Mustafa *et al.*
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Drying Profile and the Mineral Content in Quality Determination of *Kappaphycus Alverezii* (Rhodophyceae) from Semporna, Sabah, Malaysia

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ASTRACT

This study was carried out to determine the mineral bioavailability of *Kappaphycis alverezi* in different solution and to obtain the drying condition for seaweed to achieve the acceptable level of moisture content of 40%. Acetic acid, sodium chloride and water are the parameters used in the mineral availability analysis to see the percentage of solubility after been subjected using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Results showed that *Kappaphycis alverezi* treated with acid has a significantly increased in solubility of calcium which were 77.65, 63.64 and 60.02% respectively. In the drying experiment, the fresh seaweed and the commercial seaweed were dried in a cabinet dryer to study drying time to achieved the desired moisture content. The result based on drying showed that temperature have a significant difference ($p > 0.05$) in drying time and the best drying temperature was 40°C in retaining the seaweed quality after the seaweed were subjected to syneresis analysis. The syneresis analysis demonstrated that 40°C had a lowest syneresis percentage which was 3.10% compared to temperature 60, 80 and 100°C at 11.51, 16.61 and 18.89% respectively. Proximate analysis showed that moisture content in *Kappaphycis alverezi* was 56.69% and ash content (26.34%), crude fibre (9.77%), protein (3.13%) and fat (0.67%). In dietary fibre analysis, by using enzymatic gravimetric method to determine the total dietary content in seaweed showed that seaweed can be classified as a high source of dietary fibre as the total dietary fibre obtained was 56.29 %.

Keywords: *Kappaphycis alverezi,* seaweed, drying profile

ABSTRAK

Kajian ini telah dijalankan untuk menentukan kadar kelarutan mineral *Kappaphycus alverezii* dalam larutan yang berbeza untuk menentukan masa pengeringan untuk memastikan tahap kelembapan mencapai 40%. Asid asetik, sodium klorida dan air adalah parameter yang digunakan untuk menentukan kelarutan mineral dan peratusan kelarutan selepas dianalisis menggunakan *Inductively Coupled Plasma Optical Emission Spectrometry* (ICP-OES). Berdasarkan keputusan yang diperolehi, penggunaan asid diikuti sodium klorida dan juga air dalam penentuan kelarutan kalsium meningkat dengan signifikan iaitu 77.65, 63.64 and 60.02%. Untuk kajian pengeringan, rumpai laut yang belum dikeringkan iaitu dalam keadaan basah dan juga selepas dikeringkan iaitu yang dijual selepas melalui proses pengeringan telah dikeringkan di dalam pengering untuk menentukan kadar pengeringan bagi mencapai tahap kelembapan yang dimahukan iaitu 40%. Keputusan menunjukkan ada perbezaan yang signifikan antara keempat-empat suhu terhadap masa pengeringan dan keputusan menunjukkan bahawa suhu 40°C merupakan suhu yang terbaik untuk pengeringan. Analisis kehilangan air juga menunjukkan suhu 40°C mempunyai kehilangan air yang paling sedikit iaitu 3.10% berbanding dengan suhu 60, 80 dan 100 °C iaitu 11.51, 16.61 dan 18.89% masing-masing. Sebelum analisis ini dijalankan, keputusan analisi nutrisi makanan menunjukkan kandungan air (56.69%), abu (26.34%), serat (9.77%), protein (3.13%) and lemak (0.67%). Untuk analisis serat diet, *enzymatic gravimetric method* dijalankan untuk menentukan kandungan total serat diet dan keputusan menunjukkan rumpai laut boleh dijadikan sebagai sumber serat kerana kandungannya sebanyak 56.29 %.

Katakunci: *Kappaphycis alverezi,* rumpair laut, profil pengeringan

INTRODUCTION

Algae are a large and diverse group of plant like organisms ranging from unicellular to multicellular forms. According to Abirami and Kowsalya, (2011) seaweed are the largest and most complex marine algae. Seaweed has also been identified and grouped into different categories, which are Chlorophyceae (green seaweed), Phaeophyceae (brown seaweed) and Rhodophyceae (red seaweed) according to Abd-Rahim *et al* (2014). Seaweed is capable to grow in salt or fresh water. They are categorized into non vascular plant where they do not have vascular tissue such as roots, stems and leaves but they consist of talus and sometimes a stem and a foot and transport water and other nutrients through cell to cell osmosis (Mc Hugh, 2003).

Seaweed mineral content is higher than that of animal and land products. In most land vegetables, ash content ranges from 5-10g/100g dry weight. Sweet corn has a low content (2.6%) while spinach has an exceptionally high mineral content (20.4%) for a land plant. Based on the ash content edible seaweeds may be an important source of minerals, since some of these trace elements are lacking in land vegetables (Rajasulochana *et al.*, 2010). Davis et al (2003) have also been reported that seaweeds may contain a high mineral content, as their cell wall polysaccharides and proteins contain anionic carboxyl, sulphate and phosphate groups that are excellent binding sites for metal retention.

