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Aqueous Extraction, Purification and Characterization of Galactomannans from Aren Sugar Palm (*Arenga pinnata*) Fruits

Anis Shobirin Meor Hussin[#], Che Wan Nur Safraa Che Wan Sapawi[#], Aliaa Anzian[#], Hajar Balkhis Ramli[#]

[#]*Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, Selangor, Malaysia*
E-mail: shobirin@upm.edu.my, safraasapawi@gmail.com, alyaanzian91@gmail.com, balkhis_ramli89@yahoo.com

***Abstract*— The effect of different aqueous extraction conditions on the crude gum extraction yield of Aren sugar palm (*Arenga pinnata*) fruit was evaluated. A water-soluble polysaccharide was extracted from the endosperm of *A. pinnata* fruit with water at different extraction conditions. The results indicated that water to seed ratio, alkaline pH and temperature were significantly ($p<0.05$) effect the extraction yield of the crude gum. The ideal extraction conditions (W/S ratio: 20:1, pH: 10 and temperature: 80˚C) led to the highest yield (5.50%) of the *A. pinnata* fruit gum. The purified gum was characterized as white, thread-like precipitate and become a powder-like substance after being freeze dried. It had relatively low protein content (1.15%) and partially solubilized at ambient (50.93%) and at elevated temperature (71.00%). The gum had a high water holding capacity but lower oil-holding capacity which was 150.00 g water/100 g and 103.33 g oil/100 g of gum respectively. The viscosity of the purified gums increased with the increase of solution concentration. This revealed that *A. pinnata* gum is suitable for applications as a stabilizer for oil-in-water emulsion or as food additives due to its capability to hold water molecules and form a viscous solution at low concentration.**

***Keywords*— *Arenga pinnata*; galactomannans; aqueous extraction; purification; characterization**

I. INTRODUCTION

Galactomannans are water-soluble polysaccharides that can be isolated mainly for endosperm cells of legume seeds. The molecule consists of repeating units of mannose (M) and galactose (G) at M/G ratio of 2:1 to 4.5:1, depending on the source [1]. There was an increase in the use of hydrocolloids for the food [2] pharmaceutical industry [3]. Religious and vegetarian lifestyle choices may prohibit certain consumer groups from eating foods like yogurt, whipped desserts, low-fat margarine spreads, marshmallows, ice cream, and other products containing gelatine, an animal-based ingredient. Plant-based hydrocolloids could be the alternative.

The ability of galactomannan to bind with water led them to be one of a good binding agent when introducing into various kind of food such as soup, sauces, dressings and ice cream in order to improve the texture and enhance other physical properties.

Aren sugar palm (*Arenga pinnata*) fruits are normally consumed as sweetmeat or served as dessert such in cocktails or fruit mixes due to its gelatinous texture. It is rich in crude fiber (16.2%), protein (10.0%) and minerals (7.9%), and a small amount of fat (1.5%) [4]. The *A. pinnata* fruit is reported to contain water-soluble galactomannans, in which the mannose/galactose (M/G) ratio varies from 2:1 to 5:1 depending on the maturity of the fruit [5].

The water-soluble galactomannans can be extracted via aqueous or water extraction followed by precipitation with alcohol [6]. The yield of polysaccharide extracted varies with extraction conditions such as temperature, pH of extraction medium and ratio of water to samples. Increasing water to seed ratio has been demonstrated to increase the gum yield and to some extent the purity of gum obtained. According to The presence of excess water during the aqueous extraction led to the greater binding ability of the water-soluble components present in the seed endosperm, thus increase the extraction yield [7]. High temperature applied during the extraction process enhanced the mass transfer rate of the water-soluble polysaccharides from cell wall into the solvent [7], [8].

There is still a lack of research on the polysaccharides extracted from *A. pinnata*. Torio et al. [5] indicated that the extraction of galactomannan from the fruit was low in which high amount of sample is needed to produce an acceptable yield. Knowing the best extraction conditions will allow the wide utilization of the fruit as a source of the polysaccharide. However, knowing the best extraction conditions will allow the wide utilization of the fruit as a source of the polysaccharide. Therefore, the objectives of this study were

to investigate the effects of aqueous extraction conditions; water to seed ratio, pH, and temperature on the extraction yield of galactomannans from *A. pinnata* that mainly used as a gelling agent and thickening in food. The physicochemical properties of that purified gum were also analysed to determine their characteristics that could bring about an upgrade towards our food industry and increase the competitiveness of *A. pinnata* in the market.

