanol) and a base (pyridine) as a buffering agent. Next, sulphur dioxide (SO_2) and iodine (I_2) solution are added from a brown titrant to the sample solution. Iodine reacts with water and loses its colour with the titrant solution. An additional solution of titrants is added until another reaction between water and iodine is completed, as shown by the titrant solution, which recovers its colour due to iodine disponibility. The water content of the original solution of the sample is determined on the basis of the quantity of titrant solution added prior to re-colouring.

Colorimetric methods were used for many years in the monitoring of moisture. The combination of cobalt chloride $(CoCl_2)$ in the dry matter as an indicator of their water pickup is a common example of this. Cobalt chloride $(CoCl_2)$ seems to be light blue in its dehydrated form. Cobalt chloride as dihydrate $(CoCl_2 \cdot 2H_2O)$ becomes violet and pink when it is hydrated to produce a hexahydrate $(CoCl_2 \cdot 6H_2O)$. Figure 2.10 shows the classification of drying methods for moisture content measurement.

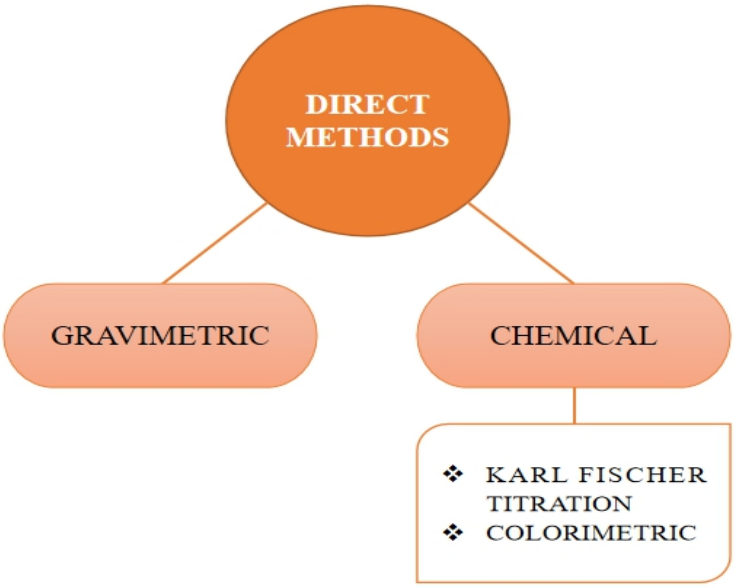

Figure 2.10: Direct methods (Zambrano *et al.*, 2019)

Indirect Methods

Indirect methods is used to determine different material properties such as moisture content. These indirect methods must also be calibrated with a direct method. Indirect methods can become more rapid and not destructive than direct methods, but can be susceptible to environmental (e.g. temperature) and material properties (e.g. density). Indirect methods include optical, dielectric, nuclear and hygrometric methods, which are known as quantitative methods. Most indirect methods are using electromagnetic radiation to measure the moisture content, except for hygrometric methods, by using the strong effect of water on the electromagnetic field (Zambrano *et al.*, 2019).

In the scenario of a defined electromagnetic field, the moisture content can be determined by comparing physical changes such as the refractive index (i.e., optical methods) generated by the alternating electromagnetic field in the presence of water in a sample before and after drying. The ways the waves propagate and interact with an applied electromagnetic field is determined by the magnetic, electrical, physicochemical properties of a material and the distance where the sensor is positioned. To integrate the radiation signal in to the moisture content, material characteristic calibration curves are necessary. The selection of signal range relies on the absorption, reflection and transmission of the targeted material, expected moisture in a sample, the water bond type and the contrast between the targeted material and water optic properties (Zambrano *et al.*, 2019).

Optical measurement methods are indeed effective in determining samples with a homogeneous surface, while rough surfaces or colour variations may lead to errors. Another limitation is the penetration depth of electromagnetic radiation, which is affected by the absorption and reflective properties of the material. Both the material and the moisture content affect the length of the radiation path, producing the calibration of these processes material-specific. Optical methods are being used in the food industry for colour processing and surface defects detection, mainly in huge processing plants (Zambrano *et al.*, 2019).

Infrared (IR) spectroscopy is among the most popular techniques of remote sensing of soil moisture content in a wide range of biological samples including foods for moisture measurement. The trend of this method is due to the low measurement time, that little or no sample preparation (e.g. grinding, weighing and grinding) is required, the ability to perform non-destructive testing, the sensitivity of the test method, and the fact that no reagent is required (Zambrano *et al.*, 2019).

Hyperspectral imaging has served as an effective methods for non-destructive measurement and visualisation of food material moisture content. The drying kinetics of the drying method are based on this assessment. HSI is one of a class of imagery spectrometer techniques generally referred to as spectral imaging or spectrum analysis which captures both conventional and spectroscopic imagery. Zambrano et al. (2019) also state that hyperspectral imaging has been used to assess the quality of dried soybeans and also to identify the moisture content of prawns at various dehydration levels. In general, to analyse the spectral data, partial least square regression or multiple linear regression calibration models were used. A key benefit of HSI is its ability during the "on-line" drying process to conduct non-destructive measurements of oddly shaped objects.

Due to the constant dipole of water molecules, the dipole is highly dilectric or relative permittive. The ability of a material to store electromagnetical energy is its dielectric constant. In response to the applied electromagnetic field, water molecules rotate and align its electric dipole moments, and this re-orientation produces electrical polarizations noise that is used to measure the dielectro-constant and dielectrical loss of a material and therefore to determine the content of the material. It was because the dielectric constant of water is significantly higher than the most substances. Thus, small variations in a material's water content cause significant changes in its dielectric constant. The dielectric properties of the material rely on its structure, the moisture content, ionic conductivity, the temperature of the material, dispersal because of the nature of the heterogeneous materials (food samples), the density and frequency variations as well as its geometry and the electrical field-orientation. Furthermore, dielectric constant calibrations are commonly material-specific (Zambrano *et al.*, 2019).

Electrical conductivity is the principle of direct current conductivity measurement for several types of moisture content measurement methods. Resistive capacities and methods in drug, soil and grain applications are widely used. Moisture content is measured by the variation in the ability or resistivity of a material's dielectric properties before and after drying. Commonly accessible moisture metres apply capacity and resistance principles, whereby a small electrical current is flowing via a sample contact process. The resistance is based on the moisture content of the material. Certain inexpensive man-held moisture metres based on electrical conductivity (or resistance) measurements are subject to semi-quantitative moisture content assessment methods (Zambrano *et al.*, 2019).

The microwave method is commonly used to evaluate moisture content in the agriculture, clothing, construction and food industries, and others. Like IR waves, moisture content can also be measured by using microwaves, or by resonance techniques, transmitted, absorbed or reflected. In the presence of a wet material the moisture content can be linked with a wave attenuation. No other substances with a high relative permittability, like titanium dioxide as well as other metal oxides, should be found in a microwave field in order to apply it effectively. A moisture content metre developed by the Department of Agriculture in the United States and incorporated into a drying convection system of peanuts is an example of the use of the microwave method. This enables the determination of moisture in a peanut kernel without having to shell the peanuts in real time (Zambrano *et al.*, 2019).

The radio frequency (RF) method is mostly used to quantify the moisture content of materials with a homogeneous composition, make them ideal for gas moisture assessments. However, the method has also been implemented to foodstuffs, such as wheat moisture measurement, for example. This method is used to determine the moisture content by measuring the delay in the propagation of electromagnetic waves in a material that used a single frequency or different frequency range to evaluate one or two electrical parameters at the same time (Zambrano *et al.*, 2019).

Hydrogen nuclear magnetic resonance (NMR) is a flexible standard laboratory methodology used in food, cosmetic and pharmaceutical industries. Moisture content is determined based of the impact of electromagnetic radiation on the angular momentum or rotate of subatomic particles (the most widely used hydrogen proton) with an odd number of protons and neutrons. A magnetic dipole is produced in the direction of the axis of rotation as water molecules become charged by an external magnetic field, creating a nuclear magnetic moment with a magnitude equal to the magnitude of the dipole created. A low RF alternating field, producing a detectable high frequency resonance pulse, often between MHz and GHz, excites this magnitude. The material's moisture content is dependent on the intensity of the signal detected (Zambrano *et al.*, 2019).

Hygrometric methods are mainly based on equilibrium relative humidity (ERH) balance rather than moisture content. ERH is numerically equal to the activity of water, but expressed in percentage of the total amount of water in the air as compared to the amount of water at saturation that the air could hold. As a method of evaluating the moisture content of food products, relative humidity (RH) sensors are relatively easy to use. Usually, sensors are based on capacitance or resistance and work over a reasonably broad range of temperatures that is ideal for most implementations (e.g. 0 °C–50 °C). The range of measurements almost all generally ranges 20 per cent –90 per cent RH, including an accuracy of ±2 per cent –5 per cent at the middle range, with higher potential variability at the extreme ends of RH range. The temperature is measured consistently including an accuracy of ± 1.0-1.5 °C. This is a significant consideration in the selection of a relative humidity metre because of the high degree of reliance of vapour pressure on temperature (Zambrano *et al.*, 2019). Figure 2.11 shows the classification of indirect methods for moisture content measurement.