Other than that, food product include instant spice uses seaweed of *Kappaphycus alverezii* where incorporation of seaweed powder into the spice enhance the ash, crude fibre, protein, niacin, vitamin E content and addition of seaweed up to 20% has a high consumer acceptability (Senthil et al, 2011). Edible marine seaweeds may be an important source of certain minerals since some of the trace elements present in seaweeds are presence in a smaller amount compared to land plant foods (Rajasulochana *et al.*, 2010). *Kappaphycus alverezii* is one of the members of the red algae (Rhodophyta) produce galactans such as carrageenan and agar (Pereira et al., 2013). Thus, most study done on *Kappaphycus alverezii* focused on its used as gelling agent and stabilizers in the food and pharmaceutical industries (Mohamed *et al.*, 2012). Studies of minerals in seaweeds mostly focused on the mineral content analysis itself and there is less information on the bioavailability of the mineral of this seaweed subjected to various treatments.

The drying method of harvested seaweed in Semporna, Sabah is usually by using the sun drying method to dry the seaweed that resulted inefficient drying of the seaweed. The inefficient method may affect the final moisture content. Therefore, further study on the drying profile of the seaweed can determine whether the technique applied by seaweed farmers can reach the desired moisture content. It is hoped that results from this study can be further used as a basic information for seaweed processing industry for more advanced research on seaweed nutritional information and also for utilization as an ingredient in future functional food development based on their potential against various disease especially colon cancer. This can be used as a mark in the industry on the best solution that have the highest solubility after treated in retaining most of its minerals that can absorb into the muscular cells. The data obtained from the drying of seaweed can also used as a reference in the seaweed harvesting industry to improve their ways in drying the seaweed in order to preserve the quality of the seaweed before used. Hence, this study aimed to determine the mineral bioavailability of *Kappaphycis alverezi* in different solution and obtain the drying condition for seaweed to achieve the acceptable level of moisture content.

MATERIALS AND METHODS

Materials

Sample colletion and preparation
Kappaphycus alverezii sample were collected from Semporna, Sabah, Malaysia. Samples were washed thoroughly with seawater to remove the macroscopic epiphytes, sand particles and other extraneous matter then sealed in plastic bag. Samples were also washed thoroughly with tap water to remove excess salt on the surface. Seaweeds were dried by using blotting paper to remove excess water.

Preparation of Reagent
In each of the analysis, a specific reagent or chemical was used in determining the results. In the Protein analysis for Kjedahl method, sulphuric acid was used with Kjeltabs tab that aid in digestion process. Samples were distillated by using water and sodium hydroxide (NaOH) and proceeded to titration process where boric acid was titrated in the sample. For fat extraction, the solvent used to extract fat was petroleum ether. In dietary fiber analysis, α–amylas, glucoamylase and protease were used to digest the sample in determining the total dietary fiber content. In mineral analysis, hydrochloric acid (HCl) and nitric acid (HNO_3) were used while for mineral solubility analysis, sodium chloride (NaCl) and acetic acid (AcOH) were used.

General experimental procedure
Dried samples were tested for moisture contents by using a convection oven (VENTICELL) followed by ashing in a muffle furnace. Samples were digested in digestion machine (Gerhardt Kjedahlterm) and distilled in (Gerhardt Vapodest). For ashing, muffle furnace (WELCH 1200) was used to determine the presence of

minerals in the sample. The ashed sample was then introduced to ICP-OES to determine specific elements of minerals and heavy metal in the seaweed sample. For mineral bioavailability determination, fresh sample was blended with acetic acid, sodium chloride and water before subjected to ICP-OES for mineral analysis. The total dietary fibre was determined by enzymatic gravimetric method using three enzymes namely amylase, protease and glucoamylase in a VELP GDE enzymatic digester and VELP CSF 6 filtration equipment. Drying analysis was done in cabinet dryer.

Methods

Preparation of seaweed powder
The raw material was dried at 60°C using a lab dryer (Protech FDD720) for overnight before dried samples were grounded using dry blender (Philips brand) and stored at room temperature in airtight container for further analysis.

Proximate composition analysis

Moisture Analysis

Moisture analysis of the sample was determined by using the oven drying method which have been approved by the AOAC international as the standardize method in determining the amount of moisture in food sample.
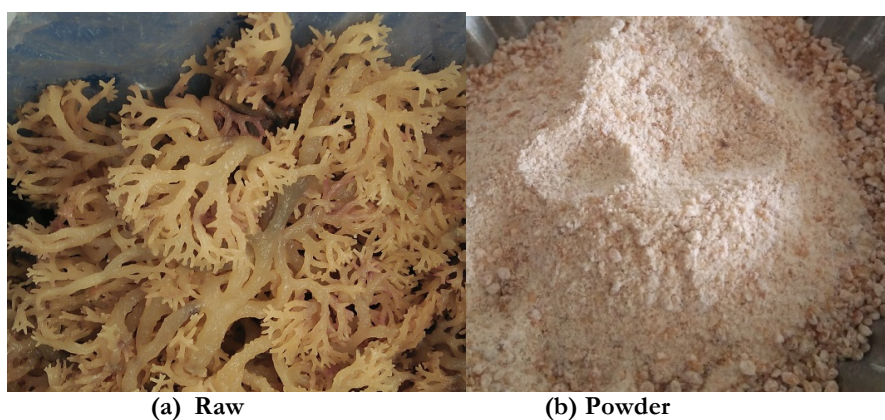