II. Material and Methods

A. Materials

Sugar palm fruits (*A. pinnata*) in syrup and sunflower oil for oil holding capacity determination were purchased from a local store in Seri Kembangan, Selangor. The fruits were repeatedly washed with water to remove the sucrose-rich syrup.

All other chemicals were of analytical grade commercially available.

B. Extraction of Gum

The extraction yield of gum from arenga fruit was studied as a function of water to seed ratio, pH and extraction temperature. The gum was extracted according to the method described by Torio et al. [5], using 170 g sample suspended in 500 ml water. The sample was used as a control for this study.

1) Effect of Water to Seed Ratio: Fifty grams of aren sugar palm endosperms were suspended in distilled water at the water to seed (W/S) ratio of 6:1, 13:1 and 20:1 and homogenized using a blender (Panasonic blender, MX-337, Malaysia). The viscous mass was stirred overnight at room temperature, followed by centrifugation at 3800 g. The clear supernatant was separated from the residue, and an equal amount of ethanol (95%) was added to the supernatant with continuous stirring. The resulting white precipitate was allowed to settle and further separated by decantation. The precipitate was washed with ethanol and freeze dried (SCANVAC, Coolsafe 110 -4, Denmark).

2) Effect of pH: The W/S ratio that produced the highest extraction yield was used to determine the effect of pH on the extraction yield. The homogenized sample was adjusted to pH 8, 10 and 12 using 0.1 M NaOH, followed by extraction as described above.

3) Effect of Temperature: The W/S ratio and pH that produced the highest extraction yield was used to determine the effect of temperature on the extraction yield. The viscous mass obtained following the homogenization was stirred at 40, 60 and 80°C for 1 hour and centrifuged at 3800 g. The precipitate was freeze-dried to obtain powdered arenga fruit gum.

C. Determination of Extraction Yield

The extraction yield of arenga gum was calculated as below.

$$\text{Extraction yield, Y (g)} = M1/M2 \times 100 \quad (1)$$

Where,

M1: is the mass (g) of extracted dried *A. pinnata* fruit gum

M2: is the mass (g) of *A. pinnata* fruit

D. Purification of Extracted A. pinnata Fruit Gum

The purification process was performed for control gum (untreated) and gum obtained from ideal extraction conditions (treated), i.e. highest extraction yield. The dried samples were completely dissolved in distilled water followed by addition of 5 mL of Fehling's solution (34.66 g of copper (II) sulphate in 500 mL distilled water), resulting in the formation of a light blue precipitate. The supernatant was decanted, and the precipitate was washed and suspended in 100 mL of distilled water and 1 ml of 2 M HCl. The mixture was stirred, followed by the addition of an equal amount of 95% ethanol. The gum extract was washed again with ethanol and freeze dried. The appearance of purified gum was observed.

E. Physicochemical Characteristics of Purified A. pinnata Fruit Gum

The purified control and treated Arenga gums were analysed for their physicochemical properties. The treated gum was obtained from the ideal extraction conditions (W/S of 20:1, pH 10.0 at 80°C).

1) Protein Analysis: The protein was determined by using Kjeldahl method [9]. 0.15 g of gum sample was weighed and placed into the boiling tube. 0.8 g of mixed catalyst and 2.5 ml of concentrated sulphuric acid was added. The boiling tube was swirled gently to mix the content and then, heated slowly on a heating coil under a fume hood. The content was boiled until the solution became clear and gave blue-green color. The boiling tube then was cooled until approximately 40°C. 10 ml of distilled water was added, and the digested product was transferred into the distillation tube. 10 ml 45% NaOH was slowly added to the solution to separate the two layers of the solution. In conical flasks, 10 ml 2% boric acid and few drops of the indicator were added. The conical flask was placed at the distillate platform, and the tip of distillation tube was immersed into the acid solution. The content of distillation flask was mixed by swirling it gently. Steam was purged into the flask. The ammonia solution was being distilled into the conical flask for about 120 ml. After mixing the distillation product by swirl the flask gently, unreacted boric acid was titrated with 0.05 N H_2SO_4 until neutral.