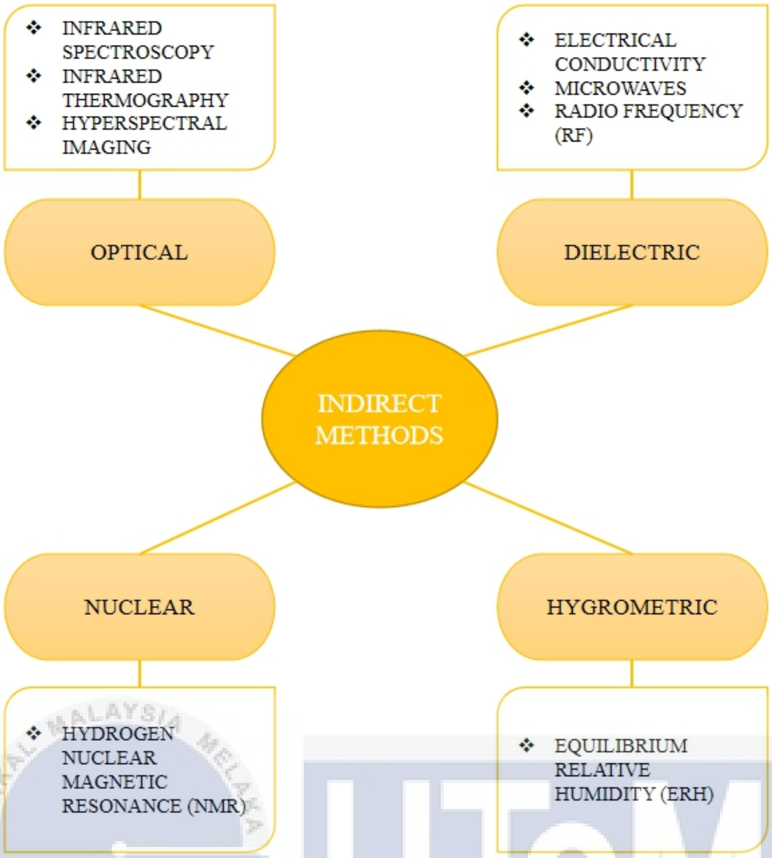

Figure 2.11: Indirect methods (Zambrano *et al.*, 2019)

2.3.2 Mineral Analysis

Minerals are elements found in nature and in fruits and vegetables which human bodies require in addition to developing and function properly. According to Al-Fartusie and Mohssan (2017), elements perform a variety of essential functions in the human body, including some that are required for enzyme reactions, in which they entice and enable the transformation of substrate molecules to particular final products. Furthermore, several of them give or gain electrons in redox reactions which are crucial throughout the production and consumption of energy metabolism. Minerals have such a variety of health benefits, which include tissue maintenance, bone and tooth structure and health, acting as co-factors and co-enzymes in various enzyme systems, assisting throughout the regulatory and synchronization of most organ systems, and other physiological and biochemical functions (Godswill *et al.*, 2020). The nutritional quality of seaweeds is indeed focused on their mineral content, which includes sodium (Na), magnesium (Mg), phosphorous (P), potassium (K), iodine (I), iron (Fe), and zinc (Zn) (Circuncisao *et al.*, 2018). Table 2.6 shows the health benefits of minerals.

Table 2.6: Health benefits of minerals (Ryan-Harshman & Aldoori, 2005)

Mineral element	Possible health benefits
Calcium (Ca)	Weight management, high blood pressure, bone health, colon cancer
Magnesium (Ca)	Diabetes, hypertension, osteoporosis, cardiovascular disease
Zinc (Zn)	Immunity
Iron (Fe)	Cognition
Chromium (Cr)	Blood glucose control

Mineral analysis is the application of mineralogical composition that provides qualitative or quantitative techniques for predicting and monitoring mineral composition, formation, or structure. According to Ware (2015) claimed that mineral analysis is the process of defining the chemical correlations within and between mineral grains. Microanalytical methods, such as mass spectrometry and X-ray spectrometry, are required. For trace and major element analysis, laser ablation and electron probe processes are widely utilized. Other mineral analysis technique that are commonly used including electrochemical technique, atomic spectrometric technique and activation analysis. Potentiometry, which employs stripping voltammetry and ion-selective electrodes (ISEs), which frequently employs polarographic procedures, are the two primary electrochemical methods being used trace identification (Brown and Milton, 2005).

Atomic spectrometry techniques atomize or ionize samples at extremely high temperatures before analyzing the constitutive atomic components by mass or interaction with electromagnetic waves. X-ray techniques are frequently used for assessment for mineral analysis. Due to the extremely poor LODs and lack of matrix sensitivity offered, they have found extensive usage in the assessment of geological materials, cements, steels, forensic samples, environmental sample sand archaeological samples. Activation analysis is the determination and quantification of radionuclides generated by a specific element. Activation analysis is highly suitable to the determination of trace samples, which can be exposed to radiation without the need for a dissolution step (Brown and Milton, 2005). Table 2.7 shows the methods of mineral analysis.

Table 2.7: Methods of mineral analysis (Brown and Milton, 2005)

Classification	Methods/Techniques	Explanation
Electrochemical	Ion-selective electrodes (ISE)	ISEs were around for a while and have become particularly well known in chemical tests for measuring electrolyte concentrations in plasma or blood.
	Stripping voltammetry	Voltammetric methods' sensitivity is improved significantly by using an accumulation or pre-concentration, process whereby the element is gathered at the electrode through a faradaic or non-faradaic process.
Atomic spectrometric	Flame atomic absorption spectrometry (FAAS)	FAAS performs by dissolving the sample in a flame and separating it into constitutive particles. Electromagnetic spectrum in the Ultra violet range of the spectrum is oriented thru the flame and slightly soaked up in a way that is characteristic of the particles existent.
	Graphite furnace atomic absorption spectrometry (GFAAS)	GFAAS use higher atomization temperatures (as much as 3000K) than FAAS. It has LODs that are 10–100 times higher than FAAS. Despite this, heat - resistant elements could remain hard to evaluate with acceptable precision.
	Inductively coupled plasma-atomic emission spectrometry (ICP-AES)	Since very extreme temps (8000 K) are attained throughout plasma atomisation, ICP-AES offers an invaluable scope for the identification of refractory elements with great sensitivity. ICP-AES has equivalent LODs to FAAS, but it can recognize multiple elements at once and has a much wider dynamic range compare to AAS-based techniques.
	Inductively coupled plasma-mass spectrometry (ICP-MS)	The same kind of extreme argon plasma being used ICP-AES is used, but conventional MS methods are being used to recognize the various elemental species. As the mass filtration, whether its a magnetic or a quadrupole sector can be used.

X- ray	X-ray fluorescence (XRF)	XRF was frequently used to analyze nearly every single element from Na to U, which include non - metals. The sensitivity of XRF is determined by the geometry of the device, the energy of the incident radiation and the detector's efficiency.

2.3.3 Scanning Electron Microscopy (SEM) Analysis

Scanning electron microscopy (SEM) is a vital method for characterizing micron-scale materials. By using electrons rather than photons of imaging samples, SEM can obtain a subnanometer structural resolution, exposing topological and compositional characteristics invisible to conventional light microscopy. SEM is also commonly used in a wide variety of areas, including material science, bio-medicine, chemistry, physics, nano-fabrication, and forensics. For instance, technological advances such as nano cutting, in which a silicon wafer can be cut at m/s speeds by using a diamond blade, were already demonstrated. Applications like these need SEM characterization and thus, as new techniques for processing or investigating the characteristics of materials are being created, there will be a growing need for enhanced electron microscopy tools (Haan *et al.*, 2019). The study was carried out on the samples of dried *Tagus* algae by lyophilization or in the oven before and after the different processes of water extraction and also with the aqueous extracts of ocean algae and capsules collected at 100℃. Figure 2.17 shows the SEM images of the dried particles of the Tagus algae formed by different drying as well as extraction processes.

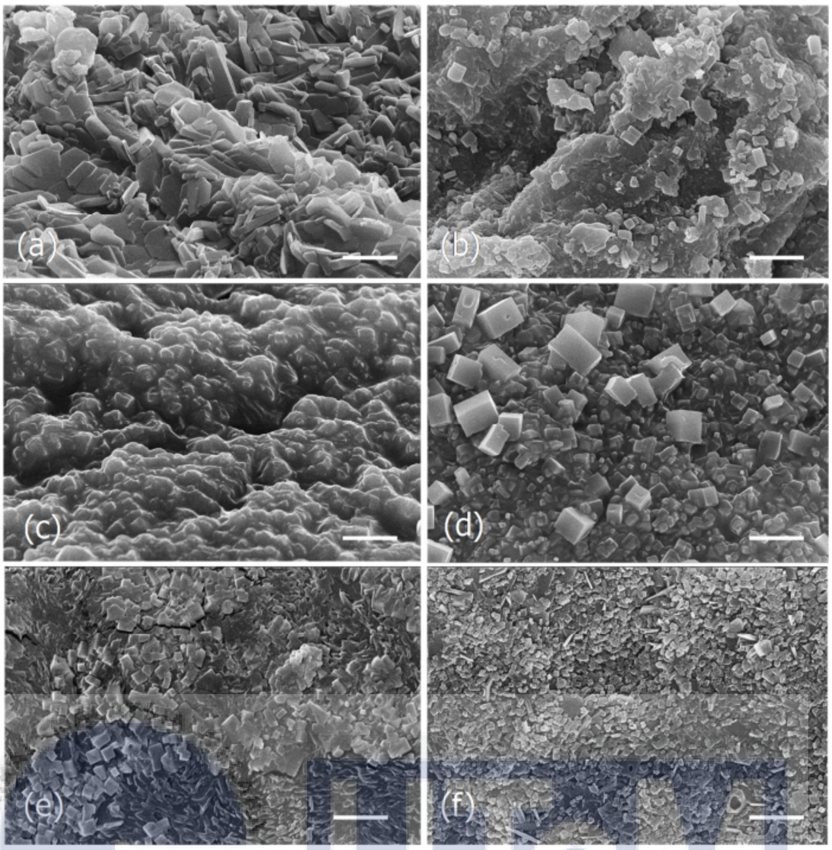

Figure 2.12: SEM images of the dried particles of the *Tagus* algae formed by different drying as well as extraction processes. (a) Lyophilized algae. (b) Dry in the oven (180 °C, 30 min). (c) Lyophilized and collected at a temperature of 25 °C. (d) Dry in the oven and collected at a temperature of 25 °C. (e) Lyophilized and collected at 100 °C. (f) Dry in the oven and collected at 100 °C. Scale bar = 5 µm (Andre *et al.*, 2020).

