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Production of Fresh Seaweed Powder using Spray Drying Technique

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Abstract: Spray drying technique is a common industrial process in the production of powder and granules from liquid materials. The advantage of spray drying technique is not only in the ability to control the product particle size, but also good for the ability of retaining and protecting some of volatile compounds. Since, major content of seaweed is of liquid compounds, therefore, the production of seaweed powder using a spray drying technique was considered an appropriate process technique. In this study, a study on production of powder from Sabah Green Seaweed (*Kappaphycus alvarezii*) was conducted. A laboratory scale spray dryer (Lab Plant SD-05) was used as the main equipment for the powder production. The experimental study was conducted at various processes operating conditions and the powders produced were analyzed for moisture content, particle size and antioxidant activity. Experimental result obtained show that there are correlation between powders size, antioxidant activity and moisture content with process operation conditions. The result show that the particle size and the antioxidant activity of the powder increases with the rise of spray drying inlet temperature, whereas the moisture contents has inverse relationship to the inlet temperature. This works shown that the spray drying technique can be considered for the production of seaweed powder.

Key words: *Kappaphycus alvarezii*, Sabah green seaweed, seaweed antioxidants activity

INTRODUCTION

Malaysia, especially Sabah, is a maritime state with more than three quarters of its boundaries adjoining the sea. More than half of the sea boundaries are naturally suitable for edible seaweed plantation. Seaweeds are Algae (Ismail and Tan, 2002) which are classified by their pigment. These algae are non-flowering plants with neither roots nor leaves. Usually, these algae were found attached to a fixed structure by means of a holdfast. Sabah coast which has the suitable sea environment is abundant with wild seaweed growth that consists mostly of genus Eucheuma, Gracilaria (Rhodophyta), Sargaassum, Turbinaria (Phyaeophyta), Caulerpa (Cyanophyta). Sabah seaweeds have a high market demand from industries. Usage of this environmentally friendly product is increasing. Traditionally, seaweeds have been used as food, fodder, fertilizer and also as sources of medicinal drugs. They are nutritionally valuable as fresh or dried vegetables, or as ingredients in wide varieties of prepared foods. In particular, certain seaweeds contain significant quantities of lipids, protein, vitamins and minerals (Sanchez-Machado *et al*., 2004) which is good for human body.

There are many methods of seaweed processing and the most popular method is drying, which is the oldest known method for preserving the food. Historically, in Sabah, seaweeds were dried in the sun with arrays of it were lay on a mattress. Dried seaweed has many advantages as compared to fresh seaweeds. Basically, the drying process preserves seaweed by removing enough moisture from the food to prevent it's from decaying. Dried seaweed is compact so that less storage space is needed. Also, dried seaweed keeps well. At around 1939 and 1941, in Iceland, an oldest drying method was found which is using geothermal water and steam from a hot spring as a source of drying seaweed (Hallsson, 1992). Unfortunately, all these drying techniques require long drying time and usually have low thermal efficiency. The key objective in any drying procedure is to achieve high moisture removal efficiency at a reduced processing time. In this respect, a procedure that has the ability to quickly transform seaweeds into dried particulate form and has the ability to control the particle size distribution is the spray drying technology (Obon *et al*., 2009). Transformations of these products into fine powder will results in much reduced volume and longer shelf life (Cano-Chauca *et al*., 2005).

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In last decades, several reports have documented on the application of spray drying in the drying of organic compounds to form fine particulate, such as hydrolyzed protein from *Oreochromis mossambicus* (black tilapia) (Hamid *et al*., 2002), watermelon powder from it juices (Quek *et al*., 2007), tomato pulp (Goula and Adamopoulos, 2005), ice-cream mixes (Vega *et al*., 2005), soymilk (Jinapong *et al*., 2007), pet food (Polo *et al*., 2005) and also proteins and essential oils from various parts of plants and plant seeds. However, fruit juices powders that were obtained using spray drying process may have some constraints in their physical and chemical properties such as stickiness and solubility, due to the present of low molecular weight sugar and acids (Tonon *et al*., 2008).