$$\%\ \text{of nitrogen} = ((Is-Ib) \times N \times 1.4)/W \quad (2)$$

Where,

% of protein = % nitrogen x 6.25

W = Weight of sample

Is = Volume of sulphuric acid to titrate boric acid

Ib = Volume of sulphuric acid to titrate blank N = Normality of sulphuric acid

2) Determination of Solubility: Solubility of both untreated and treated samples at 25 and 80°C was measured according to Dakia et al. [10]. Dried extracted gum (1%, w/v) was suspended in distilled water followed by stirring at 25 and 80°C for 30 min. The solution was centrifuged (1800 g for 30 min at 25°C) and supernatant dried at 105°C for 24 hours. The weight of the dried supernatant was expressed as a soluble fraction.

$$\text{Solubility (\%)} = \frac{\text{Supernatant concentration (mg/ml)}}{\text{Initial preparation concentration (mg/ml)}} \quad (3)$$

3) Determination of Water Holding Capacity: Water-holding capacity (WHC) of the samples was determined according to the method described by Galla and Dubasi [11]. One gram of sample was suspended in 10 mL distilled water, vortexed for 2 min and centrifuged at 3,000 g at 4°C for 30 min. Water absorbed by the sample was expressed as weight of water absorbed per 100 g of seed gum.

4) Oil Holding Capacity: Oil-holding capacity (OHC) of the samples was determined by dispersing the 1 g of gum powder in 10 mL sunflower oil. The mixture was vortexed for 2 min and centrifuged at 3,000 g at 4°C for 30 min. Free oil was decanted, and the oil absorbed by the samples was expressed as weight of oil absorbed per 100 g of seed gum [10].

5) Viscosity: Dried gum powder was dispersed in water at concentration of 0.5, 0.75, 1.0, and 2% (w/v). The dispersion was heated with continuous stirring. The viscosity of the dispersion was measured using rheometer (Physical rheolab, Anton Paar, Austria). The sample was added into the test viscometer cup, and after the viscometer was started, the viscosity value was recorded once the numerical number shown on viscometer became stable. All tests were carried out at room temperature (25°C). The assays were performed in triplicate.

F. Statistical Analysis

All the analysis was performed in triplicate. Means of the data were analyzed using Minitab (Version 16.0) using one-way ANOVA and Tukey's test was performed to compare significant differences between samples at $p<0.05$. All the data were presented as a mean ± standard deviation.

III. Result and Discussion

A. Extraction Yield

The results indicated that all extraction variables (W/S ratio, pH, and temperature) were significantly ($p<0.05$) affected the extraction yield (refer to Table 1). In this current study, it showed different values of extraction yield which were range from 2.18% to 5.50%.

The extraction yield was significantly increased ($p<0.05$) by simultaneously increasing the W: S ratio from 6:1 to 20:1 where W/S ratio of 20:1 showed the highest yield when compared to other samples. This trend was in agreement with other findings by Koocheki et al. [12] and Sepulveda et al. [13] who reported that when the volume ratio of water to seeds was increased, a greater mucilage yield obtained from *Alyssum homolocarpum* and *Opuntia* spp. seeds. Conversely, Singthong et al. [14] stated that a higher extraction yield was at a low ratio of solid to water in Yanang leaves gum.

The effect of W/S ratio on the extraction yield of the crude gum can be explained based on finding by Amid and Mirhosseini, [7] where the presence excessive amount of water during the aqueous extraction prompted a greater binding of water-soluble component parts which present in the seed endosperm, in this way expanding the extraction yield. Besides that, they also reported that the presence of a greater amount of water contributes to the lowering of slurry stickiness, subsequently giving a more proficient extraction of the mucilage. The increase in the ratio of water to the substrate may increase the solvent diffusivity into cells consequently enhance desorption of the polysaccharides from the cells into the extract [15]. Koocheki et al. [12] also clarified that the extraction *A. homolocarpum* yield increase exponentially due to the increasing of W/S ratio. This is due to the availability of high liquid content that causes the driving force of mucilage out of the seeds into the extract increases, therefore increase the extraction yield [16].

In the current study, W/S of 20:1 was used to determine the further effect of alkaline extraction with different pH due to the highest yield produced at the first stage. Based on the result obtained the pH was significantly ($p<0.05$) affect the extraction yield of Arenga crude gum. The highest yield obtained was 4.72% at pH 10 while the lowest yield (2.18%) was obtained at pH 12. In fact, the extraction yield was significantly improved under an alkaline condition at pH 10 from the yield of the control sample. It is, however, the extraction yield was reduced about 2.58% at higher pH 12 where up to this point the extraction becomes less efficient to release the gum.