(a) Raw   **(b) Powder**

Figure 1 Photograph of *Kappaphycus alverezii* (a) raw (b) powder

Empty crucibles were heated in an oven at temperature 105°C for 4 hours before cool down in a desiccator and weighed after it had attained room temperature (W1). 5g of the seaweed powder was weighed into crucible (W2) and placed in oven at 105°C for overnight. Dried sample was then removed and cooled in desiccators and weighed after attaining room temperature (W3).

Calculation on the percentage of moisture

$$\% \text{ Moisture} = \frac{(W2-W3)}{W2-w1} \times 100$$

W 1 = Weight of Crucible
W2 = Weight of Crucible + Weight of wet sample (g)
W3 = Weight of crucible + Weight of Dried sample

Ash content

Ash content of seaweed was determined according to the method by AOAC (1990) with slight modifications. Dried sample obtained from the moisture analysis was heated into ashes in a muffle furnace at 550 °C overnight. The ash content was expressed as weight of ash obtained per weight of sample used.

$$\text{Ash (\%)} = \frac{(W3 - W1)}{W2} \text{ X } 100$$

Where:
W1: Weight of crucible (g)
W2: Weight of sample (g)
W3: Weight of crucible + ash (g)

Crude Protein

Digestion tubes were labelled and put in a convection oven (Venticell) for dried overnight . 1 g of sample was weighed and 15 ml of concentrated sulphuric acid and two kjeltabs with a blank (without sample) were added in a digestion tube. Receiver solution which consists of 25 ml of 2% boric acid mixed with 5 drops of universal indicator were prepared for distillation process. After the distillation process, the titration process was conducted using 0.1 M HCl. The volume of HCl was recorded. The total nitrogen (N) was calculated by multiplying the per cent of nitrogen found with a factor of 6.25.

$$\text{Crude protein} = \frac{A \text{ X } (T - B) \text{ X } 14.007 \text{ X } 6.25}{\text{Weight of sample (g) X } 1000} \text{X } 100$$

Where:
T: Volume of acid for sample (ml)
B: Volume of acid of blank (ml)
A: Normality of H
F: Protein factor, 6.25

Crude Fibre Content

Crucibles were dried in oven for overnight before use. 1 g of sample was weighed and added into each fibre bag and inserted into carousal before assembled into fibertherm fiber analyser for 2 hours and 30 minutes. After the process, all fiber bags were placed in muffle furnace overnight. The percentage of crude fibre was calculated as below

% Crude Fibre = % fiber=(W3-W1)-(W4-W5)*100/W2

Where:

W1	=	Weight of fiber bag
W2	=	Weight of Sample
W3	=	Weight of crucible and fiber bag after digestion
W4	=	Weight of crucible and ash
W5	=	Weight of blank value of the empty fiber bag
W6	=	Weight of crucible
W7	=	Weight of crucible and ash of the empty fiber bag

Crude lipid was extracted from the seaweed powder according to AOAC (1990) with some modification using the Soxtherm 416 Gerhadt (Germany) with petroleum ether as solvent. Extraction cups were dried overnight in a convection oven at 105°C before cooled in a dessicator and weighed. Approximately 3 g of sample was weighed and added into a thimble. 150 ml petroleum ether was then added. The extraction cups were attached to Soxhlet extractor machine. After extraction, extraction cups were dried overnight and cooled before weighed. The percentage of total lipid was as follow:

% Fat = **(**W3-W2) / W1*100
Where

W1	=	Weight of sample
W2	=	Weight of extraction cup
W3	=	Weight of Extraction cup+ fat

Carbohydrate Content
Carbohydarte content were calculated based on the difference calculation

[%] Carbohydrate= 100- (% Moisture+ % Ash+ % Crude fibre + %Crude protein+ % Fat)

Mineral bioavailability
Total mineral determinations
Preparation of sample for mineral analysis was done as stated by Santoso et al, 2006) Samples were analysed by using Inductively Coupled Plasma Optical Emission Spectroscopy ICP-OES America (Thermo Scientific Icap 7600 ICP-OES Analyser) for detecting the presence of minerals such as Sodium (Na), Pottasium (K), Calcium (Ca) and Magnesium (Mg).