Observations show that the surface morphology of the two samples of dried algae, which were lyophilized and oven-dried, was different, as were the respective extracts collected at 25°C and 100°C. For both scenarios, the algae extract lyophilized or oven-dried show groups of cubic and parallelepiped crystals, but the aqueous extracts of lyophilized algae tend to be trapped in an amorphous matrix.

2.3.4 Summary of Literature Review on Characterization and Analysis

From the journal that has been reviewed, the material characterization and analysis of *Kappaphycus alvarezii sp.* seaweed powder can be summarized as:

a) Moisture content analysis is performed in order to evaluate the water content in the seaweed powder after going through all the process. The higher amount of water content will cause the seaweed to microbial growth, which can make the seaweed powder to spoil quickly. The suitable amount of water content, which is between the range of 10% to 15%, will increase the durability of the seaweed powder.
b) Mineral analysis is very important in order to keep and preserve the seaweed powder quality and beneficial for human body health. A lot of minerals loss during drying duration will produce a low quality of seaweed powder. Minerals are necessary for human's health. Minerals are used by human's body for a variety of functions, such as maintaining the muscles, bones, heart, and brain in proper working order. Minerals are also essential for the production of hormones and enzymes.
c) Scanning Electron Microscopy (SEM) analysis is conducted to characterize and study the surface morphology and microstructure of the dried seaweed before grinding process takes place. It also to investigate how the drying methods and drying duration affect the change of the seaweed microstructure.

CHAPTER 3

METHODOLOGY

This chapter presented the step-by-step procedure proposed for this research to be carried out. The discussion consists of a process flow of the experimentation required throughout the research, experimental materials as well as procedures based on the previous observation in the previous chapter, which is the literature review.

3.1 Introduction

This chapter can be separated into two sections, which are the experimental materials and experimental procedure to investigate the effect of drying condition on the quality characteristics of seaweed *Kappaphycus alvarezii sp.* by using the oven-drying method. In addition, the procedure must be performed in order to accomplish the scope and objective of the research in Chapter 1. Experimental work for moisture content analysis and Scanning Electron Microscopy (SEM) were performed. However, mineral analysis was conducted by the critical review method due to the Covid19's pandemic constraint. A summary of the experimental studies and procedures is included in Figure 3.1.