Spray drying is a process which involves conversion of liquid feed into dry fine droplets form by exposing them to a hot drying media (Goula and Adamopoulos, 2005). Typically, the hot drying media is air, but for sensitive materials such as pharmaceuticals products, or solvents such as ethanol which require oxygen-free drying, nitrogen gas is used instead. The feed that is to be transformed into dried particulate form can be in the form of a solution, suspension, dispersion, emulsion, while the dried product can be in the forms of powders, granules, or agglomerates depending upon some process variables, such as physical and chemical properties of the liquid feed (particle size, flow rate, viscosity, solubility) and of the drying air (inlet and outlet temperature, pressure) as well as the dryer design (type of atomizer) (Cano-Chauca *et al*., 2005).

Though quite energy-intensive in many cases, spray-drying is often the drying method of choice because of its continuous design and flexibility. It delivers a powder of specific particle size and moisture content regardless of the dryer capacity or product heat sensitivity (Al-Asheh *et al*., 2003). In a continuous operation, the spray-dryer delivers a highly controlled powder quality with relatively easy control. Also the surface area produced by atomization of the liquid feed enables a short gas residence time, ranging from 3-40 sec depending upon the application, which permits spray drying without thermal degradation. This allows for fast turn-around times and product changes because there is no product hold up in the spray drying equipment. Besides, materials can be processed directly from farm to factory without any other extraction process or else. The most important thing is encapsulation by carrageenan itself which occurred during spray drying process (Gharsallaoui *et al*., 2007). The main advantage behind the encapsulation process is it preserves many useful properties of seaweed.

The aim of this study is to develop spray drying methodology for production of fresh seaweed powder. The powder produced using this method is expected to be useable as a food supplement. Therefore, the effect of process parameter on the properties of powder produced i.e., particle size, anti-oxidant activity and moisture content will be determined.

MATERIALS AND METHODS

The production of seaweed powder involves the preparation of seaweed samples and the spray drying process. Since the powder product is targeted for food supplement application, analysis of particle sizes, moisture content and antioxidant activity is conducted. The basic flow process of seaweed powders production is shown in Fig. 1.

Preparations of samples: Fresh seaweed (*Kappaphycus*) samples were collected from seaweed farm around Sabah. Seaweed samples were washed with distilled water and chopped into small pieces (5-7 mm) and liquidized using electronic blender (Panasonic MX-898M). The liquidized seaweed sample was then filtered using 0.45 μm membrane filter. The filtrate collected was heat up to 60°C prior spraying drying process.

Spray drying: Spray drying process was performed using the laboratory scale spray dryer LabPlant SD-05. The seaweed filtrate was fed into the main chamber through a peristaltic pump at the rate of 8 mL h^{-1}. The hot air flow rate in to the drying chamber was set at 40 m^3 h^{-1}, while compressor air pressure was set at 1.2 MPa. Three different inlet temperatures were used in these experiments, i.e., 130, 140 and 150°C. The spray drying process was performed at constant process condition. The seaweed powder obtained was kept in plastic container and stored in a desiccators containing silica gel before it was analyzed.

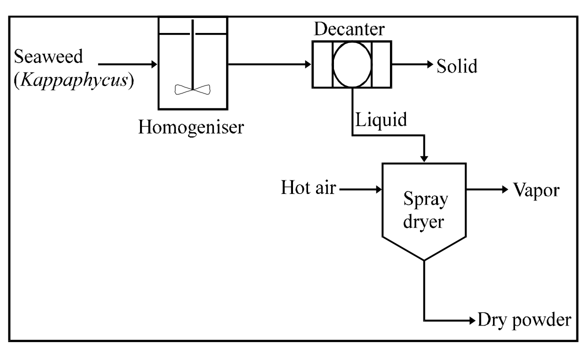

Fig. 1: Seaweed drying process

Particle size distribution and moisture content: The particle size was measured using laser scattering particle size distribution analyzer (Horiba LA-300). The moisture content was determined by drying the powders (0.5 g) in Binder oven at 60°C for 24 h. The moisture content is expressed in terms of wet basis (wb).

