Effect of Endosperm Maturity Stages and Processing Methods on the Physicochemical Characteristics of Arenga Gum Powder Produced from Industrial Discarded Sugar Palm Endosperms

Nurul Fatin Syahirah Zainal Abidin[1,2] and Somchai Jomduang[1,*]

Abstract

Sugar palm (Arenga westerhoutii Griffith) endosperms are processed into canned product in syrup. Some of the sugar palm endosperms (SPEP) that were discarded during sorting could be potentially used as texturizing agent because of their galactomannan content. The objectives of this study were to determine the physicochemical characteristics of discarded SPEP and the simplest processing methods for arenga gum powder production. It was found that all maturity stages (young, midmature, and mature) did not differ ($p > 0.05$) in glucose, fructose, mannose, and galactose content of SPEP. Mature SPEP showed the hardest texture (12,868.11 ± 7284.4 g.force) compared to young and mid-mature endosperms. Among the four processing methods, crushing the mature endosperms before drying was the simplest, as it was a noncomplicated method with the highest production yield (15.02 ± 0.59%). In addition, it was found that higher drying temperatures produced arenga gum with lower viscosity; 80 °C was the maximum critical drying temperature for arenga gum powder production with high viscosity. Arenga gum powder had similar functional properties to commercial guar gum in terms of water-holding capacity, oil-holding capacity, and water solubility. At room temperature, 2.75% (w/v) of the arenga gum had the same viscosity as recommended-concentration (1% w/v) commercial guar gum in food applications.

Keywords: Sugar palm endosperms, Maturity stage, Galactomannan, Arenga gum powder, Texturizing agent

[1] Faculty of Agro-Industry, Chiang Mai University, Chiang Mai 50100, Thailand

[2] Graduate School, Chiang Mai University, Chiang Mai, 50100, Thailand

* Corresponding author(s), e-mail: somchai.j@cmu.ac.th

Received: 10 July 2018/ Revised: 6 August 2018/ Accepted: 20 August 2018

1. Introduction

Sugar palm plants (*Arenga westerhoutii* Griffith) are naturally available in Southeast Asian countries (Cambodia, Thailand, Lao PDR, and Malaysia) (Chalermklin *et al.*, 2006; Worasuntarosot *et al.*, 2001; Lim, 2012). Suitable matured sugar palm fruits are harvested from the palm tree in the jungle, and then their endosperms are separated for human consumption. Sugar palm endosperms (SPEP) have a gelatinous structure, eaten as fresh fruit or as dessert in the form of fruit mixes and cocktails (Hussin *et al.*, 2017). SPEP are known to contain the polysaccharide galactomannan, which consists of a repeating water-soluble mannose backbone with galactose residues (Torio *et al.*, 2006). In Thailand, some factories utilize SPEP as a raw material for large-scale canned SPEP in syrup production. One medium-size factory utilizes 2 million kilograms of SPEP annually. According to Anuduang (2017), during processing, about 5% (100,000 kg/year) of SPEP are discarded because of nonconformity of color, sizes, and maturity stages (too young or too old). Most discarded SPEP are still edible (Anuduang, 2017). There have been no studies done to determine the suitable utilization of discarded SPEP for human consumption.

Galactomannan is a well-known texturizing agent for its ability to bind clusters of water (Juan-Mei and Shao-Ping, 2016). Texturizing agents are food additives that act as stabilizers, emulsifiers, gelling agents, and thickeners. Texturizing agents can be derived from numerous natural resources such as gelatin (animal derivatives); xanthan gum (microorganism secretion); agar, alginates, and carrageenan (marine plant based); gum arabic (plant exudates); pectin (plant cell walls); Konjac glucomannan (tuber) and guar gum; and locust bean gum and tara gum (plant seeds) (Mathur, 2012; Nussinovitch, 1997). Discarded SPEP have an excellent potential as a source of raw material to produce a texturizing agent because of their high galactomannan content (Torio *et al.*, 2006). First, this research aimed to determine the effect of maturity stages of discarded SPEP on physicochemical attributes related to texturizing agents. Second, the selected maturity stage was used to study the optimum processing methods to produce arenga gum powder. Finally, the functional properties of arenga gum powder were compared to a commercially available galactomannan product (guar gum).