The standard procedure described in AOAC (2000) was followed for preparation of samples for the analysis of heavy metals. Accurately 2g of wet sample was transferred into a silica crucible and added with 10 ml of 70% of nitric acid and left overnight. The was added to crucibles to dissolve contents before 2 ml of 30% hydrogen peroxide was added until a clear solution was obtained. The final residue was filtered using Whattman 102mm in 100 ml volumetric flask with deionized water. Mineral was then analysed using an Inductively Coupled Plasma Optical Emission Spectroscopy ICP-OES (America).

Dietary Fibre Analysis
The total dietary fibre of seaweed was determined according to the method described by AOAC using an Enzymatic Gravimetric Method. The total dietary fibre (TDF) content was determined using the enzymatic–gravimetric method (AOAC, 1990). The defatted samples was gelatinised with α-amylase at 95°C using a GDE heating bath for 15 min, followed by enzymatic digestion by protease for 30 min at 60°C. The protein and starch contents was removed with glucoamylase at 60°C for 30 min. The beaker containing the samples was let to precipitate for 1hr after added with preheated ethanol (60°C) before filtrated using VELP 6 filtration unit. The fitted crucible containing celite was fixed and the contents are filtered to obtain the residue. Similar steps were repeated on blank to control possible contribution from reagents to final result. Residues were then oven-dried (105°C) overnight. The values obtained using the enzymatic method were corrected by determining the nitrogen content with the Kjeldahl method and ashing at 550°C .

Calculation

average blank residue (ABR)	=	Final weight-(weight of residue –celite)
blank protein residue (BPR)	=	G of protein in blank
blank ash residue (BAR)	=	G of ash in blank
corrected blank (CB)	=	ABR-BPR-BAR
average sample residue (ASR)	=	Average sample final weight-initial weight
sample protein residue (SPR)	=	g of protein in sample (g)
sample ash residue (SAR)	=	g of ash in sample
corrected sample residue (CSR)	=	ASR-SPR-SAR-CB
% TDF	=	CSR / sample weight (g)*100

Soluble mineral determination
The fresh samples (10g) were blended in a tube with water, 1% sodium chloride and 0.5% acetic acid (40 mL) separately at 5000-10000 rpm for 2 min by using a blender (Philips) to produce a water- soluble fraction (0 min-

treated sample). The tube was then boiled in a water bath at 100ºC for 20min. Samples were then centrifuged at 10 000 xg, 2ºC for 10 min, and filtered through a filter paper. Non-boiled samples were directly centrifuged and filtered. Mineral concentrations of filtrates were measured using an ICP-OES (Santoso et al, 2006). The solubility of each mineral was calculated using:

$$\text{Solubility \%} = \frac{\text{Soluble mineral mg/g}}{\text{Total mineral mg/g)}} \text{ x } 100$$

Relation between different drying temperature to moisture content
90 g of samples from dry seaweed and wet seaweed were dried using a cabinet dryer using different temperature parameter which were 40°C, 60°C. 80°C and 100°C to determine the best temperature needed for the seaweed to achieve the moisture content of 40 %. The seaweeds were cut into small pieces and the initial weight was recorded (Wo) together with the tray weight. The weight of the container was recorded at each 30 min interval until equilibrium was reached. The final moisture content was calculated.

Synreresis
The syneresis analysis method was based on Chan *et al.* (2013) with slight modification. The solution of 1% (w/v) was prepared by weighing 1g from the dried sample of four different temperature of sample powder into conical flask. 50 ml of hot (80°C) deionised water was then added into a flask and the solution were magnetically stirred at 700 rpm for 30 mins. The gel was set inside a petri dish and stored overnight in a container at a room temperature (25°C) for 2 days. The initial weight of the gel samples (Wo) and the weight of the petri dish were recorded, where (Wo) is the initial weight of the gel and (Wt) is the final weight of the gel. The syneresis of the gel was calculated as the cumulative weight of the water collected divided by the weight of original sample and multiplied by 100:

Syneresis (%) = Wo-Wt / Wo * 100

Statistical analysis
 All experiments were performed in triplicates. The significances were analysed and tested by using one sample T-test and also one way ANOVA test from SPSS software. Mean value of the samples were subjected to Duncan test to compare the properties and compositions of samples.

RESULTS AND DISCUSSION

Proximate composition of *Kappapaphycus alverezii*
Protein, fibre ash content and moisture content are the most important biochemical composition in algae. The proximate composition and dietary fiber of *Kappaphycus alverezii* were analysed and shown in the Table 1 below.

