Food Science and Engineering
http://ojs.wiserpub.com/index.php/FSE/

Research Article

Impact of Encapsulation Wall Materials and Drying Method on Physicochemical Properties and Digestibility of Encapsulated Chayote (*Sechium edule* (Jacq.) Swartz) and Kohlrabi (*Brassica oleracea var gongylodes* L.) Extracts

Thongkorn Ploypetchara[1], Waraporn Sorndech[1*], Chiramet Auranwiwat[2], Wiriyaporn Sumsakul[2], Monsicha Pinthong[1], Antika Kansuwan[1], Siriporn Butseekhot[1], Sinee Siricoon[1]

[1]Expert Center of Innovative Health Food, Thailand Institute of Scientific and Technological Research, Pathum Thani, Thailand
[2]Expert Center of Innovative Herbal Products, Thailand Institute of Scientific and Technological Research, Pathum Thani, Thailand
E-mail: waraporn_s@tistr.or.th

Received: 18 August 2021; **Revised:** 26 October 2021; **Accepted:** 2 November 2021

Abstract: Chayote (*Sechium edule* (Jacq.) Swartz) and kohlrabi (*Brassica oleracea var gongylodes* L.) are medicinal plants widely distributed in Thailand. Several traditional medicines usually contain these extracts due to their pharmaceutical activities. However, appropriate technologies that are used for protection, stabilization, and slow release of plant extracts are a lot desired in terms of food application. In this study, chayote and kohlrabi extracts were encapsulated by several kinds of wall materials (maltodextrin, and the combination of maltodextrin and gum arabic or alginate) and drying methods (freeze-drying and tray-drying techniques). Thus, the objective of this research was to determine morphological and physicochemical properties, wall materials releasing, and antioxidant activity of encapsulated chayote and kohlrabi extracts powder. The morphology of all encapsulated chayote and kohlrabi extracts powder showed irregular spherical shape, monodispersity, and smooth surface. The encapsulated chayote and kohlrabi extracts powder with tray-drying technique tend to have more darkness and redness in color than the freeze-drying technique. Wall material releasing was expressed in glucose liberation of encapsulated extracts powder after amylolytic enzyme digestion. Encapsulation using maltodextrin as wall material provided higher wall material releasing than the other samples. After digestion analysis, the digested residues were examined for antioxidant activity. The results showed that the combination of maltodextrin and alginate for both freeze-drying and tray-drying techniques provided higher antioxidant activity after 60 and 120 min of digestion. Thus, the combination of maltodextrin and alginate, and drying with the freeze-drying technique was the best treatment in this experiment. This data can lead to a better understanding of wall materials types and releasing characteristics, which are used to control bioactive compounds liberation in the gastrointestinal tract.

***Keywords*:** extracts, encapsulation, wall materials, digestibility, chayote (*Sechium edule* (Jacq.) Swartz), kohlrabi (*Brassica oleracea var gongylodes* L.)

1. Introduction

The medicinal plants are widely distributed in tropical and subtropical countries. *Sechium edule* (Jacq.) Swartz

DOI: https://doi.org/10.37256/fse.3120221110

is locally named chayote and belongs to the Cucurbitaceae family, which can be found in the North and Northeast of Thailand. This plant has been used for the treatment of renal disease, obesity, and arteriosclerosis [1]. There are several documents that reported about chayote phytochemical investigation [1-5]. There are various groups of secondary metabolites were produced, including fatty acid derivatives [2], flavonoids [1, 3, 4], and organic acids [5]. Furthermore, these compounds exhibited pharmaceutical activities such as anti-endothelial dysfunction activity [5] and lipid accumulation inhibition [4]. In addition, *Brassica oleracea var gongylodes* L. is a member of the Brassicaceae family which is a source of nutrients such as dietary fiber, folic acid, calcium, and vitamins [6, 7]. The phytochemical investigation of this species found groups like alkaloids [8], flavonoids [9], glucosinolate derivatives [10], phenylpropanoids [9-11], and terpenoids [12]. The isolated compounds from *B. oleracea* showed antioxidant and antimicrobial activities [9]. From the literature, these plants are sources of phenolic constituents, thus can be applied as functional food ingredients.