2. Material and Methods

2.1 Materials

Discarded SPEP were collected from a canning plant owned by Uttaradit Junpanich Limited Partnership, Uttaradit, Thailand. The plant produces canned SPEP in syrup. These SPEP were arbitrarily classified into three groups of young, midmature, and mature through visual observations of the physical properties and manual assessment of texture. Young

endosperms have a very soft texture while midmature endosperms have a medium-soft texture. The mature ones were hard and had some white parts inside the endosperms. The classified SPEP were separately washed, blanched in boiling water for five minutes, cooled, and stored in a sealed LDPE bag at room temperature (25–28 °C) (Anuduang, 2017) until the intended usage. Figure 1 shows a photograph of the classified SPEP after washing.

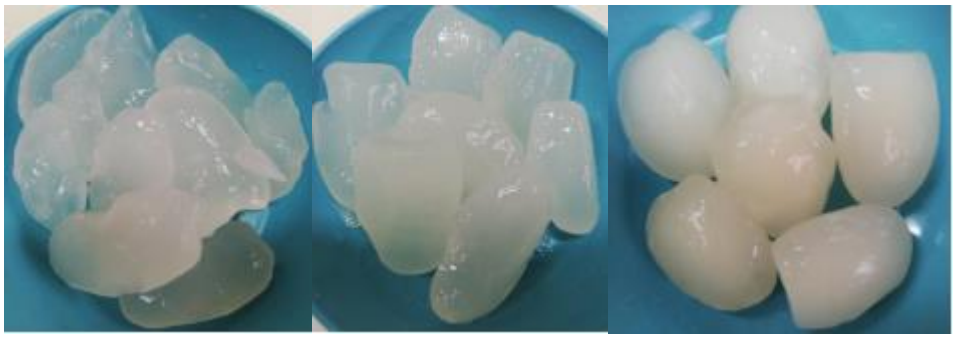

Figure 1 Young SPEP (left), midmature SPEP (middle), and mature SPEP (right)

2. 2 Determination of physicochemical characteristics of discarded SPEP at different maturity stages

Completely randomized design (CRD) was employed in this study. From the maturity stage classification, the weight proportions for each stage were calculated from three replications. The weight of individual classified SPEP were recorded in triplicate and expressed as g/endosperms. Hardness in each maturity stage was measured from an average maximum load at 30% compression of 20 replications using TA.XT Plus Texture Analyzer with cylinder probe number P/50 (Anuduang, 2017). The dried powder samples were prepared by blending the SPEP with a food blender (Model: Philips HR2071/20) followed by drying in an electric hot-air oven (Model: KluaynamThaiTowop, Thailand) at 70 °C. The dried SPEP was milled followed by fine crushing and 50 mesh-size sieving. Proximate analysis of moisture, protein, fat, ash, crude fiber, and carbohydrate content of the powder was determined in triplicate according to the AOAC method (AOAC, 2012).

Sugar composition analysis was performed using high-performance liquid chromatography (HPLC), following the modified method by Liyanage *et al*. (2015). Both acid and nonacid hydrolysis were conducted. For acid-hydrolysis samples, sulfuric acid (0.5 M) was used. For nonacid-hydrolysis samples, sulfuric acid was replaced with distilled water. HPLC chromatograms of samples were measured using HPX-87H column, 45 °C column temperature, 32 °C refractive index detector temperature, 80 bar column pressure, and 0.65 mL/min mobile phase flow rate. The mobile phase was 5mM sulfuric acid with a 5 µL injection volume. Standard calibration curves were prepared by using standard glucose,

galactose, mannose, and fructose solutions ranging from 0.2 mg/mL to 1.0 mg/mL. All data were evaluated using one-way ANOVA and Duncan's multiple range test was performed to compare the significant differences among the means of each maturity-stage samples at $p \leq 0.05$. The maturity stage with high yield and value-added potential was selected for further study.