Table 1 Proximate composition and dietary fibre composition of seaweed

Composition	*Kappaphycus alverezii*
Moisture (% fresh sample)	57.35 $\pm$ 0.42
Ash (% dry weight)	26.34 $\pm$ 2.34
Protein (% dry weight)	3.13 $\pm$ 0.11
Fat (% dry weight)	0.67 $\pm$ 0.18
Fibre (% dry weight)	9.77 $\pm$ 0.90
Carbohydrate (% dry weight)	54.68 $\pm$ 2.01
Dietary fibre analysis	56.29 $\pm$ 1.89

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

The moisture content obtained in *Kappapaphycus alverezii* is 57.35% (Table 1). The moisture content obtained was lower compared to previous study reported by Ahmad *et al.* (2012), which is (78.78 %). The moisture content that was reported was higher than the result obtained may be due to the composition of seaweed itself before subjected to moisture analysis. The samples may be taken from fresh seaweed that has not subjected to drying instead to the samples that was used in this experiment which is seaweed that have been subjected to drying cause a lower moisture content value. The reported data also been supported by the value obtained by determining the moisture content of wet seaweed which gives moisture content near the value as reported by Ahmad *et al* (2012) which is 85 %.

The ash content is the second highest component of dried material for the seaweed sample .The ash content is the measure of the total amount of mineral present within a food and it is crucial for several reasons include nutritional labelling, quality, microbiological stability and nutrition. The results show that *Kappapaphycus alverezii* has a higher ash content (26.34% d.w.) The ash content was nearly closed to the value previously reported by Ahmad *et al* (2012) where the ash content is (23.25%). Based on Chan et al. (2013) for k-carrageenan, the moisture and ash contents are the most crucial components in determining the quality of the product.

The protein content of *Kappaphycus alverezii* is (3.13%) is lesser than the one obtained from Ahmad et al (2012). As reported by Graham and Wilcox et al (2000) the amounts of seaweed component vary generally according to the season, age of population, species, geographic location and temperature. This may be the reason on the lower amount of the protein content determined compared to the one obtained by Ahmad et al (2012).

The lipid contents of *Kappaphycus alverezii* were present in a small amount which is 0.67%. This result reflects the findings from Pereira et al. (2011) that content of lipid in brown, green and red seaweeds is generally ranging from (0.5 to 2.5%). So in general protein, fat and fiber are present in a small amount comparable to the ash and moisture content.

Carbohydrate in this study falls between the ranges of 54.67%. Although the seaweed has a high amount of carbohydrate, its greater proportion is available as polysaccharide dietary fibre, which is not taken up in the human body. For crude fibre analysis, the result obtained are 9.77 % (Table 1).The result were within the range reported by Ahmad et al. (2012) in crude fibre (4.03-34.71 % dry weight) for red and also green seaweed.

Mineral bioavailability

Mineral bioavailability is the degree to which the amount of the ingested material is absorbed and available to the body. One of the factors that affect the bioavailability is the pH. Based on the observed result, the treatment with an acidic which is acetic acid; and alkali, which is sodium chloride had given different bioavailability of calcium after subjected to mineral analysis using ICP-OES. The solubility of calcium in different solution are shown in the Figure 2. Based on the result, the solubility of calcium in *Kappapycus alverezii* is also influenced by pH where there is a significant difference among these three treatments. Acetic acid had significantly increased the solubility of calcium in *Kappaphycus alverezii* and treatment with sodium chloride while water had a lower solubility compared to acetic acid. The result complied with Santoso et al. (2006) that reported that the solubility of calcium in Indonesian seaweed was also increased in seaweed treated with low pH. Thus to conclude, the acid act as the best solvent to be used in seaweed processing industry in the pre-processing step before being further processed in order to make the nutrients such as mineral that naturally present in the seaweed are retained and gives benefit to the one who consumed.

The percentage of soluble calcium obtained in this experiment (77.6 %) was in the range compared to the one reported by Santoso et al. (2006) which is 80% and the slightly difference in the percentage may be due to the content of high dietary fibre (Table 1) that is associated with minerals and at the same time influences their soluble fibre components such as cellulose, hemicellulose and other polysaccharide may form an insoluble complexes with elemental minerals and thus may reduce the mineral bioavailability of these mineral.

Heavy Metal Analysis

Results show that the range of the heavy metal in seaweed in Table 2. The heavy metal is present in a very trace amount. The maximum permitted proportions of heavy metals are 2 mg/kg and 1 mg/kg for lead and also cadmium respectively (Food Act. 1983). The amount obtained in this study was lesser than the stated amount suggesting that there are no potential on toxicity to the one who consume the seaweed.
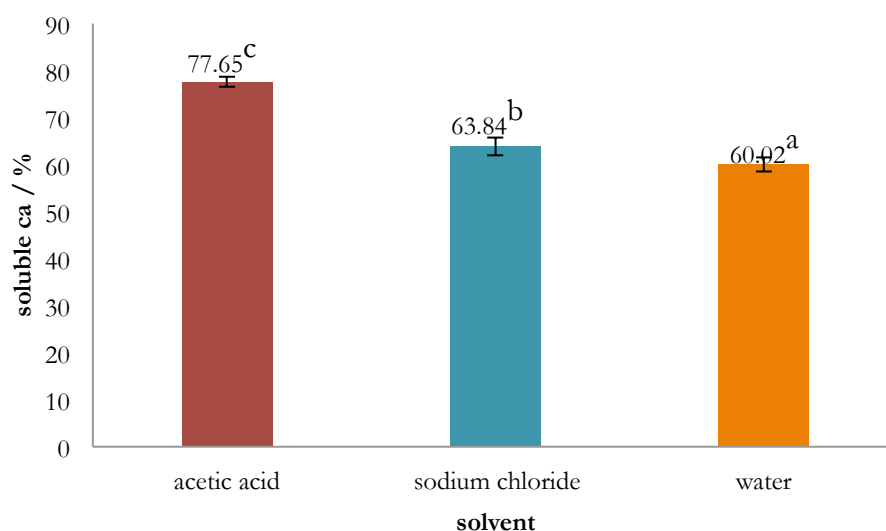
Figure 2 Percentage solubility of calcium in different solutions
*mean value with different superscript is significantly difference at $p < 0.05$