Encapsulation is a physicochemical method that compounds or active agents are trapped with the wall material. The encapsulation technology has been selected to prevent the degradation of bioactive compounds in the extracts under high temperature or strong pH conditions. The majority group of compounds from chayote and kohlrabi are phenolics which can be affected under high temperature, light, and pH conditions. The most common wall materials for plant extract encapsulation are polysaccharides including starch, maltodextrin, and Arabic gum, and some synthetic polymers (poly D, L-lactide, and poly lactic acid) [13]. The controlled-release for the active agent makes them available to release in the interesting condition. In part of active ingredients, the absorption of active components is protected while digestion in GIT and release at target organs [14]. A lot of drying methods have been developed and applied in various kinds of products. The tray dry process contains a number of stacks and is put in the chamber with the circular hot air or natural flow [15]. Furthermore, freeze-drying is normally used for thermal labile materials. Target materials are frozen and then primary drying to remove water molecule [16]. Those methods are commonly used for drying methods in the present. The encapsulated particle can describe the physicochemical properties such as particle size, encapsulation efficiency, and controlled compound release [13, 17]. Herein, we report the investigation of method development of encapsulation the mixture of chayote and kohlrabi extracts with different ratios and types of the selected wall materials. The physicochemical of the particles were determined including morphological property, color value, moisture content, aw, water-solubility, wall materials releasing, and antioxidant activity after digestion of all encapsulated extracts powder. The aims of this work are the most effective condition for encapsulation of the extracts with low Aw, high solubility, and antioxidant activity.

2. *Materials and methods*

2.1 *Materials*

Maltodextrin, gum arabic, and alginate (Krungthepchemi Co., Ltd., Thailand). Fresh chayote (*Sechium edule*) and kohlrabi (*Brassica oleracea var gongylodes* L.) were purchased from The Royal Project Foundation (Chiang Mai, Thailand). Porcine pancreatic α-amylase (EC 3.2.1.1, specific activity 22 U/mg), glucoamylase from *Aspergillus niger* (EC 3.2.1.3, specific activity 129 U/mg), pepsin (EC 3.4.23.1, 2,500 units/mg protein), and pancreatin from porcine pancreas were purchased from Sigma-Aldrich (Missouri, USA). Enzyme activity units of α-amylase, glucoamylase, pepsin, and pancreatin are given according to the supplier.

2.2 *Preparation of chayote and kohlrabi extracts*

Fresh chayote or kohlrabi was cut into small pieces and dried at 60 °C for 24 h and then milled. The dried sample (150 g) was added to by 600 mL of 70% (v/v) ethanol, stirred for 30 min, and soaked until precipitated. All samples were filtrated using a filter paper (Whatman No.1, 125 mm. of pore size) and the residue was extracted again. The extracts were made in duplicate. The filtrate solvent was removed under the reduced pressure (Rotavapor® R-300, BÜCHI Labortechnik AG, Switzerland) and the obtained dark brown gum extracts were kept in an amber bottle.

2.3 *Encapsulation powder preparation*

Encapsulation of chayote and kohlrabi extracts were performed according to Table 1. Maltodextrin at 8-10% (w/w) was dispersed in distilled water and kept overnight to make an aqueous dispersion. Similarly, 2% (w/w) of gum arabic and 2% (w/w) of alginate were dispersed in distilled water at 60 °C separately to form the aqueous solution. Aqueous dispersions of maltodextrin and each hydrocolloid were mixed separately to obtain the different wall material solutions. These solutions were cooled to room temperature. Chayote (2.5% w/w) and kohlrabi (2.5% w/w) extract were added into these wall material solutions and stirred for 1 h. The mixtures were homogenized in a high shear mixer (T25 IKA, Ultra-Turrax®, Germany) which were operated at 5,200 rpm for 5 min. After mechanical homogenization, the samples were dried by using a freeze dryer (LyoLab ST, Lyophilization System, INC. USA) or tray dryer (DHP-9082B, Yanhe Instrument, China) at 60 °C until constant weight to obtain the encapsulated extract powders. The powders were ground into the size at 80 mesh, then kept in plastic bags and stored under a dry atmosphere with silica gel in light-protect desiccators at 25 °C until measurements [18].

Table 1. Wall material compositions of encapsulated chayote and kohlrabi extracts preparation

Sample	Chayote and kohlrabi extracts*	Maltodextrin	Hydrocolloids
Mal-FD	5%	10%	-
MalGA-FD	5%	8%	Gum Arabic2 %
MalAlgi-FD	5%	8%	Alginate 2%
Mal-TD	5%	10%	-
MalGA-TD	5%	8%	Gum Arabic 2%
MalAlgi-TD	5%	8%	Alginate 2%

* Ratio of chayote:kohlrabi extracts is 1:1
Mal: Maltodextrin; GA: Gum Arabic; Algi: Alginate; FD: Freeze Drying; TD: Tray Drying

2.4 *Morphological and physicochemical analysis*

2.4.1 *Morphological analysis of encapsulated extracts powder*

Morphological properties of powder samples were observed using a light microscope (EVOS XL core, Thermo Scientific., USA). The micrographs were present at 40× [18].