Previous studies [17], [18], [19] reported that extraction in the alkaline solution provided the highest yield of white mustard seeds, mesquite (*Prosopis chilensis* (Mol) Stuntz) seed, and malva nut gums. Nevertheless, the effect of pH on extraction yield was minor as reported by previous researchers for *Linum usitatissimum* L. seeds, *Sterculiae lychnophorae* seeds, and *Lepidium perfoliatum* seeds gum [12], [20], [21]. According to Karazhiyan et al., [22] the effect of alkaline pH may result from hydrolysis and dissolution of insoluble constituents in polysaccharides, therefore increase the extraction yield.

The next effect of different temperatures on extraction yield of Arenga gums also was determined by using 20:1 (W/S) and pH 10. The results showed that the extraction yield was significantly increased ($p<0.05$) by the increase in temperature from 40°C to 80°C. This effect may be due to the reduction in viscosity caused by elevated extraction temperature. At higher temperatures, the viscosity of mucilage which linked to the seeds decreases and makes the seeds become less sticky and consequently facilitate the released of mucilage and therefore, increases the extraction yield [12]. Temperature increases the ability of the solvent to solubilize the compounds and, reduce the viscosity of the liquid solvent which allows better penetration of the solvent into the solid matrix [23]. Apart from that, at the elevated temperature, the polysaccharides become more soluble and thereby resulting in higher extraction efficiency [21]. There is also a rapid and easier mass transfer of polysaccharide occurs from cell wall into the extract, once the extraction process subjected to elevated temperature [21].

Based on the result obtained, the ideal extraction condition which led to the highest extraction yield (5.50%) of crude gum extracted from sugar palm endosperm was in the combination of 20:1 W/S ratio, pH condition of 10 and 80°C temperature of extraction. The extraction yield was significantly ($p<0.05$) improved from the yield of the sample

without any treatment. The yield value obtained also was slightly higher than the extraction yield reported for crude galactomannan of *A. saccharifera* (4.99%) [24], and Yanang leaves gum (4.54%) [14].

TABLE I
EFFECTS OF WATER TO SEED (W/S) RATIO, PH, AND TEMPERATURE ON EXTRACTION YIELD OF CRUDE AREN FRUIT GUM

Treatments	Extraction yield (%)
Water to seed ratio	
Control (2.9:1)	$3.85^{bc} \pm 0.28$
6:1	$3.13^{c} \pm 0.42$
13:1	$4.28^{b} \pm 0.33$
20:1	$5.34^{a} \pm 0.25$
pH[1]	
Control	$3.85^{b} \pm 0.28$
8.0	$2.26^{c} \pm 0.20$
10.0	$4.72^{a} \pm 0.27$
12.0	$2.18^{c} \pm 0.16$
Temperature (˚C)[2]	
Control (25)	$3.85^{bc} \pm 0.28$
40	$3.15^{c} \pm 0.24$
60	$4.46^{b} \pm 0.58$
80	$5.50^{a} \pm 0.38$

[1]Water to seed ratio used was 20:1
[2]Water to seed ratio used was 20:1, pH 10

B. Purification Process

The purification process was done for a crude control sample and the crude gum obtained from ideal aqueous extraction conditions (W/S: 20:1, pH: 8, and temperature: 80°C) in order to compare the physicochemical characteristics between them in further analysis. The freeze-dried purified gum for both samples was characterized by white, thread-like precipitate and become a powder-like substance (Fig. 1). The same characteristics were described by previous researchers [5] on the purified gums extracted from different nut maturity of *A. saccharifera.*

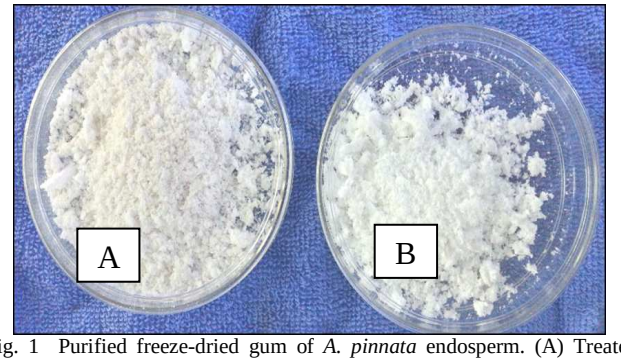

Fig. 1 Purified freeze-dried gum of *A. pinnata* endosperm. (A) Treated sample and (B) Untreated sample