$$\text{w.b (\%)} = \frac{\text{weight of water}}{\text{weight of wet material}} \times 100$$

Antioxidants activity (DPPH assay): The knowledge of the effect of process condition on the antioxidant activity is important for food products. The antioxidant analysis conducted based on a methods known as 2, 2-Diphenyl-1-Picrylhydrazyl (DPPH) assay (Ganesan *et al*., 2008; Chew *et al*., 2008; Kumar *et al*., 2008). For comparison purposes, the antioxidant activity of the filtrate and the seaweed powder produced was measured.

Seaweed filtrate: Three different dilution of seaweed filtrate in distilled water was prepared (10, 20, 30 mL juice in 100 mL of solution). An aliquot of 0.1 mL of diluted seaweed filtrate was added to 3.9 mL of DPPH solution in ethanol (1 mM) and vortexed. The mixture was shielded from light and kept in a container at room temperature for 30 min. Using a visible spectrophotometer (Novaspec II), the absorbance was measured (at 517 nm). The measurement was repeated until the reading reached a plateau. The antioxidant activity was expressed as percentage of DPPH- scavenging activity, relative to the control using the following equation:

$$\text{\%Radcal scavenging activity} = 1 - \frac{\text{Absorbance of sample at 517 nm}}{\text{Absorbance of control at 517 nm}} \times 100$$

Seaweed powder: similar procedure to the measurement of antioxidant activity of seaweed filtrate was applied for the seaweed powder. For the seaweed powder the dilution was prepared at 2.0, 3.0 and 4.0 mg powder/mL distilled water. Then 2.0 mL of DPPH solution in 1.0 mM ethanol was mixed with 2 mL of seaweed solution. The procedure was repeated for all powder solutions.

RESULTS AND DISCUSSION

Particle size distribution: Figure 2 shows the particle size distribution for the powders produced at different inlet temperatures (130, 140 and 150°C) with feed flow rate in the range of 6-10 mg mL^{-1}.

These conditions are relative to the axial points of the experimental design, in which one variable fixed in three levels. As shown in Fig. 2, particles showed a unimodal distribution graph, which mean the distribution graph showed one higher peak which representing a predominant size.

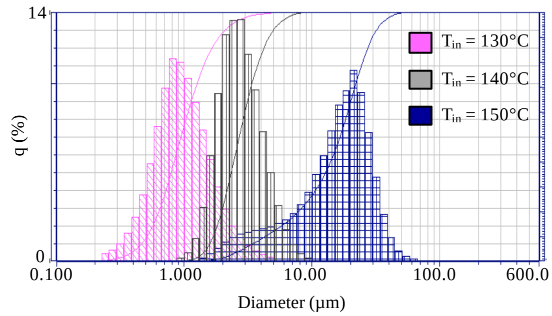

Fig. 2: Particle size distribution for seaweed powders

Table 1: Mean diameter of powder produced at different temperature

Temperature (°C)	Mean diameter (µm)
130	1.11
140	2.97
150	17.10

Table 2: Moisture content of powder produced at different temperature

T_{in} (°C)	Moisture content (%)
130	10.4
140	9.7
150	8.9

The increases in inlet air temperature resulted in larger particles (Table 1), which is related to the higher swelling caused by higher temperatures. Reiniccius (2001) reported that drying at higher temperature cause faster drying rates and produce larger particles as compared to drying at lower temperature which contribute to slower drying rates. This is due to the fact that very fast drying or drying at high temperature set up a structure early and does not allow the particles to shrink during drying. When the inlet temperature is low, the particles remain more shrunk and thus, with smaller diameter.