Table 2 Heavy metal content in *Kappaphycus alverezii*

Heavy metal			Chan et al. (2013)
Zinc	0.14	± 0.03	ND
Lead	0.26	± 0.19	ND
Arsenic	0.95	± 0.80	ND
Cadmium	0.03	± 0.04	ND
Mercury	0.14	± 0.14	ND

Drying

Moisture content plays an important role in determining the quality of seaweed. According to McHugh (2003), moisture content is significant because high moisture leads to deterioration of the seaweed during storage and transport, and a consequent loss in carrageenan content and quality. Moisture content must be 40% or less, preferably 35% in order to retain its best quality until the end. The result of drying using different temperature parameter has led to different drying time taken for the sample to achieved moisture content of 40 %. Based on the moisture analysis of the fresh sample, the moisture content of the dry seaweed claimed by the Department of Fisheries Sabah (Rizal, personal communication 2017) was 40 %. However, proximate analysis of this type of seaweed shows that moisture content was 61.77 %. (Figure 3). This may be due to the way of drying process carried out by the seaweed farmers which was either by sun drying or by placing harvested seaweed on wood floor that has an opened top (Figure 4). It is also observed that both ways exposed seaweeds directly to the sun whereby the top portion tends to dry efficiently or sometimes are also burned away while the lower portions were still wet.

The inefficient way of drying contributed to various moisture content in the dried seaweed obtained from the field. A specific temperature with a drying time is important information needed by the industry players to ensure harvested seaweeds are dried accordingly to obtain desired moisture content of seaweed of 40 %. In this study, drying time at four different temperatures (40, 60, 80 and 100°C) for both dry and wet seaweeds was studied. This study observed that high temperature lowers the drying time for both wet seaweed and fresh seaweed collected fresh from sea. The trend shows that at 40°C, seaweed achieved the desired moisture content within 2 hours while at 100°C, moisture content of 40% is achieved at less than 1 hour. The result reflected that there are significant differences of total drying time among all temperatures to obtain moisture content of 40 %.
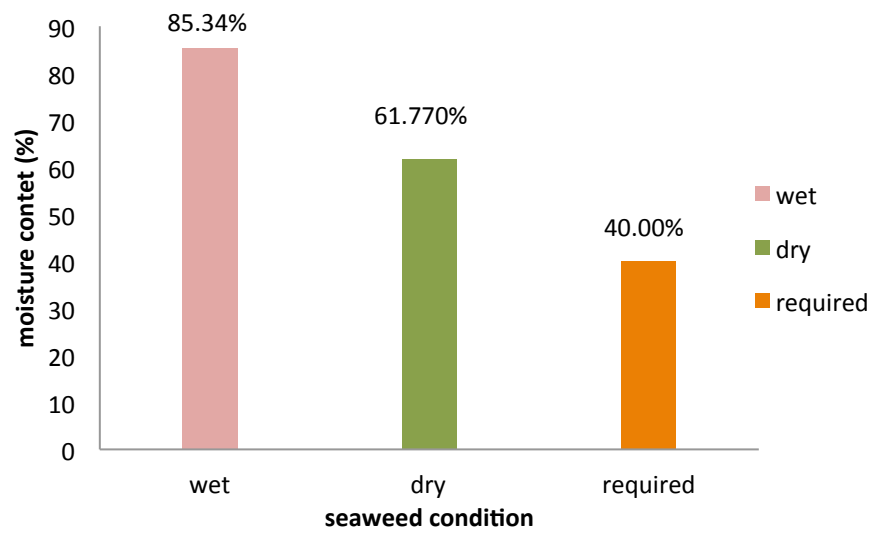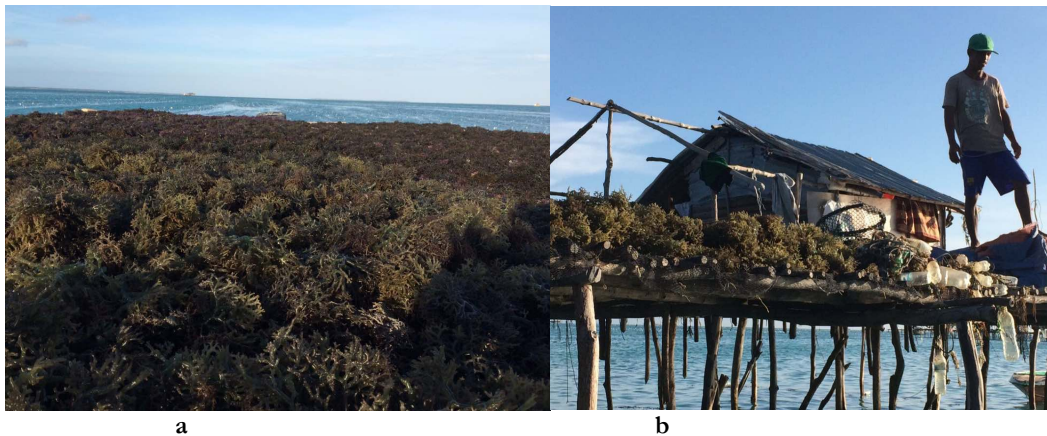
Figure 3 Moisture content of seaweed