C. Physicochemical Characteristics of Purified Arenga pinnata Fruit Gum

1) Protein Content: The protein content of both samples was significantly different ($p<0.05$) between each other. The results in Table 2 indicated that the treated sample had a higher amount of extracted protein content when compared with an untreated sample. This condition most probably was due to the effect of combination high W/S ratio (20:1) and high temperature (80°C) during the extraction process before the crude gum being purified and analysed. This is in agreement with the previous study done by Cui et al., [20], revealed that higher amount of protein was extracted from the effect of higher water: seed ratio and at a higher temperature of aqueous extraction. The protein content in treated Arenga gum sample was 1.15% lower than the value reported for *Prosopis chilensis* (Mol) Stuntz seed gum (5.16%) which was extracted under same alkaline condition [18]. This value of protein content was fall in the range of the small amount of protein content reported in gum karaya wherein the protein content was reported to be 0-1.4% [25].

Crude protein content in raw endosperms of *A. pinnata* (1.42-3.11%) was determined by the previous researcher at a different stage of nut maturity which was higher when compared to the crude protein content of Arenga gum after being extracted and purified in the present study. The reduction of protein content might be due to the effect of extraction condition which causes the alkaline hydrolysis of protein molecule structure thus led to the reduction of protein content.

Instead of extraction condition, purification process also may involve in the reduction of protein content in both Arenga gum samples where in the present study, Arenga gum samples were purified using Fehling's solution. As reported by Cunha et al., [26] the complexation of the copper ions from the Fehling solution with protein may precipitate the free proteins inside of the crude gums and lead to the reduction in protein content. Bouzouita et al., [27] reported that the purification process contributes to the reduction of ash and protein contents in locust bean gum. They also clarified that for biological purposes, the purified gum containing a small amount of protein fraction is more pure and suitable than the gum with high protein content.

When compared the protein content of untreated purified Arenga gum (0.87%) with the previous study, the value was slightly lower compared to purified guar gum (0.94%) [26] but the protein content of purified guar gum was lower when compared to the treated sample (1.15%) in the present study.

TABLE II
PROTEIN CONTENT OF PURIFIED A. PINNATA GUM FOR UNTREATED AND TREATED SAMPLE

Samples	**Crude protein (%)**
Untreated	$0.868^{b} \pm 0.011$
Treated	$1.151^{a} \pm 0.007$

Values are expressed as the mean ± standard deviation (n=2). Means with different superscript letters in columns indicate a significant difference using Tukey's test ($p<0.05$) for different samples.

2) Solubility: Solubility of gum at various temperatures is one of the main criteria for the selection an appropriate gum [28]. Gums also referred to as hydrocolloid since it can form gels when coming in contact with water molecules. According to Laaman [29], the maximum functionality of some hydrocolloids is induced by fully dissolving in water. In the presence of water molecule, hydrocolloids entrap a large amount of water between the chains and branches present in their molecular structures thus, reduce the diffusion and stabilises the presence of hydrocolloid in water. Full solubility is beneficial from the viewpoint of appearance and texture. Therefore, it is essential to achieve

the maximum solubilisation in order to maintain the desirable functionality [7].

Torio *et al*. [5] reported that the sugar palm endosperm gum isolates were partially soluble in cold and hot water similar to the characteristics of commercially available gums such as guar gum, tragacanth gum, and gum ghatti. In this study, the solubility of control and treated *Arenga* seed gum showed no significant different (p>0.05) at both rooms and elevated temperature (refer to Table 3). However, the treated sample was slightly higher in terms of solubility when compared to the control sample at both temperatures. In fact that, the treated *Arenga* gum sample which was extracted under alkaline condition and at the elevated temperature was considered to be more soluble than the control *Arenga* gum extracted under normal conditions (neutral and room temperature).

The treated gum sample was partially soluble (50.93%) at room temperature, and this value was lower than the solubility reported for galactomannan from purified mesquite seeds (*Prosopis spp*.) (69%) [30], but higher when compared to purified locust bean gum (45%) [10] and purified durian seeds gum (40%) [7] under the same temperature which was 25°C. The difference solubility in gums could be associated with the degree of branching or galactose content of the gums since the extension of mannan chains by galactose side chains prevents the formation of hydrogen-bond intermolecular association [5]. In addition, *Arenga* gum isolates behave as partially soluble in hot and cold water due to the presence of galactose side chains in their structure or are highly branched [24], [31] .