2.4.2 *Color value of encapsulated extracts powder*

The color differences of samples were identified using CIE L*a*b* coordinates. Color of the chayote and kohlrabi encapsulated extracts powders was measured with a Minolta colorimeter (CR-400/CR-410, Japan). Color in terms of luminosity, light versus dark (L*), red versus green (a*), and yellow versus blue (b*) were reported and all samples were measured in triplicates.

2.4.3 *Water activity (Aw) and moisture content of encapsulated extracts powder*

Water activity (Aw) of encapsulated chayote and kohlrabi extracts powder was measured with water activity analyzer (4TE, AQUALAB®, USA) and all samples were measured in triplicates. The moisture content of chayote and kohlrabi encapsulated extracts powder was measured. The sample (2 g) was dried at 105 °C in an oven (SLW 35 STD; POL-EKD APARATURA SP.J., Poland) until the weight was constant. The moisture content of the sample was calculated using the equation written below:

$$\text{Moisture content (\%)} = \frac{(\text{Weight before dried} - \text{Weight after dried})}{\text{Weight before dried}} \times 100 \quad (1)$$

2.4.4 *Water solubility of encapsulated extracts powder*

Water solubility was measured by the method of Schoch and Leach with modifications [19], the sample (10% w/v) was mixed with distilled water in a centrifuge tube and the mixture was incubated at room temperature for 30 min and centrifuged at 3,000 g for 15 min. The liquid supernatant was collected and dried at 60 °C until constant weight and solubility were calculated using the equation written below:

$$\text{Solubility(\%)} = \frac{\text{Weight of dried sample} \times 100}{\text{Weight of initial sample}} \quad (2)$$

2.5 *Wall materials releasing analysis in vitro digestion*

Wall-materials releasing which was expressed as glucose liberation by *in vitro* digestion was analyzed by a modification of Sopade and Gidley method [20]. Encapsulated extract powder (500 mg), were incubated in triplicates with 1 mL of artificial saliva containing 250 U of porcine pancreatic α-amylase (Sigma A-3176) for 15-20 s. Pepsin (1 mg/mL in 0.02 M HCl, Sigma P-6887) was added and incubated at 37 °C for 30 min and reciprocating at 85 rpm in a shaking incubator. The sample was neutralized by using 5 mL of 0.02 M NaOH before adjusting the pH to 6 (25 mL of 0.2 M sodium acetate buffer) prior to the addition of 5 mL of pancreatin (2 mg per mL of buffer, Sigma P1750) and amyloglucosidase (28 U per mL of buffer, Sigma A-7420). The mixture was incubated for 3 h, during which the glucose concentration in the digested samples was measured at 0, 20, 60, 120, and 180 min by using PGO enzymes (Sigma P7119). The glucose released (%) was calculated using the following equation written below:

$$\text{Glucose released (\%)} = \left(\frac{\text{Total weight of glucose} \times 0.9 \times 100}{\text{Weight of initial sample}} \right) \quad (3)$$

where 0.9 is the molar mass conversion from glucose to anyhydroglucose.

2.6 *Antioxidant activity of digested residue by DPPH method*

Antioxidant activity of all encapsulated samples after wall material releasing analysis was analyzed by the DPPH method. The determination of the antioxidant activity of chayote and kohlrabi encapsulated extracts powder was performed using 1, 1-Diphenyl-2-Picrylhydrazyl (DPPH), which was prepared in ethanol [21]. The standard solutions of vitamin C (L-ascorbic acid) in the ranges of 1-200 μg/mL were used as positive controls and the samples were serially diluted with ethanol in a 96-well plate. A quantity of 100 μL of 200 μM DPPH was added to 50 μL of the standards and samples. The reaction mixtures were then kept in the dark for 30 min. The absorbance of the sample was measured at 517 nm by using a microplate reader (TECAN, Infinite M200 pro, DKSH (Thailand)., Ltd, Thailand). The DPPH scavenged (%) was calculated for all samples and compared to the standard solutions using the equation written below:

$$\text{DPPH Scavenged (\%)} = \left(\frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control} \times 100} \right) \quad (4)$$

2.7 *Statistical analysis*

The results of the sample were obtained on all data considered as mean ± standard deviation. Analysis of Variance (ANOVA) was conducted to decide a significant difference ($p \leq 0.05$) among the samples, using the software SPSS 17.0. Differences between means were expressed using Duncan's test.