Moisture content: Powder moisture content varied from 8.9 to 10.4%. Moisture content was significantly influenced by inlet air temperature of spray dryer. Shown in Table 2 are the temperature influences on the powder moisture contents. The relationship is that an increase in an air inlet temperature leads to a decrease in moisture content.

This inverse phenomena happen because at higher inlet air temperature, there is a greater temperature gradient between the atomized feed and the drying air, resulting in a greater driving force for water evaporation and thus producing powders with lower moisture content. When the drying medium is air, temperature also plays a second important role which is mass transfer As water is driven from the particles in the form of water vapor, it must be carried away, or the moisture will create a saturated atmosphere at the particle surface and will slow down the rate of water removal. The hotter the air, the more moisture it will be able to hold before becoming saturated. Thus, high temperature air in the vicinity of the drying particles will take up the moisture being released out from the seaweed powder to a greater extent than with cooler air.

Antioxidant activity (DPPH assay): The importance of antioxidant constituents of plant materials is maintaining the health of a human such as protection against coronary diseases and cancer. The presence of different antioxidant components in plant tissues makes it relatively difficult to measure each antioxidant component separately. Therefore, several methods have been developed, in recent years, to evaluate the antioxidant activity of samples (Kaur and Kapoor, 2002). DPPH is a compound that possesses a nitrogen free radical and is readily destroyed by a free radical scavenger. This assay was used to test the ability of the anti-oxidative compounds function as proton radical scavengers or hydrogen donors (Singh and Rajini, 2004).

The DPPH radical scavenging effects of seaweed filtrate at different dilutions are presented in Fig. 3. As shown in Fig. 3, the relationship of antioxidant activity is inversely proportional to dilution concentration as expected. This show that the validity of antioxidant activity.

The DPPH radical scavenging effects of spray-dried seaweed powders are presented in Fig. 4-6. In the Fig. 4-6, it is clearly shown that the relationship between absorbance at t = 0 min and absorbance at t = 30 min is linear. Based on that figures, its show that the absorbance at t = 30 min is increase linearly against the absorbance at t = 0 min. The main reason for this behavior is the increasing concentration of seaweeds increased the number of hydrogen donating ability (Jayaprakasha *et al*., 2007). The antioxidants are believed to intercept the free radical chain of oxidation and donate hydrogen from the phenolic hydroxyl group, thereby forming a stable end-product which does not initiate further oxidation of lipid (Jayaprakasha *et al*., 2007). The data obtained from the antioxidants assay method revealed that the extracts are free of radical inhibitors and act as primary antioxidants that react with free radicals.

The hydrogen donor ability of DPPH radical was also evaluated for the spray-dried extracts obtained at temperatures of 130, 140 and 150°C. Figure 7 presents the

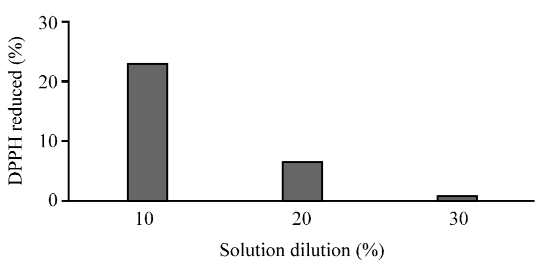

Fig. 3: The relation of antioxidant activity and solution dilution for seaweed juice

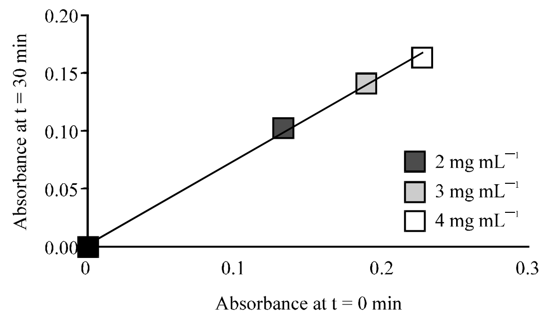

Fig. 4: The relationship between Absorbance at t = 0 min and t = 30 min at t = 130°C