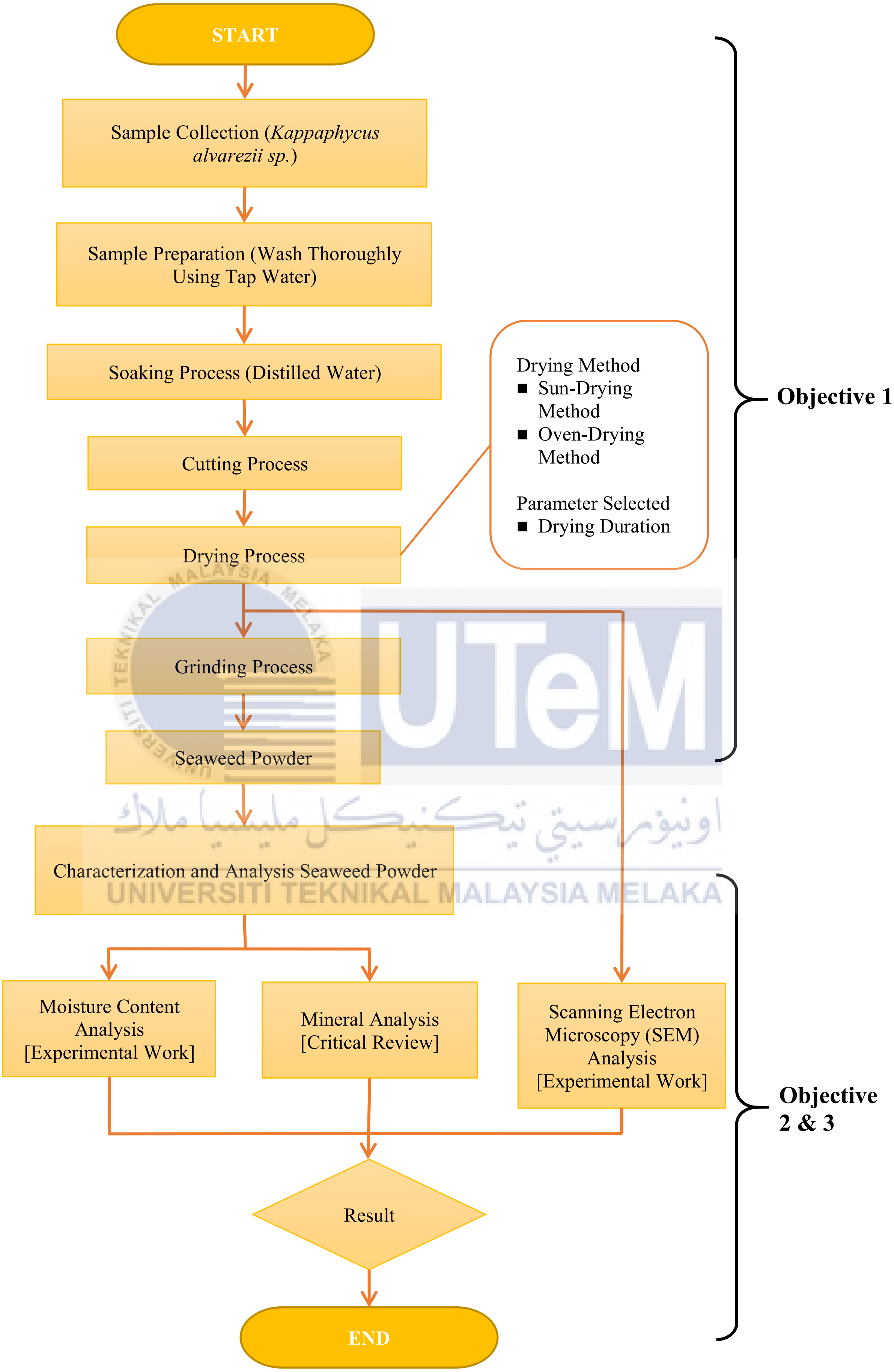

Figure 3.1: The flowchart of experimental study

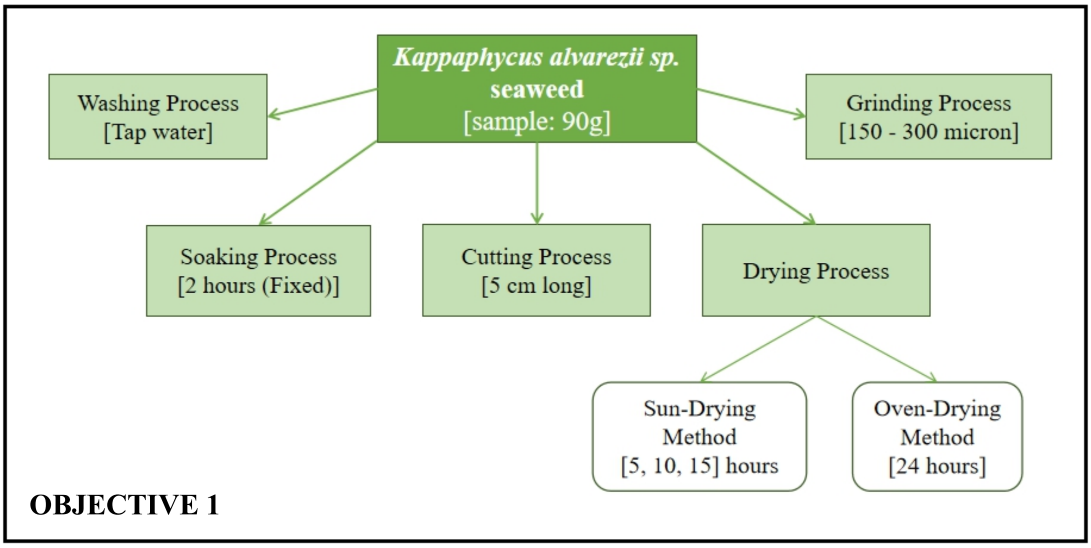

Figure 3.2: Details on experimental works in Objective 1

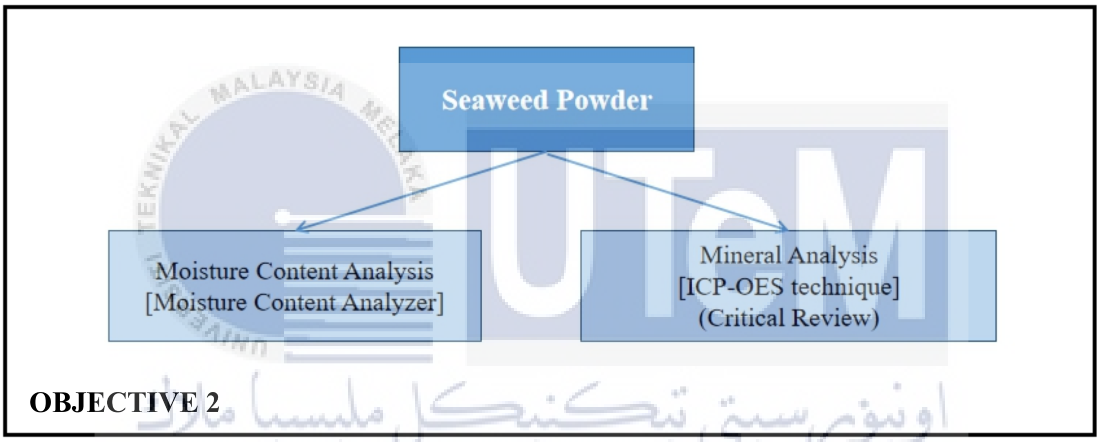

Figure 3.3: Details on experimental works in Objective 2

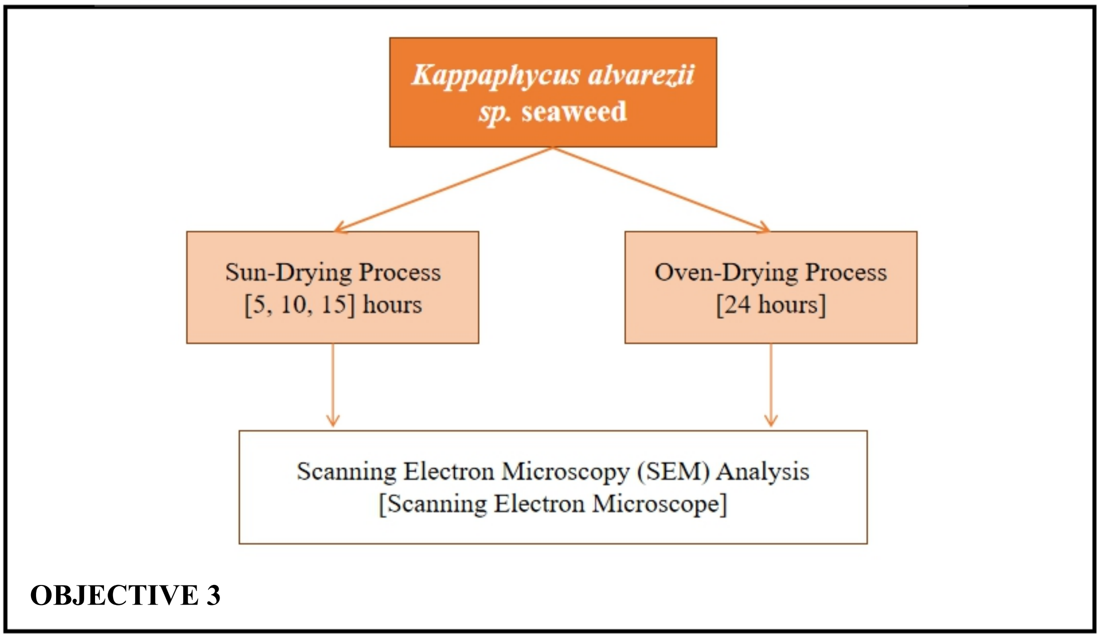

Figure 3.4: Details on experimental works in Objective 3

3.2 Experimental Work Regarding Objective 1

This section explained the experimental work involved in Objective 1 from the preparation of the raw material to the formation of seaweed powder.

3.2.1 Experimental Materials

The following aspect explains the key experimental materials used in Objective 1, including raw materials, chemicals and reagents, equipment and machinery, gloves, glassware and various functional items.

3.2.1.1 Raw Materials

In this research study, seaweed was used as the raw material in order to investigate the effect of the drying process on the quality characteristics of the material. More specifically, the seaweed species that have been chosen are *Kappaphycus alvarezii sp.* of seaweed. *Kappaphycus alvarezii sp.* seaweed has been chosen because of its high contents of antioxidant properties, and is also found abundantly grows in the coastal area of Sabah, Malaysia and easy to get. In this research study, the seaweed procured from a local company called Saanen Utama Sdn. Bhd., located in Melaka, Malaysia. The seaweed thoroughly washed at the beginning of the sample preparation process in order to eliminate the preservative salt and other impurities on the surface of seaweed and then soaked with distilled water.

3.2.1.2 Chemical and Other Substances

Overall, this experiment requires no chemical substance in the process of converting the raw seaweed to form the seaweed powder. Distilled water is the only pure substance included in this study which used in the soaking process. The distilled water is being used in the soaking process due to its inert properties, which means it will not affect the final result for this study since it free from any chemical or water contamination.

3.2.1.3 Experimental Equipments

Throughout the experiment's completion regarding the Objective 1, among the equipment used in the experiment, including hot plate stirrer, magnetic stirrer, lab glassware and spatula, mini pulverizer machine seaweed powder grinder and drying oven machine.

Figure 3.5: Hot plate stirrer

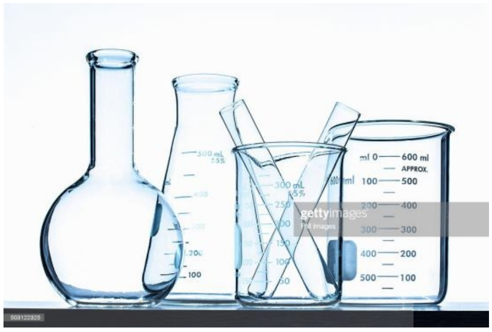

Figure 3.6: Lab glassware

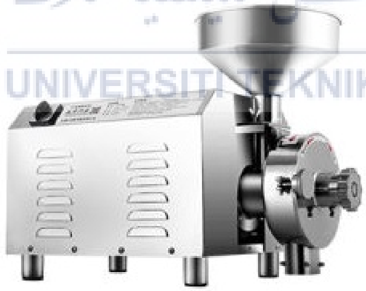

Figure 3.7: Mini pulverizer machine seaweed powder grinder

Figure 3.8: Drying oven machine

3.2.2 Experimental Methods

There are a variety of experimental methods to be conducted to develop *Kappaphycus alvarezii sp.* seaweed powder. These include the sample preparation, the soaking process using distilled water, the cutting process, the drying process and the grinding process. These methods performed in order to achieve the very first objective of this research study.

3.2.2.1 Sample Preparation

The raw material, which is *Kappaphycus alvarezii sp.* red seaweed, was prepared in this process. For each sample, the decided quantity is 90g. So each drying methods, which is sun-drying and oven-drying method contain three drying durations. The necessary number of samples is 6 samples. So, an estimated 540g of dried red seaweed was prepared. Firstly, thoroughly wash the red seaweed repeatedly to remove any impurities and contaminants on the seaweed using tap water.

3.2.2.2 Soaking Process

For the soaking process, prepared each sample in the quantity of 90g. In order to smooth the stirring process, the sample divided into three beakers, which means 30g for each beaker. It is to prevent disruption of the stirring process when the seaweed is expanding and become heavier. For each 30g of sample, 300ml of distilled water is poured and mixed with the seaweed sample. These three beakers placed on the hot stirred plate without applying any temperature. The sample is left to stirred with distilled water for 2 hours. After 2 hours of stirring, the seaweed sample will become expanding and swollen. This process repeated for the other samples with fixed soaking duration, which is 2 hours.

3.2.2.3 Cutting Process

After the soaking process, the sample should be cut to facilitate the grinding process. The sample is being cut to a length of 5cm.

3.2.2.4 Drying Process

a) Sun-Drying Method

The sample that was cut placed on the aluminium foil. The sample was then placed under the open sunlight with a certain drying duration. The drying duration is a predetermined parameter of 24 hours.

b) Oven-Drying Method

The sample that was cut placed on the aluminium foil. The sample was then placed in the drying oven machine and dried at the temperature of 60°C with a certain drying duration. The drying duration is a predetermined parameter of 5, 10 and 15 hours.

3.2.2.4 Grinding Process

The dried samples are separated one by one. It is because, during the drying process, the cut samples would usually stick to each other. The separated dried sample is then put into the mini pulverizer machine seaweed powder grinder to going through the grinding process. The grinding process starts with a coarse grinding process, then adjusted to a finer grinding process. This grinding process is repeated until the seaweed powder has formed.

3.2.3 Design of Parameter

In this research study, the sample drying duration is a predetermined parameter. Besides comparing the effect of different drying methods on the seaweed powder quality, this study also investigates the effect of the same drying method with a different drying duration on the seaweed powder quality. Therefore, there are three drying duration that have been selected for each drying methods. The duration is as shown in Table 3.1.

Table 3.1: Design of parameter

Drying Method	Sample	Drying Duration (hours)
1) Oven-Drying Method	1	5
	2	10
	3	15
2) Sun-Drying Method	4	24

Based on the Table 3.1, both drying methods apply the same drying duration parameter for the same number of sample. This is to allows the comparison of drying results between these two drying methods.