2.3 Optimal processing methods of arenga gum production

The selected maturity stage of discarded SPEP was processed following four methods: (1) whole SPEP drying, (2) crushed SPEP drying, (3) single water extraction, and (4) double water extraction. Raw materials for (1) and (2) were dried at 70 °C in an electric hot-air oven until moisture is reduced to less than 10%. On other hand, single and double water extractions were performed using a slightly modified method by Mittal *et al*. (2016). The single water extraction started from a SPEP-to-water ratio of 1:2, followed by a 24 h soak and grinding with a food blender; then, centrifugation at 4,000 rpm for 30 min was performed to obtain the supernatant. The double water extraction started with the first extraction similar to single extraction. After that, the residues were reextracted with the same SPEP-to-water ratio. Both first and second supernatants were mixed to obtain double-extraction supernatant. Supernatant from each method was added with 1.5 times the volume of absolute ethanol to obtain galactomannan precipitate, which was separated using Whatman filter paper (number 4). The precipitation was dried in a hot-air electric oven at 60 °C until less than 10% moisture content remained. Each sample was ground and sieved through a 50-mesh sieve to obtain arenga gum powder. The optimal processing method was selected for its noncomplicated process and high production yield.

2.4 Effect of drying temperature on the functional properties of arenga gum powder

Focusing on drying temperatures, the prepared samples from the selected previous study were dried in a hot-air oven at different temperatures (70, 80, 90, 100, 110 and 120 °C) until moisture content was less than 10%. Dried samples were milled using hammer miller, finely crushed using high-speed blender, and sieved through a 100-mesh sieve. The experimental design was CRD with three replications. The yield and moisture content of the dried powder were recorded.

The functional properties of dried arenga gum powder produced at different drying temperatures were evaluated. Water-holding capacity was determined according to Thanatcha and Pranee's (2011) modified method, oil-holding capacity was analyzed using Bashir and Haripriya's (2016) modified method while water solubility was evaluated using Hussin *et al.* (2017) modified method. Viscosity of gum solutions at 1.5% (w/v) was measured according to Gillet *et al.*'s modified method (2017). The data was analyzed by one-way ANOVA. Duncan's

multiple range test was conducted to compare the significant differences between the means of each sample at $p \leq 0.05$. The suitable drying temperature was selected according to superior functional properties.

2.5 Comparison of the functional properties of arenga gum powder with guar gum as texturizing agent

The arenga gum powder from the selected processing method was compared with commercial guar gum bought from Union Science Company Limited, Thailand. Particle size distribution was analyzed using a set of sieves with different sieve numbers (100, 140 and 200-mesh), which were stacked and placed onto an Endecotts Octagon 200 test sieve shaker for 5 minutes set to 600 rpm. The functional properties were evaluated the same way as the previous study.

3. Results and Discussion

3.1 Physicochemical characteristics of discarded SPEP at different maturity stages

Results of the physicochemical characteristics of the discarded SPEP (Table 1) revealed that the midmature SPEP formed the highest proportion ($69.14^{a} \pm 29.54\%$) while the mature SPEP formed the least ($6.85^{b} \pm 10.28\%$). The average weight of each SPEP was significantly affected ($p < 0.05$) by the maturity stage. The average weight of the immature SPEP (1.33 g/endosperm) was lower than those of the midmature and mature SPEP. However, the average weights of the midmature and mature SPEP were similar (2.38 and 2.41 g/endosperm, respectively). The mature SPEP had the highest hardness (12,868.11 g.force) compared to immature and midmature SPEP. The hardness values of the immature and midmature SPEP were not significantly different (477.28 and 1467.91 g. force, respectively). For chemical characteristics, it was found that moisture and carbohydrate content decreased as the endosperms become more mature. The mature SPEP had the lowest moisture and carbohydrate content (86.97 ± 1.52 and $46.10 \pm 2.98\%$, respectively). In contrast, the more mature the endosperms, the higher the protein and ash content. The mature endosperms had the highest protein and ash content (25.68 ± 1.40 and $12.45 \pm 1.41\%$, respectively). The fat and fiber percentages were similar for all maturity stages (ranging from 0.26 to 0.56% and 13.41 to 15.51%, respectively).