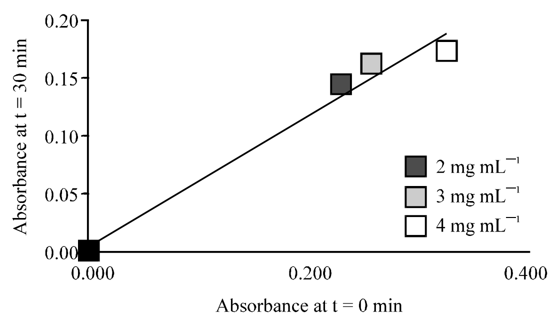

Fig. 5: The relationship between Absorbance at t = 0 min and t = 30 min at T = 140°C

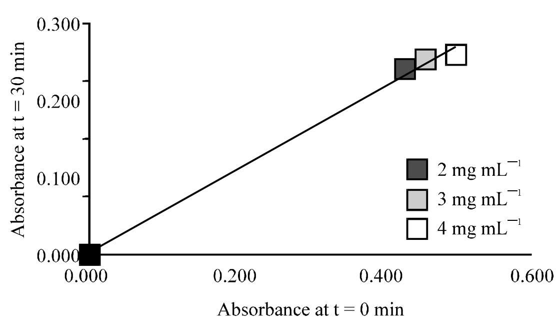

Fig. 6: The relationship between Absorbance at t = 0 min and t = 30 min at T = 150°C

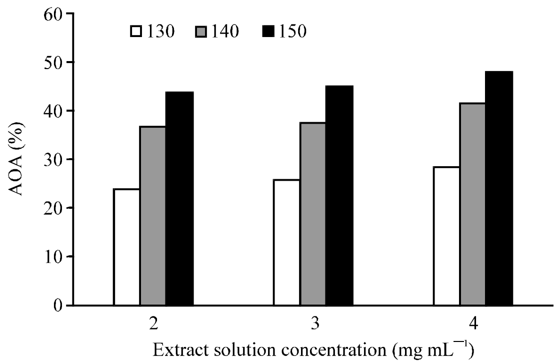

Fig. 7: Antioxidant activities of different solvent extracts and different temperatures of *K. alverazii*

experimental result the antioxidant activity showed dose-response, being the maximum activity close to 50%, in which a plateau effect was observed. This property is associated with the presence of reductions that are reported to be terminators of free radical chain reaction (Duh, 1998). Also, Ragan and Glombitza (1986) reported that the radical-scavenging activity of seaweeds to be mostly related to their phenolic content. This unclear relationship between the antioxidant activity and the phenolic may be explained in numerous ways. In fact, the total phenolic content does not incorporate all antioxidants present in the extract (Djeridane *et al*., 2006). This is the reason why samples with similar concentration of the total polyphenol, may vary in their scavenging activity. In addition, the occurrence of synergism between the chemical compounds in the whole extract makes the antioxidant activity dependent of the chemical structure of the antioxidant substance and interaction between them, besides its concentration. This is the reason why plant extracts with similar concentrations of total phenolic, may vary significantly in their antioxidant activities. In industry, *Kappaphycu alvarezii* is the main industrial source of carrageenan which contain D-galactose 4-sulphate and 3, 6-anhydro D-galactose residues, that also contribute to the antioxidant potential of this seaweed (Kumar *et al*., 2008). Components, such as low molecular weight polysaccharides, pigments, proteins or peptides, also influence the antioxidant activity. (Siriwardhana *et al*., 2003).

CONCLUSION

Spray drying is one of popular drying process with the ability to control particles size, moisture and retards volatile.

For the production of fresh seaweed powder, using spray drying technique, it is shown that the product with the expected properties can be produced easily. High air inlet temperature produced large particle sizes, higher antioxidant activity and lower moisture content. These results conclude that spray dryer is suitable process for producing powder of fresh seaweed.

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