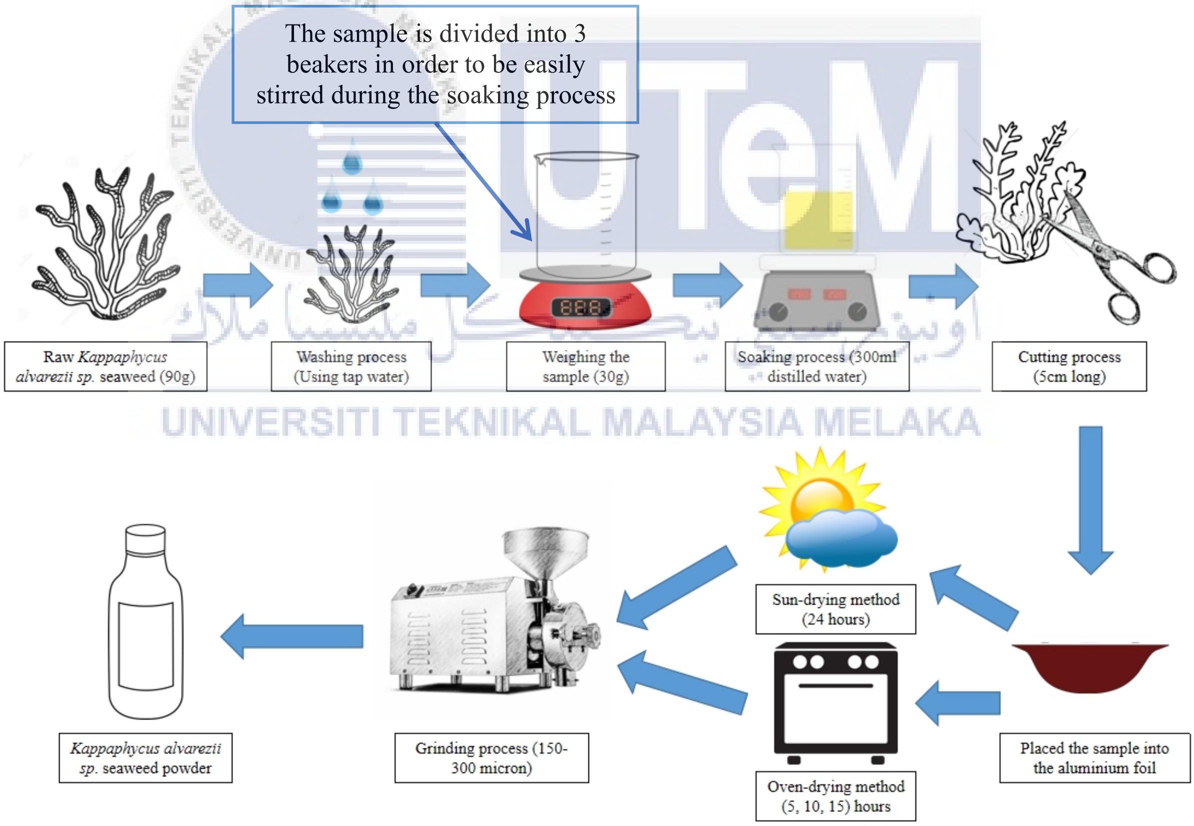

Figure 3.9: Illustration of preparation of seaweed powder

3.3 Experimental Work Regarding Objective 2

This section explained the experimental analysis involved in Objective 2, which include the moisture content analysis and mineral analysis.

3.3.1 Moisture Content Analysis

In this research analysis, the moisture content of the *Kappaphycus alvarezii sp.* seaweed powder has been analyzed by using the Moisture Content Analyzer. By using a moisture content analyzer, the percentage of moisture content of seaweed powder can be determined in only a few minutes. In order to use the Moisture Content Analyzer, the instrument or system should be turned on. The sample then placed and distributed evenly over the entire weighing pan. Then, the start button needs to be pressed in order to perform the analysis process. The instrument is continuously recorded the sample weight until the consistent value is reached, then the instrument stopped analyzing the weight automatically. Based on the previous research review, it is expected that the value of the moisture content in the *Kappaphycus alvarezii sp.* seaweed powder should between 10% to 15%. It is acknowledged that if the moisture content is higher than 15%, the seaweed powder cannot be stored for a long period due to the microbial's rapid growth. The procedure has been repeated for all dried seaweed samples to obtain the moisture content value for all sample.

Figure 3.10: Moisture content analyzer

3.3.2 Mineral Analysis

In this study, mineral analysis was conducted in order to determine the mineral content value in the seaweed powder. Mineral content value was determined by using the method of Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). ICP-OES was conducted by the Perkin Elmer Optima 8300 DV machine, along with an auto sampler as well as Mira mist nebuliser. To plan the calibration criterion, solutions were prepared of a singular element standard solution (1000 ppm) comprises of two elements (Ca, Mg) from Perkin Elmer system (German) have been used. In the basic preparation, ultrapure water has been used. The operational parameters of the ICP-OES machinery could be seen in Table 3.2.

Table 3.2: The operational conditions of the ICP-OES machine

No	Parameter	Flow Rate
1	Argon plasma	12 L/min
2	Nebuliser gas	0.5 L/min
3	Auxilary gas	0.4 L/min
4	Radio Frequency (RF)	1500 Watts
5	Pump	1.5 mL/min

Both elements had been identified throughout the radial mode. Both samples were evaluated in triplicate to avoid any particular error, to ensure sample consistency, as well as to assess the consistency of the process. The quality control (QC) requirement with a concentration of 10 ppm comprising two elements was evaluated alongside the *Kappaphycus alvarezii sp.* seaweed solution extraction for verification. Based on the previous research review, it is expected that the longer the drying duration, the low the mineral content remains. The procedure has been repeated for all dried seaweed samples to obtain the mineral content value for all sample. However, due to the restriction of the Covid19's pandemic, the mineral analysis were done via postulating the critical review.

3.4 Experimental Work Regarding Objective 3

This section explained the experimental characterization involved in Objective 3, which is the Scanning Electron Microscopy (SEM) Analysis.

3.4.1 Scanning Electron Microscopy (SEM) Analysis

Scanning Electron Microscopy (SEM) analysis provides excellent imaging that is useful in evaluating different surface fractures, defects, contamination or corrosion materials. This analysis is being analyzed by using Scanning Electron Microscope. In this research study, SEM was used to examine the surface morphology of *Kappaphycus alvarezii sp.* seaweed after the drying treatment. A small piece of samples was put on the aluminium studs and coated with gold using a mini sputter coater before the analysis. The images were obtained with an acceleration voltage of 2 kV with a resolution of approximately 10nm and magnification from 5 to 1,000,000X. The effect of the drying treatment on the *Kappaphycus alvarezii sp.* seaweed surface was then identified as well as further analyzed. From the result of the previous research, it is expected that the longer the oven-drying duration, the fewer cavities appear on surface of the seaweed's cross-sectional area. It is also expected that surface of the seaweed's cross-sectional area contain a lot of cavities due to the lower and inconsistent drying temperature..

Figure 3.11: Scanning Electron Microscope

CHAPTER 4

RESULTS AND DISCUSSION

This chapter describes the experimental results obtained from multiple analyses which were carried out during the experimental study period. In this chapter, several tests were performed to analyze the *Kappaphycus alvarezii sp.* seaweed after going through different drying methods and duration. Moisture content analysis was used in order to determine the moisture content of *Kappaphycus alvarezii sp.* seaweed powder. Meanwhile, mineral analysis was done through the critival review analysis due to the pandemic Covid19 restrictions. Mineral analysis is to identify the mineral elements contained in the *Kappaphycus alvarezii sp.* seaweed powder after the drying and grinding process. Lastly, Scanning Electron Microscopy (SEM) analysis was used to observe the surface morphology *Kappaphycus alvarezii sp.* seaweed after going through the drying process. Furthermore, this chapter goes into detail about the clarification of the results obtained for this experiment.

4.1 Drying the *Kappaphycus alvarezii sp.* Seaweed

Drying process is one of the process in order to produce the *Kappaphycus alvarezii sp.* seaweed powder. In this study, the drying process became the most important process. This is due to the fact that this study was conducted to study the quality of different oven drying duration to replace the conventional method, which was sun-drying. Direct sun-drying exposed the sample to dirt and dust contamination, insect infestation, direct exposure overheating, long drying period (Maisnam *et al.*, 2017). Besides, the drying temperature of the sun is low and constantly varies with the weather. It not only has a negative impact on the quality of the seaweed's end products, but it also slows down production. Therefore, oven-drying has been proposed as the replacement for sun-drying method. This is due to oven-drying method appears to be capable of overcoming the majority of the issues encountered during the sun drying process. The oven drying process occurs in an oven dryer at a high and consistent temperature, in a closed environment where the samples are safe from insect attack or dust contamination (Flores and Davies, 2016). With a higher and more consistent temperature, the drying process will be faster, and the production of seaweed end products will be greater than sun-drying. The method of drying conducted in this study is oven and sun drying. Since the main purpose was to replace sun-drying method, sun-drying process also included in this study as reference to the oven-dried sample. The parameter that has been set for oven-drying process is 5, 10 and 15 hours. Oven temperature is set to be fixed at 60°C for all 3 sample. Meanwhile, the sun-drying sample has been left in open sunlight for 4 days from 10 am to 4 pm, which means the total duration for sun-drying is 24 hours (Suherman *et al.*, 2018). The temperature for sun-drying is between 23 to 32°C (Saifullah *et al.*, 2016). Table 4.1 shows the drying methods and duration of the sample.

Table 4.1: Drying methods and duration

Drying Methods	Sample	Temperature (°C)	Drying Duration (Hours)
Oven-drying	1	60	5
	2		10
	3		15
Sun-drying	4	23-32	24

4.2 Moisture Content Analysis

Moisture content analysis is an analysis to determine the water contain remain in the seaweed after drying treatment. Moisture analysis are among the most vital analysis conducted on a natural product including *Kappaphycus alvarezii sp.* seaweed. Most products contain a significant amount of water. This amount of water in the seaweed needs to be reduced in order to increase the quality and durability of the end products. This is where the role of drying process comes into play in terms of producing high-quality of *Kappaphycus alvarezii sp.* seaweed end products with greater durability. The suitable amount of water content for natural products is between 10-15%. This statement was supported by Zambrano *et al.* (2019), in which they said that it must reach a moisture content value of approximately 10% in order to prevent the growth of microorganisms, depending on the sample. Meanwhile, Del Rosario and Mateo (2019) claims that the drying process should be continued until it obtains a perfect moisture content value of 14-15% on the *Kappaphycus alvarezii sp.* seaweed.