Table 1 Physicochemical characteristics of discarded SPEP at different maturity stages

	Maturity stages[1]		
	Young	**Midmature**	**Mature**
Physical characteristics			
Weight proportion (%)	24.02^{b} ± 19.26	69.14^{a} ± 29.54	6.85^{b} ± 10.28
Weight (g/endosperm)	1.33^{b} ± 0.02	2.38^{a} ± 0.04	2.41^{a} ± 0.01
Hardness (g.force)	477.28^{b} ± 170.84	1467.91^{b} ± 648.31	12,868.11^{a} ± 7284.40
Chemical characteristics			
Moisture content (%)	94.02^{a} ± 0.43	91.90^{b} ± 0.90	86.97^{c} ± 1.52
Protein (% d.b.)	12.76^{b} ± 3.37	17.34^{b} ± 5.46	25.68^{a} ± 1.40
Fat (% d.b.)^{ns}	0.45 ± 0.20	0.56 ± 0.22	0.26 ± 0.18
Ash (% d.b.)	5.51^{b} ± 0.42	7.48^{b} ± 0.88	12.45^{a} ± 1.41
Crude fiber (% d.b.)^{ns}	13.41 ± 1.96	13.50 ± 0.78	15.51 ± 0.58
Carbohydrate (% d.b.)	67.87^{a} ± 3.52	61.12^{a} ± 6.50	46.10^{b} ± 2.98

Note: [1] Means followed by different letters in the same row were significantly different (p □ 0.05).

^{ns} = no significant difference (p > 0.05), d.b. = dry basis

The proximate analysis revealed that on dry basis, carbohydrate was the major component of the discarded SPEP. Comparing the results obtained from this study to the one reported by Torio *et al*. (2006) on SPEP, similar trends were observed in protein and ash content, with the values increasing with maturity. Both studies showed that moisture content was lowest for mature SPEP. However, contrasting results were observed for fat, crude fiber, and carbohydrate content. This study showed that fat and carbohydrate content decreased with increasing endosperm maturity. However, Torio *et al*. (2006) reported that fat and carbohydrate content were higher with increasing maturity.

The HPLC chromatograms of the mixed-sugar standard solutions were composed of four sugars (glucose, fructose, mannose, and galactose) and had retention times of 8.8, 10.5, 9.7 and 9.7 min, respectively (Figure 2). Galactose and mannose had the same retention time; therefore, only three peaks were observed. It was also found that there was no peak in the chromatograms for nonacid-hydrolyzed samples for all maturity stages, indicating the four monosaccharides were not present.