3. Results and discussion

3.1 *Characteristics of encapsulated chayote and kohlrabi extracts powder*

3.1.1 *Morphology of encapsulated chayote and kohlrabi extracts powder*

The morphology of encapsulated chayote and kohlrabi extracts powder which were measured by light microscope showed irregular spherical shape, homo-dispersity, and smooth surface. The microcapsule of samples using maltodextrin and maltodextrin combined with alginate as wall materials are shown in Figure 1. The combination of maltodextrin and alginate provided an improvement in shape and size than using pure maltodextrin. In the case of the combination of maltodextrin and gum-arabic, the encapsulated particles were not found due to the limit of magnifying power of the microscope which cannot adjust to lower than 40×. Hence, the encapsulated particles that are smaller than this magnifying power could not be found. However, there was no difference in encapsulated powder shape between freeze-drying and tray-drying methods. Sawale et al. (2017) reported that the limitation of using only maltodextrin as wall material to encapsulation might be lack of emulsifying capacity and low retention of volatile compounds, and hydrocolloids such as gum arabic and gelatin would be using added along with maltodextrin to struggle with the limitations [21]. The difference in shape and size of encapsulated chayote and kohlrabi extract microcapsules might be also related to the quantity of chayote and kohlrabi extracts in the core of capsules.

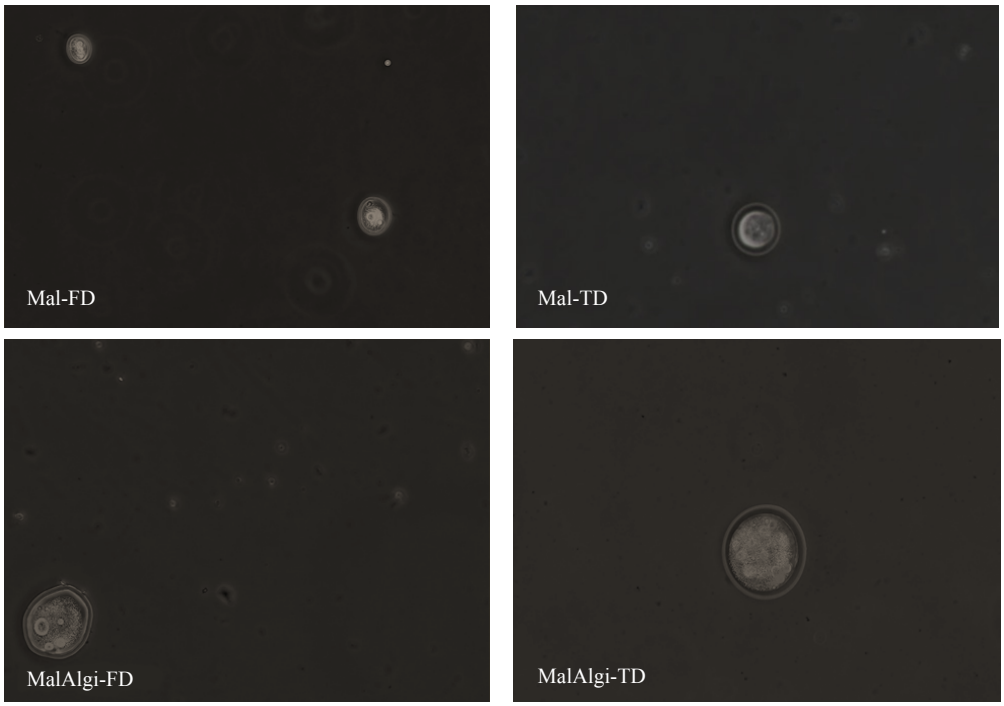


Figure 1. Morphological properties of encapsulated chayote and kohlrabi extract.
Mal: Maltodextrin; Algi: Alginate; FD: Freeze Dry; TD: Tray Dry

3.1.2 *Physicochemical properties of encapsulated chayote and kohlrabi extracts powder*

The pleasant color is one of the staple elements of functional ingredients for application in the food industry. The different color values of different encapsulated procedures of chayote and kohlrabi extracts powders were shown in Table 2. The Mal-FD showed the highest lightness (L*) and the MalGA-TD appeared the highest darkness in this experiment. The dark appearance might be affected by the light scattering properties of the empty spaces after the sublimation of water in the system [22]. The color of all encapsulated extracts powder was different depending on drying methods. The color of the sample prepared with the tray-drying technique tended to be darker and red (a*) than

that of the freeze-drying technique. The various carrier and drying methods affected the properties of encapsulated extracts powders [22, 23]. These results were similar to Ravichandran et al. [23] that all the samples have positive a* and b* values, and better color would be obtained by using maltodextrin.