a   b
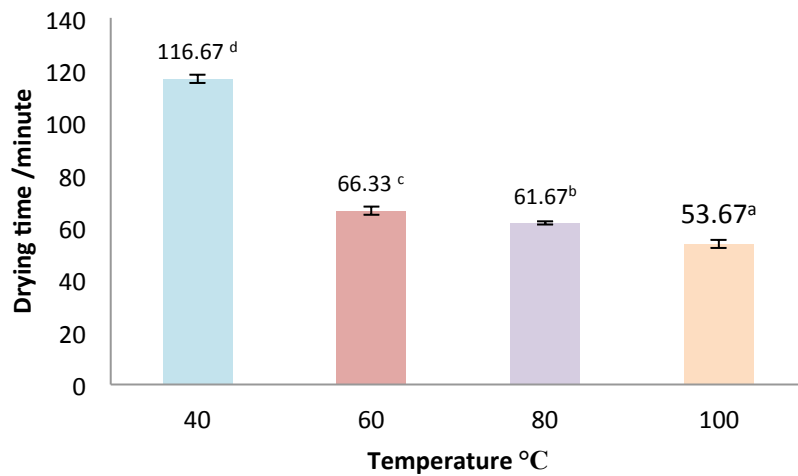**Figure 4** Seaweed drying. a) Sun drying in the middle of the sea b) wood floor drying
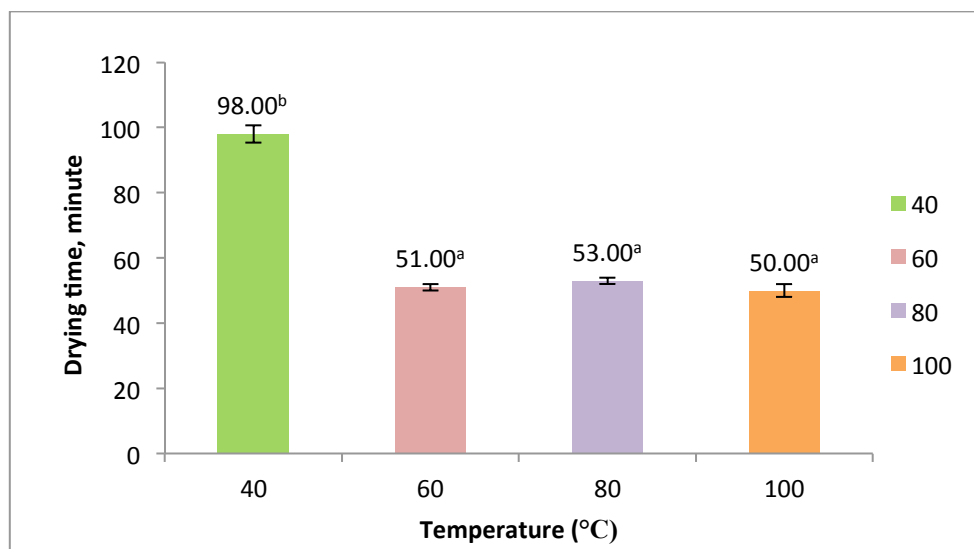

Figure 5 Drying time at which the fresh seaweed achieved moisture of 40%
*mean values with different superscript are significantly difference at $p < 0.05$

The moisture content of dry seaweed obtained from industry was 61.77 %, approximately 20 % more than the required level. Similar method was undertaken to determine the drying time of dry seaweed to acquire 40 % moisture content. Results show no significance differences on effect of temperature on drying time for temperature 60, 80 and 100°C. However, these three temperatures showed significant lower drying time ranging from 50-53 minutes as compared to 98 minute by 40°C (Figure 6). As seaweed is an important commodity, it is also important to ensure that the processing time or the drying time to obtain the optimal moisture does not reduce the final quality of seaweed.