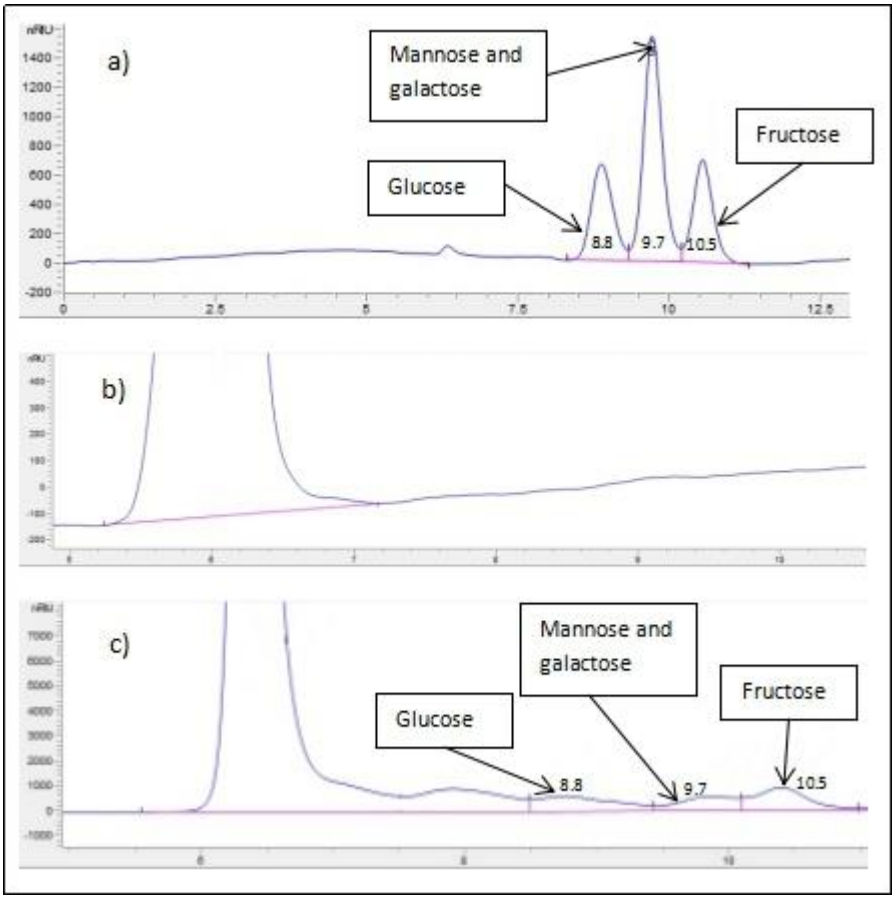

Figure 2 (a) HPLC chromatograms of mixed-sugar standard solutions, (b) nonacid hydrolysis of mature SPEP, and (c) acid hydrolysis of mature SPEP

Table 2 Sugar compositions of acid hydrolysis of discarded SPEP at different maturity stages

Monosaccharides	**Maturity stages**		
	Young	**Midmature**	**Mature**
Glucose (mg/g)^{ns}	25.98 ± 2.54	23.06 ± 3.47	26.22 ± 11.27
Fructose (mg/g)^{ns}	29.03 ± 3.35	26.33 ± 3.00	30.83 ± 10.71
Galactose and mannose (mg/g)^{ns}	19.54 ± 3.11	21.04 ± 5.74	18.84 ± 8.00

Note: ns = no significant difference ($p > 0.05$)

Table 2 shows that, after acid hydrolysis, glucose, fructose, galactose, and mannose concentrations were similar for each SPEP maturity stage. Glucose concentration ranged from 23.06 to 26.22 mg/g, fructose ranged from 26.33 to 30.83 mg/g, and galactose and mannose ranged from 18.84 to 21.04 mg/g. Focusing on galactose and mannose, which were the sugar units in the galactomannan structure, it was indicated that during increasing endosperm maturity, the percentage of mannose backbone increases as reported by Torio *et al*. (2006). The higher percentage of mannose backbones could affect the increase in SPEP hardness.

Considering the hardness of each maturity stage, it was also found that the more mature the SPEP, the harder their texture (Table 1).

3.2 Optimal processing methods of arenga gum powder production

Without further processing, mature SPEP was found to have a very hard texture for human consumption. Hence, it was selected to be evaluated as raw material for arenga gum powder production. A relatively simple and practical method with high yield and shorter times will be favored. The arenga powder yield obtained from whole and crushed endosperms before undergoing the drying process were found to be 15.15% and 15.02%, respectively (Table 3). The yield for single and double water extractions were only 1.91% and 2.10%, respectively.

Table 3 Percentage yield of different processing methods in producing arenga gum.

Processing methods	Yield (%)[1]
Whole SPEP drying	15.15[a] ± 0.56
Crushed SPEP drying	15.02[a] ± 0.59
Single water extraction	1.91[b] ± 0.04
Double water extraction	2.10[b] ± 0.14

Note: [1] Means followed by different letters in the same column were significantly different (p □ 0.05)

The results obtained from the SPEP yield study to determine the effects of preparation and processing methods showed that drying whole and crushed SPEP produced about seven times higher yield than single and double water extraction. Therefore, drying of crushed SPEP would be the preferred method for arenga gum powder production. This method is also quite simple with a low production cost. The production yield from this selected method (15.02%) is higher than the values reported by Torio *et al*. (2006) and Hussin *et al*. (2017) (5.50%).