The amount of water content in the seaweed was lost after it was heated or dried. Therefore, Moisture content analysis was conducted in order to measure the moisture content of *Kappaphycus alvarezii sp.* seaweed powder after being heated or dried. The moisture content of *Kappaphycus alvarezii sp.* seaweed powder can be measured by using a moisture content analyzer. The raw material of *Kappaphycus alvarezii sp.* seaweed contain the moisture content of 91%, supported by Del Rosario and Mateo (2019). Meanwhile, Ali *et al.*, (2014) claim that the moisture content of *Kappaphycus alvarezii sp.* seaweed is about 90.50%. In the other study, Adharini *et al.* (2020) proves that the moisture content for the *Kappaphycus alvarezii sp.* seaweed are 89.48% ± 0.17 for red strain and 90.66% ± 0.15 for green strain through the result obtained from their study. Table 4.2 shows the moisture content of raw *Kappaphycus alvarezii sp.* seaweed data from the past research.

Table 4.2: Moisture content of raw *Kappaphycus alvarezii sp.* seaweed

References	**Sample**	**Moisture Content (%)**
Del Rosario and Mateo (2019)	*Kappaphycus alvarezii sp.*	91
Ali *et al.* (2014)	*Kappaphycus alvarezii sp.*	90.5
Adharini *et al.* (2020)	*Kappaphycus alvarezii sp.*	89.48 ± 0.17 (Red Strain)
		90.66 ± 0.15 (Green Strain)

The moisture content for the dried samples of *Kappaphycus alvarezii sp.* seaweed powder were shown in Table 4.3. The temperature for oven-drying was set to be fixed to 60°C for all drying duration since this study focus on the drying duration as parameter. In the other words, the purpose of this study was to find the perfect oven-drying time for the best quality of *Kappaphycus alvarezii sp.* seaweed powder. Meanwhile, the temperature for the sun-drying was between 23 to 32°C (Saifullah *et al.*, 2016). Since this method using the heat from the sunlight, the temperature were constantly changing from time to time. The moisture content for sample 1, 2 , 3 and 4 was 17.64%, 11.84%, 12.28% and 10.47% as shown in Table 4.3.

Table 4.3: Moisture content of *Kappaphycus alvarezii sp.* seaweed

Drying Methods	**Sample**	**Drying Duration (Hours)**	**Temperature (°C)**	**Moisture Content (%)**
Raw	-	-	-	91
Oven-drying	1	5	60	17.64
	2	10		11.84
	3	15		12.28
Sun-drying	4	24	23-32	10.47

Figure 4.1 shows the moisture content of *Kappaphycus alvarezii sp.* seaweed powder line graph. By referring to the Figure 4.1, as drying time increases, the percentage of moisture value decreases, supported by Abasi *et al.* (2009). The suitable drying duration is either sample 2 (10 hour) or sample 3 (15 hours) since the moisture content for that sample is between the range of 10-15% (Zambrano et al. 2019) (Del Rosario and Matteo, 2019). Therefore, sample 2 and sample 3 produce moisture content that is close to the sun-drying method which is sample 4.

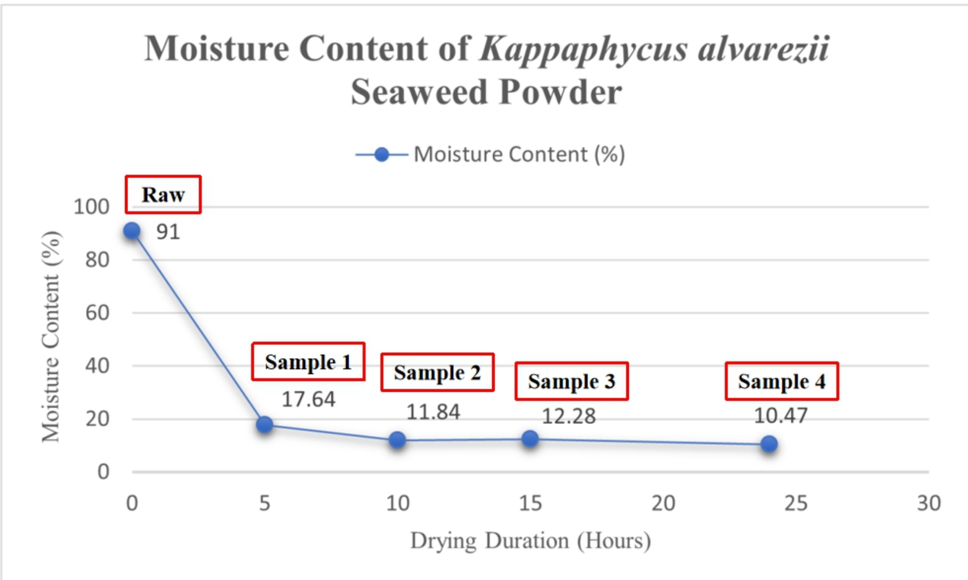

Figure 4.1: Moisture content of *Kappaphycus alvarezii sp.* seaweed powder

4.3 Mineral Analysis

Mineral analysis was conducted to determine the mineral content in the *Kappaphycus alvarezii sp.* seaweed powder. Due to the Covid19 pandemic's constraint, mineral analysis has been done via critical review by comparing the results from past research papers. In this study, the minerals that have been focused are calcium and magnesium. The result for calcium and magnesium were taken from the late research studies in order to postulate the value for this study. Mineral content for raw material was included as a control data to give the idea of how the drying process affect the mineral content. Table 4.4 shows the mineral content for raw *Kappaphycus alvarezii sp.* seaweed powder from MARDI.

Table 4.4: Mineral content of raw *Kappaphycus alvarezii sp.* seaweed (MARDI, 2018)

Elements (mg $100g^{-1}$ DW)	
Ca	**Mg**
595	498

Table 4.5 shows the mineral content for oven-dried *Kappaphycus alvarezii sp.* seaweed from previous research. The drying duration used by Nurshahida *et al.* (2018) was 8 hours while Yagame *et al.* (2017) used 48 hours. From Table 4.5, the mineral content for calcium decreased from 121.90 to 81.6 mg $100g^{-1}$ DW. Same with the mineral value for magnesium, its decreased from 221.01 to 216.87 mg $100g^{-1}$ DW.

Table 4.5: Mineral content for oven-dried *Kappaphycus alvarezii sp.* seaweed

References	**Temperature (°C)**	**Duration (hours)**	**Elements (mg $100g^{-1}$ DW)**	
			Ca	**Mg**
Nurshahida *et al.* (2018)	70	8	121.90	221.01
Yagame *et al.* (2017)	70	48	81.6	216.87

The value for both elements, which were calcium and magnesium for 8 hours was higher than the elements of 48 hours. The longer the drying duration, the lower the mineral content value, as shown in the Figure 4.2. This also supported by the result from Adharini *et al.* (2020) and Singh and Gupta (2011). Figure 4.2 shows the line graph for the mineral content value for 70℃ from the past research results.

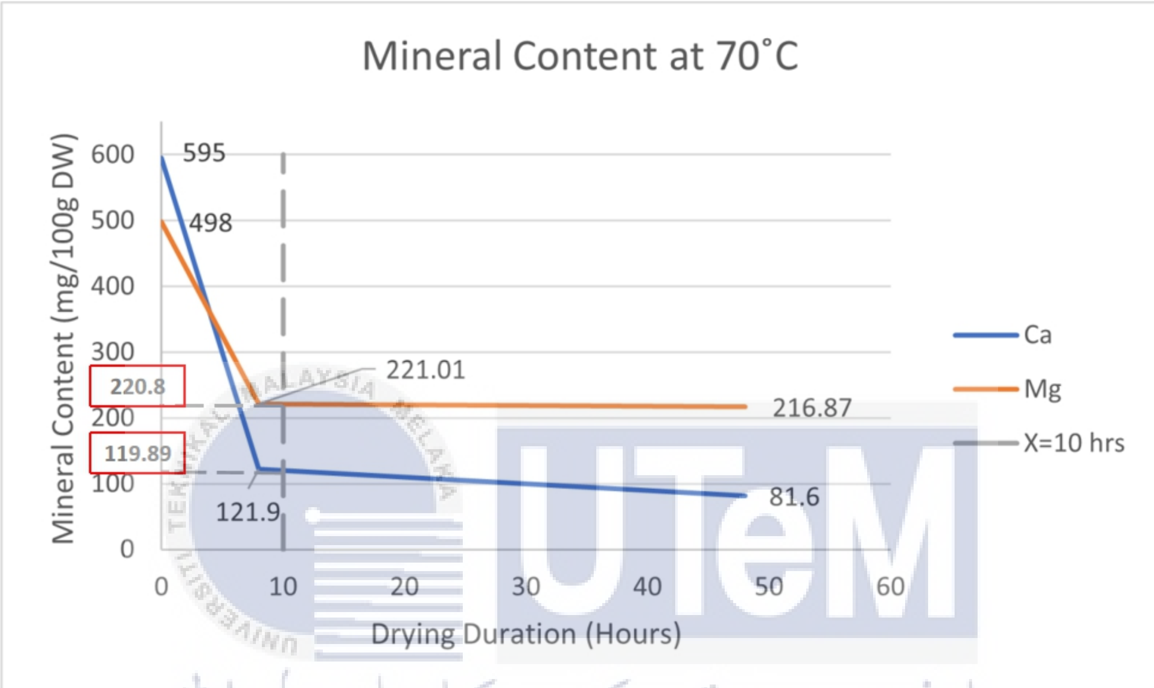

Figure 4.2: Mineral content for 70°C drying temperature (Nurshahida *et al.,* 2018) (Yagame *et al.,* 2017)

Based on the data in Table 4.5, the line graph was postulated as shown in Figure 4.2. From the Figure 4.2, the mineral content for 10 hours at 70℃ can be obtained. The mineral content for calcium was 119.89 mg $100g^{-1}$ DW while magnesium was 220.8 mg $100g^{-1}$ DW. Therefore, the mineral content for 10 hours at 60℃ can be predicted. It is predicted that the mineral content value for 60℃ was slightly higher than 70℃. Olabode *et al.* (2015) also claimed that mineral values will decrease as the temperature rises. Figure 4.3 shows the postulated data for this study at 60℃ for all oven-dried samples.