Figure 6 Drying time at which the dried seaweed achieved moisture of 40%
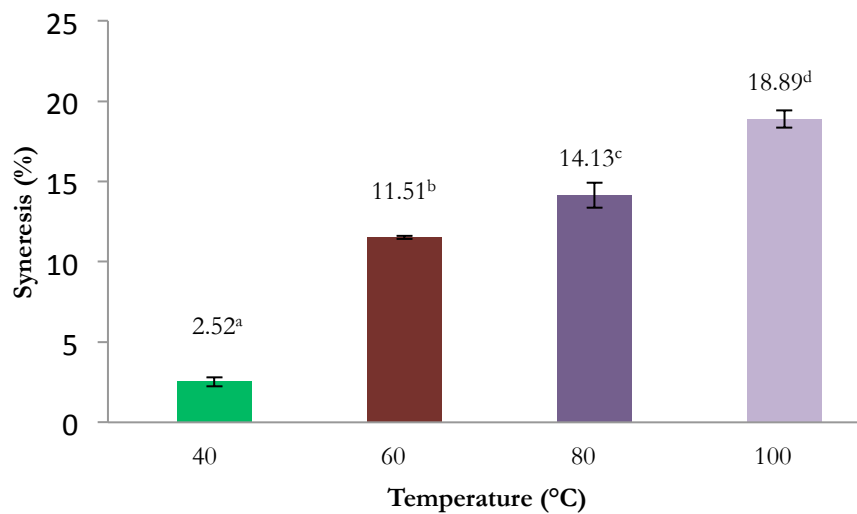*mean value with different superscript are significantly difference at p< 0.05

According to Gupta et al. (2011), drying the seaweeds at temperature above 50°C resulted colour darkening within 2 h with a complete loss in the antioxidant properties. This shows that drying at a higher temperature may give a negative effect that directly effected the quality. Thus apparently drying at temperature 40°C will be the best temperature that can be applied by seaweed industry players to obtain quality seaweed that meet the required moisture content.

Syneresis
Kappaphycus alverezii gives the strongest gel of all carrageenan. However they are also the one that are subjected to syneresis (McHugh, 2003). According to McHugh (2003), syneresis study is usually done in food manufacturing industry. Syneresis in food gels may cause gel shrinkage, textural changes and quality reduction. Results show that there are significant differences on the percentage of syneresis for each temperature. Syneresis of gel gradually increased with increase of temperature (Figure 7). According to Djaeni and Sari (2015), seaweed contains heat sensitive material such as protein and starch that are sensitive to changes in both drying time and temperature. Djaeni and Sari (2015) suggested that although high temperature can speed up the drying time, protein has a tendency to deteriorate faster. Results obtained from this study adhered to Djaeni and Sari (2015); thus suggesting that samples dried 40°C have lower syneresis percentage compared to the ones dried at 60, 80 and 100°C respectively.
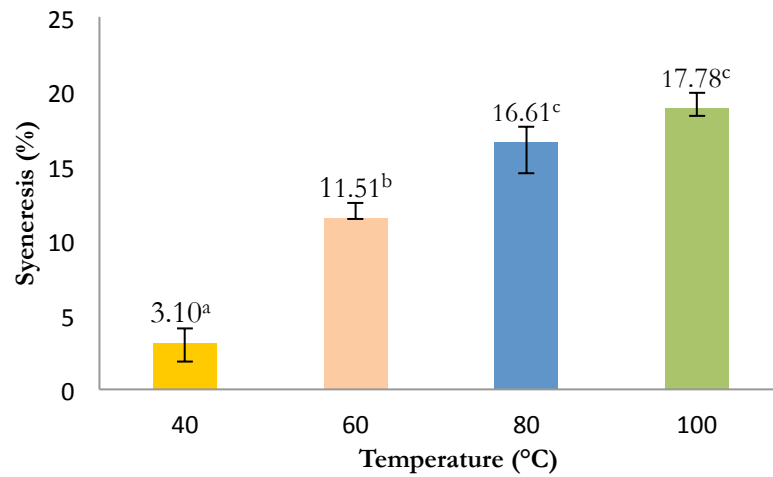
(a)

(b)

Figure 7 Syneresis occurs at different temperature of drying for (a) fresh seaweed (b) dried seaweed. *mean values with different superscript are significantly difference at p< 0.05

CONCLUSION

Kappaphycus alverezii is a valuable seaweed that can be utilized by human due to its high nutritional value. Proximate composition of this species reflected that seaweed has high nutrition content based on the dietary fibre composition. Drying temperature at 40°C is recommended as an industrial reference in seaweed harvesting industry to obtain 40 % moisture within 1.94 hour as it gave lowest gel syneresis at 3.10 %. Mineral composition

of *Kappaphycus alverezii* after treatment shows highest solubility in acetic acid which is 77.65% compared to sodium chloride and water which is 63.84% and 60.02% respectively. The lower the pH the higher the solubility. This indicates that seaweed processing may use industrial acid like acetic acid as it is the best solvent to retain minerals in seaweed.

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