3.3 Effect of drying temperatures on the physical and functional properties of arenga gum powder

Table 4 shows that the yields after drying were in the range of 12.36 ± 1.90% to 14.27 ± 1.25%. The moisture content of the powder ranged from 1.75% to 4.43%. As expected, increasing the drying temperature resulted in reduced drying time; drying at 120 °C resulted in the shortest time (130 min) compared to 360 minutes at 70 °C and 300 min at 80 °C. The study also showed that drying temperature did not significantly affect the water-holding and oil-holding capacity of the dried arenga gum powder ($p > 0.05$). However, drying temperature significantly affects powder viscosity. Drying at 70 °C and 80 °C produced arenga gum powder with the highest viscosity values, which were 153.22 ± 4.74 and 151.33 ± 1.53 cP, respectively. Further increase in drying temperatures reduced viscosity to a range of 62.67

to 85.17 cP. Hussin *et al*. (2017) reported that gum extraction at elevated temperatures reduced solution viscosity. Therefore, drying at 80 °C was selected for further study, as a shorter drying time of 300 min was achieved.

Table 4 Effect of hot-air drying temperature on physical and functional properties of arenga gum powder

	Drying temperatures (°C)[1]					
	70	**80**	**90**	**100**	**110**	**120**
Physical properties						
Actual drying temperature (°C)	70.5 ± 2.89	79.25 ± 0.96	90.33 ± 1.53	99.67 ± 1.15	112.0 ± 1.73	119.67 ± 1.53
Drying time (min)	360	300	240	210	190	130
Yield (%)	13.73^{ab} ± 0.20	13.26^{ab} ± 0.34	14.27^{a} ± 1.25	13.26^{ab} ± 0.9	12.36^{b} ± 1.9	13.27^{ab} ± 0.5
Moisture content (%)	2.64^{bc} ± 1.5	1.75^{c} ± 0.60	2.86^{abc} ± 1.4	4.43^{a} ± 2.81	3.64^{ab} ± 1.94	3.54^{ab} ± 1.42
Functional properties						
Water-holding capacity (g water/g sample)[ns]	13.25 ± 0.34	12.64 ± 0.68	12.16 ± 0.17	13.88 ± 2.88	12.28 ± 0.90	12.13 ± 0.30
Oil-holding capacity (g oil/ g sample)[ns]	3.95 ± 0.29	4.44 ± 0.30	4.31 ± 0.44	3.91 ± 0.35	3.75 ± 0.33	3.95 ± 0.50
Viscosity at 1.5% w/v (cP)	153.22^{a} ± 4.7	151.33^{a} ± 1.5	62.67^{d} ± 3.21	85.17^{b} ± 1.61	72.00^{c} ± 3.1	66.25^{cd} ± 3.2

Note: [1] Means followed by different letters in the same row were significantly different ($p \leq 0.05$).

[ns] = no significant difference ($p > 0.05$)

3. 4 Texturizing agent characteristics of arenga gum powder in comparison with commercial guar gum

Results presented in Table 5 show that all particles of the arenga gum and guar gum powder passed through the 100-mesh sieve. However, 83.09% and 68.73% of the particles from the arenga gum and guar gum, respectively, were retained when the 140-mesh sieve was used. The table also shows that the water-holding capacity, oil-holding capacity, and water solubility (at 25 °C) of both gum powders had similar values ($p > 0.05$). At 80 °C, guar gum had significantly higher water solubility than arenga gum powder. At 1.5% concentration, guar gum had higher viscosity than arenga gum (8360.0 ± 1331.47 and 151.33 ± 1.53 cP, respectively).

Table 5 Comparison on the functional properties of arenga gum powder with guar gum as texturizing agent

Quality attributes [1]	Arenga gum powder	Guar gum
Weight fraction of particle size at 140 mesh sieve (%)[ns]		
Retained at 140-mesh sieve	83.09 ± 7.48	68.73 ± 12.02
Passed through 140-mesh sieve	16.91 ± 7.48	31.27 ± 12.02
Functional properties		
Water-holding capacity (g water/g sample)[ns]	12.64 ± 0.68	12.83 ± 0.57
Oil-holding capacity (g oil/ g sample)[ns]	4.44 ± 0.30	4.48 ± 0.66
Solubility (%)		
at 25 °C[ns]	45.65 ± 3.23	58.25 ± 8.61
at 80 °C	54.83[b] ± 0.26	64.86[a] ± 1.82
Viscosity at 1.5% (w/v) (cP)	151.33[b] ± 1.53	8360.0[a] ± 1331.47

Note: [1] Means followed by different letters in the same row were significantly different (p □ 0.05).