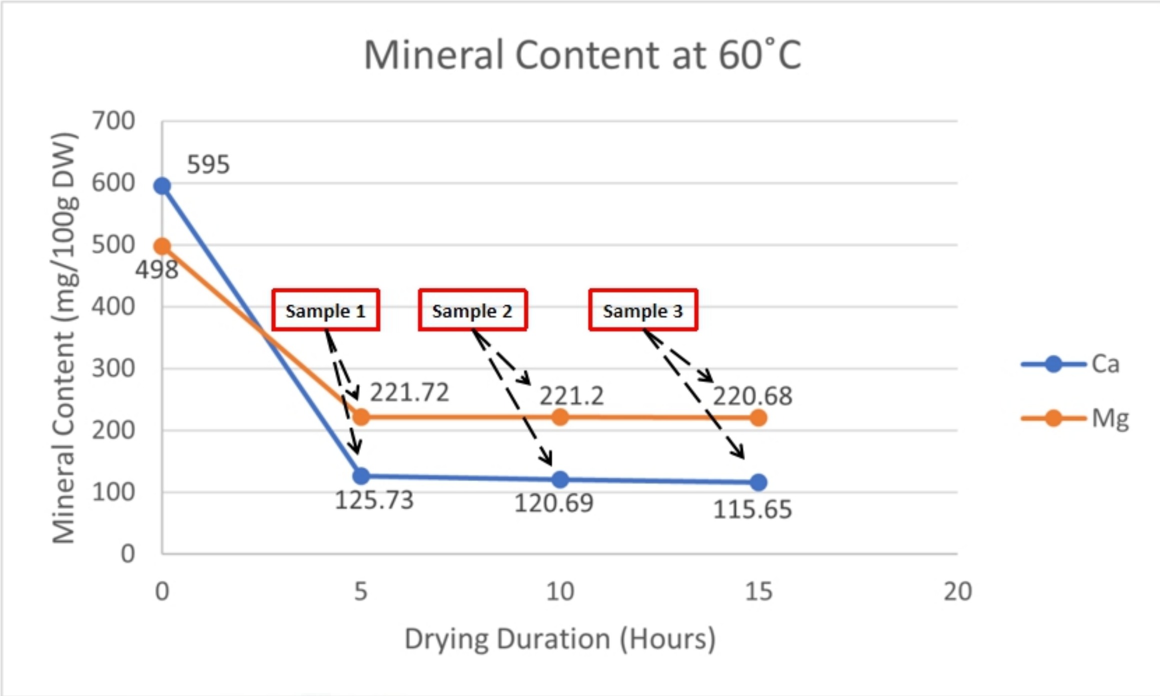

Figure 4.3: Postulated mineral content for 60℃

Meanwhile, up to date, there are no studies on the mineral content of sun-dried *Kappaphycus alvarezii sp.* seaweed. Instead of that, a lot of past researchers studies on other drying method such as freeze drying and air drying for the mineral content. However, with the limitation review data of the mineral content of the sun-dried seaweed, the purpose for this study which is to find the best oven-drying duration is still achieved. Sample 2 shows the best result, it is because sample 2 fulfilled the requirement in both analysis, which was the moisture content value between 10-15% and short drying duration. Therefore, 10 hours of oven-dried is the best option to replace sun-dried due to its low moisture content and high mineral content value.

4.4 Scanning Electron Microscopy (SEM) Analysis

After completed the process of drying treatment to the *Kappaphycus alvarezii sp.* seaweed, the resulted surface morphology for all sample oven and sun dried were studied. The results were examined with a variable pressure Scanning Electron Microscope (SEM), Carl Zeiss Model 1450 VP. The drying treatment was carried out by using different duration for oven drying which were 5 hours, 10 hours and 15 hours with fixed 60℃ of drying temperature. For sun drying, the duration that has been used was 24 hours.

Figure 4.4 shows the surface morphology for sample 1, which involved 5 hours of drying duration. Based on the figure, There is fungal spore growth on the sample's surface and around it. This statement supported by Babu *et al.* (2018), whose said that the fungal spore contain smooth-walled walls, clear, septate and with branched. Fungal spore reduces the quality of food by causing tangible and intangible defects like texture modifications, patches and spots, off-flavors and off-odors and could result in a food safety risk (Kure *et al.*, 2021). Fungal growth occur due to the high value of moisture content and affect the seaweed's end product. This result proved the statement issued by Zambrano *et al.* (2019).

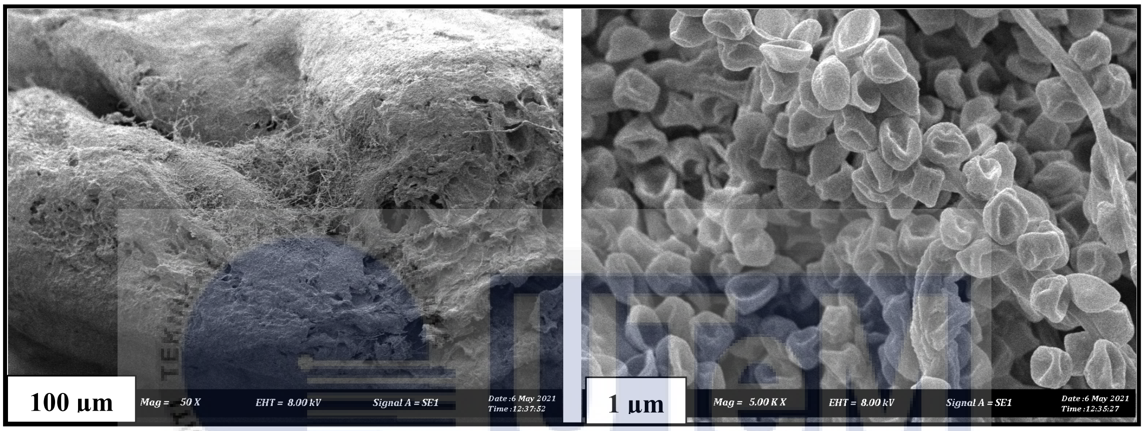

Figure 4.4 : SEM micrograph of sample 1

Figure 4.5 shows the surface morphology of sample 2. Sample 2 have a clean surface and clear from any contaminants. The suitable drying duration and method provide clean and smooth surface, supported by Kang *et al.* (2011). There also have only several small cavities in the center, as shown in Figure 4.5. This proved that higher drying temperature offers good drying treatment since the drying process covers up to the inside section of the sample, supported by Kaparanga *et al.* (2017).

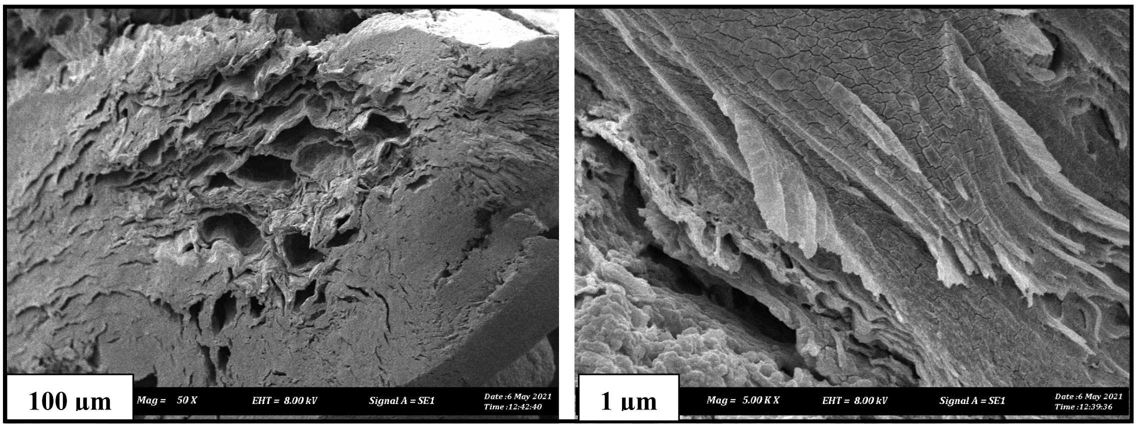

Figure 4.5: SEM micrograph of sample 2

Figure 4.6 shows surface morphology for sample 3. In terms of cleanliness, the surface of sample 3 is similar to that of sample 2. Sample 3 has fewer cavities on its surface than sample 2. This proved that longer drying duration also affected the structure of sample surface, supported by Kaparanga *et al.* (2017). From all the oven-dried samples, it can be concluded that the moisture content determine the surface of the seaweed through SEM image.