The current study revealed that the solubility for both control and treated *Areng*a seeds gum increased with increasing the temperature of gum solution. In fact, both samples were more soluble at the elevated temperature rather than at room temperature. This is because at a high temperature some molecules such as high molecular weight molecules and galactomannan with low galactose content are dissolved at high temperature but not soluble at low temperature [32]. Apart from that, at high temperature, the hydrogen (H) bonds among polysaccharide chains are broken and cause the hydroxyl groups exposed to the water, consequently enhancing the solubility properties [33].

The solubility for both samples at elevated temperature (80°C) was almost similar to the solubility reported for locust bean gum (70%) [10] and higher than durian seeds gum (~60%) [7].

3) Water Holding Capacity (WHC): Water holding capacity (WHC) is the ability of the gum to hold water molecules. The present study showed that WHC of the control *Arenga* gum was significantly (p<0.05) had lower ability to absorb water when compared to treated *Arenga* gum (refer Table 3). This is because the untreated *Arenga* gum may have the coarse structure with large pores of the gum where treated *Arenga* gum may have a finer uniform gum structure. Amid and Mirhosseini [7] stated that the degree of WHC depends on the particle size and distribution. The gums with a fine uniform structure together with lots of small pores would probably lead in higher WHC and better water retention than a coarse structure with huge pores. Small pore size probably increases the surface area exposing the gum powder to water and allows the gums to hold a greater quantity of water molecules, thus increasing the *WHC.*

In the current study, the WHC for both treated and untreated *Arenga* gum obtained was two times greater capacity to hold water when compared to previous study done by Torio *et al*. [5] who reported that the water-holding capacity for galactomannan from sugar palm (*Arenga saccharifera* Labill.) endosperm were in the range of 42.55 to 47.28 (g water/ 100 g of gums) at different nuts maturity.

There are many factors that can affect the WHC of the gums such as extraction and purification condition, which affect the contact area between the surface of the hydrocolloid and water. It also depends on the availability of the hydroxyl groups on the branched structure of galactomannan which influence the water binding site of the polysaccharide [34]. Besides that, WHC of the gums does not only depends on the hydrophilicity functional group of carbohydrates but also depends on the proteins present in the gums as they also contain functional groups which are able to bind with water molecules [35]. The previous researcher also reported that WHC of polysaccharide gums was influenced by drying process that can cause the changes in chemical composition of polysaccharide gums, thus affect their WHC properties [7], [36], [37].

4) Oil Holding Capacity (OHC): Oil-holding capacity (OHC) represents the capacity of oil absorption which is one of the most remarkable functional properties of a hydrocolloid [38]. Rincon *et al*. [39] reported that some polysaccharides present some fat characteristics by binding large quantities of fat, in that way inducing plasticity, lubricity, and melting sensation.

In the current study, OHC of the treated gum sample was significantly higher (p<0.05) than the OHC of the untreated gum sample (refer Table 3). This might be due to the presence of non-polar side chains and hydrophobic fraction such as fat and protein, which may attach the hydrocarbon units of oil, thereby inducing a higher capacity of oil on absorption [40]. In addition, the treated sample was extracted under alkaline conditions and at an elevated temperature where it seems to cause a destructive effect on the molecular structure of the hydrophilic fraction rather than the hydrophobic portion where it allows better incorporation of oil molecules into the polysaccharide structure, thus increasing OHC [7]. As also stated by Hayta *et al*. [41] and Widyarani *et al*. [42] the type and content of hydrophobic fraction present in the matrix structure of food material also influenced on the oil absorption capacity. The trace lipid fractions and hydrophobic amino acid present in the structure of *Arenga* seed gum may be responsible for its tendency to absorb oil molecules.