[ns] = no significant difference (p > 0.05)

Viscosity is one of the important functional properties of texturizing agents. At 1.5% (w/v) concentration, guar gum had higher viscosity (about 55 times) than arenga gum powder. The differences in viscosity between arenga gum and guar gum solutions were due to varying average mannose-to-galactose ratio in different plant sources, which subsequently affects the functional properties of the gum solutions (Campia *et al*., 2017; Martinez-Avila *et al*., 2014).

In practice, guar gum was recommended to be used in food products at about 1% (w/v) concentration (Mudgil and Barak, 2014). Figure 3 indicates that for the arenga gum solution to achieve the same viscosity as 1% (w/v) guar gum concentration, 2.75% (w/v) was required. Thus, to perform as a thickening agent similar to guar gum solution at 1% (w/v), approximately three times more arenga gum is needed. Compared to guar gum powder, arenga gum powder at the required concentration (2.75%) will have a lower price, as it is produced from zero-value raw material. The present study reveals that arenga gum powder has a good potential to be commercialized as a thickening agent.

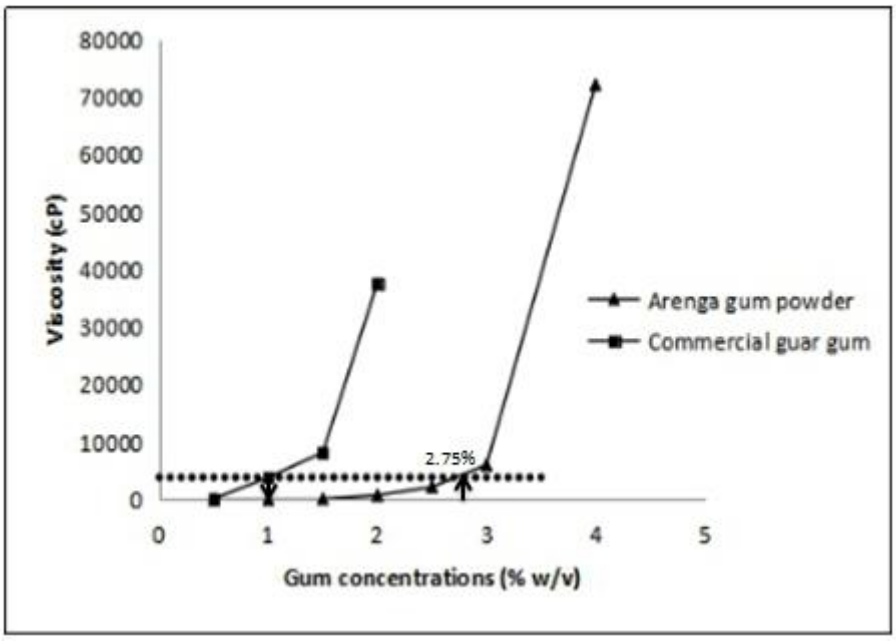

Figure 3 Effect of arenga gum and commercial guar gum concentrations on viscosity

4. Conclusions

Mature SPEP that were initially inedible as whole endosperms because of their hard texture can be converted into a texturizing agent powder through noncomplicated technology. The final yield of the powder was 15.02% of the wet weight of SPEP. The optimum processing method consisted of crushing the SPEP, drying them at 80 °C, and grinding and sieving them through a 100-mesh sieve. Arenga gum powder has similar water-holding capacity, oil-holding capacity, and water solubility as commercial guar gum. However, it had lower viscosity than commercial guar gum at the same concentration level. A concentration of 2.75% (w/v) was needed for arenga gum powder to exhibit a viscosity similar to commercial guar gum at 1% (w/v) concentration. Arenga gum powder produced from discarded mature SPEP is an innovation with industrial potential to be commercialized as a texturizing agent.