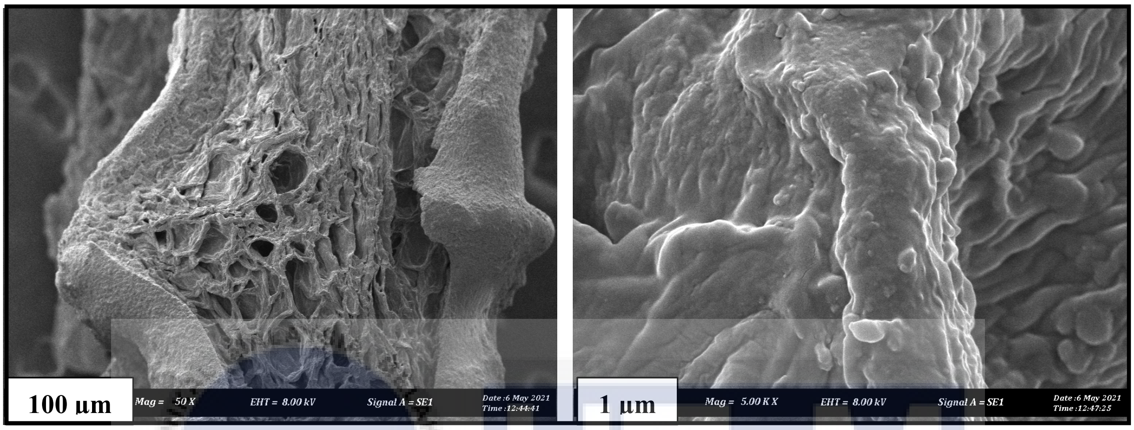

Figure 4.6 : SEM micrograph of sample 3

Figure 4.7 shows the surface morphology of sample 4, which was the sun-drying sample. Based on the Figure 4.7 , there are a lot of cavities can be found in the sample. The drying process only occur on the outside section of the sample due to uncontrollable heat and humidity, which also supported by Ahmed *et al.* (2013). There are also a lot of outside contaminant appeared on the sample. The contaminant that appeared may be the dust particle since the drying process occur in the open-placed. Dust particle have rounded-shape and can be seen in the scale of 400 nm (Carton *et al.*, 2014).

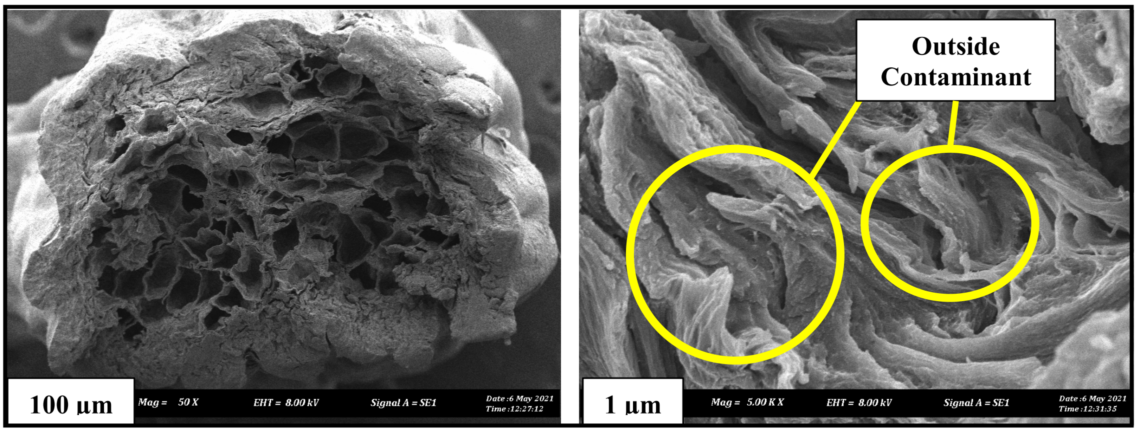

Figure 4.7 : SEM micrograph of sample 4

The surface morphology for oven-dried seen better compared to sun-dried except for sample 1. Oven drying process provide the better and effective drying treatment since it caused the heat transferred up to the inner side of the sample. It happened due to the higher and consistent temperature. Thus, sample 2 with 10 hours of oven-drying process is the optimum drying duration to replace sun-drying process due to it’s surface morphology, supported by low moisture content and high mineral content.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As the conclusion, the *Kappaphycus alvarezii sp.* seaweed powder was successfully prepared, fulfilling the first objective of this study. The *Kappaphycus alvarezii sp.* seaweed powder was prepared using different drying methods i.e., oven-drying and sun-drying method. Different oven-drying duration are used as parameters, and the temperature for all oven-drying samples was maintained fixed at 60℃. Sun-dried sample act as reference for oven-dried samples in order to identify the optimum drying duration for oven-drying. Apart from the drying process, there were several other processes involved in sample preparation including washing, soaking, cutting and grinding process.

The second objective of this study is to determine the moisture content and mineral content of the *Kappaphycus alvarezii sp.* seaweed after drying treatment using moisture content analysis and mineral analysis. Moisture content analyzer has been used in order to obtain the moisture content value for the sample. Moisture content results indicate that as the drying duration extended, the moisture content dropped. The acceptable drying duration is either 10 or 15 hours with the moisture content of 11.84% and 12.28%, respectively as both durations fulfill the ideal moisture content, between 10 to 15%. However, 10 hours is favored for an optimum oven-drying duration as its moisture content is the closest to the sun-drying's moisture content. Meanwhile, mineral analysis was conducted through critical review based on the graph trend from past research due to the Covid19 pandemic's constraint. From the past research study, the graph trend shows that as the drying period increases, the mineral content decreases. Thus, 10 hours is the optimum duration for oven-drying method as it complies both requirements for moisture content analysis and mineral analysis.

The third objective of this study is to characterize the surface morphology and structure of *Kappaphycus alvarezii sp.* seaweed by using Scanning Electron Microscopy (SEM). From the observation, it is noted that the pore on the cross-sectional surface for oven-dried samples is much fewer than the sun-dried sample and show better clean and smooth surface. In addition, sun-dried's sample surfaces have white spots which are most likely dust. Except for sample 1, which was covered by fungal growth, the surface of the other oven-drying samples appeared clean.

5.2 Recommendation

In this study, there were many questions raised in this study about the need for further investigation in order to observe in detail on the surface morphology of the dried *Kappaphycus alvarezii sp.* seaweed. For the recommendation, further research can be used Scanning Electron Microscopy (SEM) with Energy Dispersive X-Ray (EDX) analysis to obtain high-resolution images and provide elemental identification and quantitative compositional information. By conducting SEM-EDX analysis, any defect on the surface can be detect particularly.

5.3 Sustainable Design and Development

In this study, the sustainable design and development has been the major factor. Nowadays, most beauty and medical products contain chemicals that are potentially harmful to the human body. Most people are now easily manipulated by the use of chemical-containing drugs, particularly for the purpose of losing weight quickly. whereas such drugs are only effective for a limited time and will have negative long-term consequences. Similarly, most beauty products containing these chemicals will take effect quickly, but will gradually harm the skin or certain organs. Therefore, humans can avoid those risks by consuming products that contain natural ingredients, particularly seaweed.

Seaweed is also high in vitamins and nutrients that can help with a variety of issues that most people face today. Seaweed-based products can also improve the human body's endurance, in addition to providing what people want.

5.4 Complexity

In order to conduct this experiment, many unexpected constraints are involved in the final moments for this research. Initially, all the characterization supposed to be conducted through the experimental work. However, due to an increase in Covid19 cases, one analysis was not successfully carried out in experimental work, prompting the government to issue a conditional movement control order. As a result of this issue, many planned activities are affected. However, the challenging of the pandemic has been encountered through the critical review approach in order to implement the complexity element in this study. Credit is given to the faculty, panels and supervisors for understanding the current situation of students by facilitating all matters to complete the project at the end of this year.

5.5 Life Long Learning and Basic Entrepreneurship

Seaweed has a lot of potential for commercialization. This is due to seaweed's high nutrient content, which allows it to be used in a variety of industries including medicine, beauty and food. Furthermore, there are numerous seaweeds in the countryside that have yet to be discovered. Many people are unaware of the benefits and advantages of seaweed, so it is frequently ignored. As a result, information about this seaweed should be widely publicized so that everyone can benefit from it.

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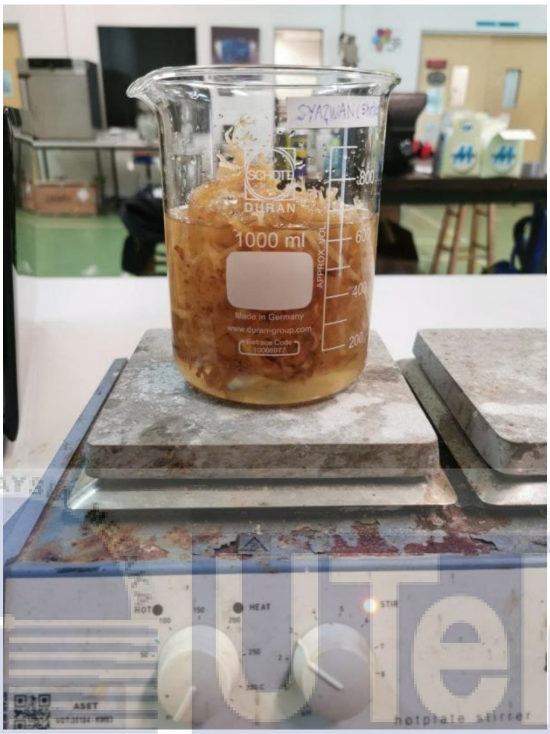
APPENDICES

A Soaking process of seaweed



B Moisture content analysis of seaweed powder

C Sun-drying process