Both treated and untreated gum sample (86.87 and 103.33 g oil/100 g hum) had the OHC levels which were closed to the OHC value reported by the previous study for cissus stem gum and sweet cassava starch–cissus stem gum mixture (55–120 g oil/100 g gum) [43]. They reported that cissus gum showed a remarkably low oil absorption capacity which it can be suitable for applications in oil-in-water emulsion systems. Segura-Campus *et al*., [44] reported that fatted chia seed gum (*Salvia hispanica L.*) showed a higher OHC than partly defatted chia seed gum, which might be related to its higher value of fat. They mentioned that this functional

property had been attributed to the physical entrapment of oil for molecules such as lipids and proteins as well as factors such as particle size and the absence of hemicelluloses; therefore allowing it to play an important role in food processing, since fat acts on flavor retainers and increases the mouth feel of foods. Other than that, Thanatcha and Pranee [45] also reported that the mucilage from *Ziziphus mauritiana* Lam had a high oil absorption capacity due to the presence of many non-polar side chain molecules in the crude mucilage that resulted in high amounts of oil particles entrapment.

TABLE III
SOLUBILITY, WATER AND OIL HOLDING CAPACITY OF PURIFIED UNTREATED AND TREATED A. INNATA GUMS

***A. pinnata* gums**	**Solubility (%)**		**Water holding capacity (g water/ 100 g gum)**	**Oil holding capacity (g oil/ 100 g gum)**
	25°C	**80ºC**		
Untreated	46.9^{aB} ± 5.6	70.7^{bA} ± 1.7	116.7^{b} ± 11.6	86.7^{b} ± 5.8
Treated	50.9^{aB} ± 1.1	71.0^{bA} ± 1.9	150.0^{a} ± 10.0	103.3^{a} ± 5.8

Means with different lowercase and uppercase superscript letters in rows and columns, respectively indicate a significant difference (p<0.05).

5) Viscosity: Table 3 indicated that viscosity values of both samples were significantly different (p<0.05) at 0.5 to 1.0 % concentrations of gum solution. Viscosity value at 2% concentration shows that gum from control sample and sample with treatment were not significantly different from each other. The viscosity of both samples at a concentration of 2% was higher compared to the viscosity reported for flaxseed gum which in the range of 16.47 to 148.50 mPa.s measured at the same concentration of gum solution [20]. The present study showed a range of viscosity which was almost similar but slightly higher compared to the previous study done by Torio *et al*., [5] on sugar palm gums that had been isolated from different stages of nut maturity. Other than that, it can be observed that the viscosity value for both gums isolates increased with the increased of solution concentration. This trend was in agreement with a study done by Vasquez *et al.*, [46] who concluded that, at a constant temperature, an increase in mucilage concentration leads to a higher viscosity, which may be due to a higher amount of solute in the dispersion.

When comparing between both samples, the viscosity of sample being treated was lower than the viscosity of the untreated sample. It seems that the treated sample was extracted under alkaline conditions (pH 8-12) and at elevated temperature (40-80°C). There are mechanisms explaining on the reduction of gum viscosity by previous researchers. Based on previous studies [31, 47, 48, 49], the extraction of galactomannan under alkaline conditions led to the reduction in viscosity of gum solution due to the reduction in the weight of the molecules and the suppression of intermolecular association. Other than that, the reduction in gum solution viscosity can occur if the extraction of the gum is performed under high temperature because, at high temperature, the interactions of the molecules in solution become weaker and resulting in irreversible changes of molecules conformation, thus affect the viscosity [18], [32]. The difference in viscosity occurs also have been reported by Yaseen *et al*., [50] as a result of the different molecular weight, polymeric nature of the gums and the interactions between polymer chains when gums are dissolved or dispersed.

TABLE IV
VISCOSITY OF PURIFIED A. PINNATA GUM FOR UNTREATED AND TREATED SAMPLE

Concentration of Aren fruit gum (%)	**Viscosity (mPa.s)**	
	Untreated	**Treated sample**
0.50	146.9^{a}± 5.7	117.6^{b} ± 3.4
0.75	174.5^{a} ± 9.7	139.4^{b}± 1.2
1.00	365.5^{a} ± 8.0	298.1^{b} ± 11.6
2.00	1711.6^{a} ± 148.8	1567.5^{a} ± 31.9

Values are expressed as the mean ± standard deviation (n=2). Means with different superscript letters in rows indicate a significant difference.

IV. CONCLUSIONS

Aqueous extraction conditions (water to seed ratio (W/S), pH and temperature) significantly influenced the extraction yield of Arenga gum). Highest extraction yield (5.50%) can be obtained using W/S ratio of 20:1 at pH 10.0 and at elevated extraction temperature (80ºC). The high water and oil holding capacities of the gum make it suitable as thickener and stabilizer for emulsion-based systems.

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