Acknowledgments

The authors thank the Graduate School, Chiang Mai University, for the Research Assistant Scholarships that had been helpful in completing this research. We would like to express our deep gratitude to Uttaradit Junpanich Limited Partnership for the raw material supply.

References

Anuduang, A. 2017. Optimal storage methods of sugar palm seeds (Arenga westerhoutii Griffith) and production of dried preserved coffee flavour sugar palm. MSc Dissertation. Chiang Mai University, Chiang Mai, Thailand.

AOAC. 2012. Official Method of Analysis of AOAC International. AOAC International, USA.

Bashir, M. and Haripriya, S. 2016. Assessment of physical and structural characteristics of almond gum. International Journal of Biological Macromolecules. 93(A):476–482.

Campia, P., Ponzini, E., Rossi, B., Farris, S., Silvetti, T., Merlinin, L., Brasca, M., Grandori, R. and Galante, Y. M. 2017. Aerogels of enzymatically oxidized galactomannans from leguminous plants: Versatile delivery systems of antimicrobial peptides and enzymes. Carbohydrate Polymers. 158:102–111.

Chalermklin, P., Kengkaj. P. and Piriyapatarakij, A. 2006. Palm in Thailand. Bangkok: Limited Partnership Pimpinij, Thailand.

Gillet, S., Aguedo, M., Petrut, R., Olive, G., Anastas, P., Blecker, C. and Richel, A. 2017. Structure impact of two galactomannan fractions on their viscosity properties in dilute solution, unperturbed state and gel state. International Journal of Biological Macromolecules. 96:550–559.

Hussin, A.S.M., Sapawi, C.W.N.S.C., Anzian, A., and Ramli, H.B. 2017. Aqueous extraction, purification and characterization of galactomannan from aren sugar palm (*Arenga pinnata*) fruits. International Journal on Advance Science Engineering Information Technology. 7(4).

Juan-Mei, L., and Shao-Ping, N. 2016. The functional and nutritional aspects of hydrocolloids in foods. Food Hydrocolloids. 53:46–41.

Lim, T.K. 2012. Edible medicinal and non-medicinal plants. Springer Dordrecht Heidelberg. New York.

Liyanage, S., Abidi, N., Auld, D. and Moussa, H. 2015. Chemical and physical characterization of galactomannan from guar cultivar (*Cyamopsis tetragonolobus* L.) Industrial Crops and Products. 74:388–396.

Martinez-Avila, G. C. G., Hernandez-Almanza, A. Y., Sousa, F. D., Moreira, R., Gutierrez-Sanchez, G. and Aguilar, C. N. 2014. Macromolecular and functional properties of galactomannan form mesquite seed (*Prosopis glandulosa*). Carbohydrate Polymers. 102:928–931.

Mathur, N.K. 2012. Industrial Galactomannan Polysaccharide. CRC Press, Florida, USA.

Mittal, N., Mattu, P. and Kaur, G. 2016. Extraction and derivatization of *Leucana leucocephala* (Lam.) galactomannan: Optimization and characterization. International Journal of Biological Macromolecules. 92:831–841.

Mudgil, D. and Barak, S. 2014. Guar gum: Processing, properties and food applications – A review. Journal Food Science Technology. 51(3):409–418.

Nussinovitch, A. 1997. Hydrocolloid applications: Gum technology in the food and other industries. Springer Science+Business Media Dordrecht.

Thanatcha, R. and Pranee, A. 2011. Extraction and characterization of mucilage in *Ziziphus mauritiana* Lam. International Food Research Journal. 18:201–2012.

Torio, M. A. O., Saez, J. and Merca, F. E. 2006. Physicochemical characterization of galactomannan form sugar palm (*Arenga saccharifera* Labill.) endosperms at different stages of nut maturity. Philippine Journal of Science. 135(1):19–30.

Worasuntarosot, P., Duriyaprapan, S., Arachawakhom, T., Tanpanich, S., Nivasprakit, C. and Sornsungnearn, P., 2001. Plant resources of South-east Asia: PROSEA. Nonthaburi Sahamidth Printing.