Table 2. Color value of encapsulated chayote and kohlrabi extracts powder

Sample	Color value		
	L*	a*	b*
Mal-FD	$80.67^{d} \pm 0.81$	$1.42^{a} \pm 0.13$	$20.54^{a} \pm 0.45$
MalGA-FD	$66.10^{b} \pm 0.87$	$4.38^{c} \pm 0.51$	$24.96^{d} \pm 0.98$
MalAlgi-FD	$76.03^{c} \pm 0.53$	$2.08^{b} \pm 0.08$	$23.12^{c} \pm 0.72$
Mal-TD	$66.95^{b} \pm 1.42$	$7.32^{e} \pm 0.58$	$21.88^{b} \pm 1.28$
MalGA-TD	$62.42^{a} \pm 1.54$	$8.29^{f} \pm 0.45$	$23.54^{c} \pm 0.84$
MalAlgi-TD	$66.73^{b} \pm 1.30$	$6.75^{d} \pm 0.42$	$22.79^{bc} \pm 0.65$

* Different letters in the same column within each treatment indicate significant difference at $p < 0.05$
Mal: Maltodextrin; GA: Gum Arabic; Algi: Alginate; FD: Freeze Dry; TD: tray dry

Table 3. Moisture content, solubility, and Aw of encapsulated chayote and kohlrabi extracts powder

Treatment	Solubility (%)	Moisture content (%)	Aw
Mal-FD	95.21 ± 6.48^{bc}	9.14 ± 0.80^{c}	0.03 ± 0.37^{bc}
MalGA-FD	94.43 ± 7.86^{bc}	10.80 ± 2.25^{d}	0.02 ± 0.36^{bc}
MalAlgi-FD	91.63 ± 0.84^{ab}	12.12 ± 0.56^{e}	0.04 ± 0.39^{c}
Mal-TD	98.86 ± 1.16^{c}	5.98 ± 0.10^{a}	0.02 ± 0.36^{abc}
MalGA-TD	98.74 ± 2.11^{c}	7.87 ± 0.57^{bc}	0.01 ± 0.33^{a}
MalAlgi-TD	87.08 ± 2.90^{ab}	7.29 ± 0.56^{ab}	0.01 ± 0.34^{ab}

* Different letters in the same column within each treatment indicate significant difference at $p < 0.05$
Mal: Maltodextrin; GA: Gum Arabic; Algi: Alginate; FD: Freeze Dry; TD: tray dry

The moisture content, solubility, and water activity (Aw) are the important characteristics that relate to the quality of the encapsulated extracts powder during storage, such as changing color and flavor, reducing the bioactive compound activity, and enhancing the growth of microorganisms [22, 24]. The moisture content, solubility, and Aw results of encapsulated chayote and kohlrabi extracts powder were shown (Table 3). The freeze-drying technique tended to be higher in moisture content and Aw than the tray-drying technique. The results might relate to the samples from the freeze-drying technique that would be generated a porous and brittle structure with cracks resulting in a greater surface area available for hydration [22]. However, the comparison of Aw in the same drying technique would not be significantly different with using a different type of wall materials. Aw of all samples was lower than the minimum value (0.6) which was required for the multiplication of microorganisms [22]. Hence, the encapsulated chayote and kohlrabi extracts powder provided a water activity lower than 0.6 and that will not provide sufficient free water to support the growth of bacteria, yeasts, and mold. The use of pure maltodextrin displayed the highest solubility while using maltodextrin-alginate showed the lowest solubility. The lower moisture content and higher water solubility of pure maltodextrin than maltodextrin mixed with hydrocolloid might be due to the hygroscopic property of hydrocolloid. The

results were similar to Zhang et al. [24] that also reported the low moisture content, high solubility, and low hygroscopic of using pure maltodextrin as wall materials in microencapsulated noni juice. The different encapsulated wall materials can provide different soluble abilities of the encapsulated extracts powder [25, 26]. Therefore, the results (Table 3) might be shown the physical characteristics of encapsulated extracts powder using pure maltodextrin as wall material better than that of maltodextrin mixed with hydrocolloid. However, the result should consider with other parts of the experiment.

3.2 *Wall materials releasing by in vitro digestion analysis*

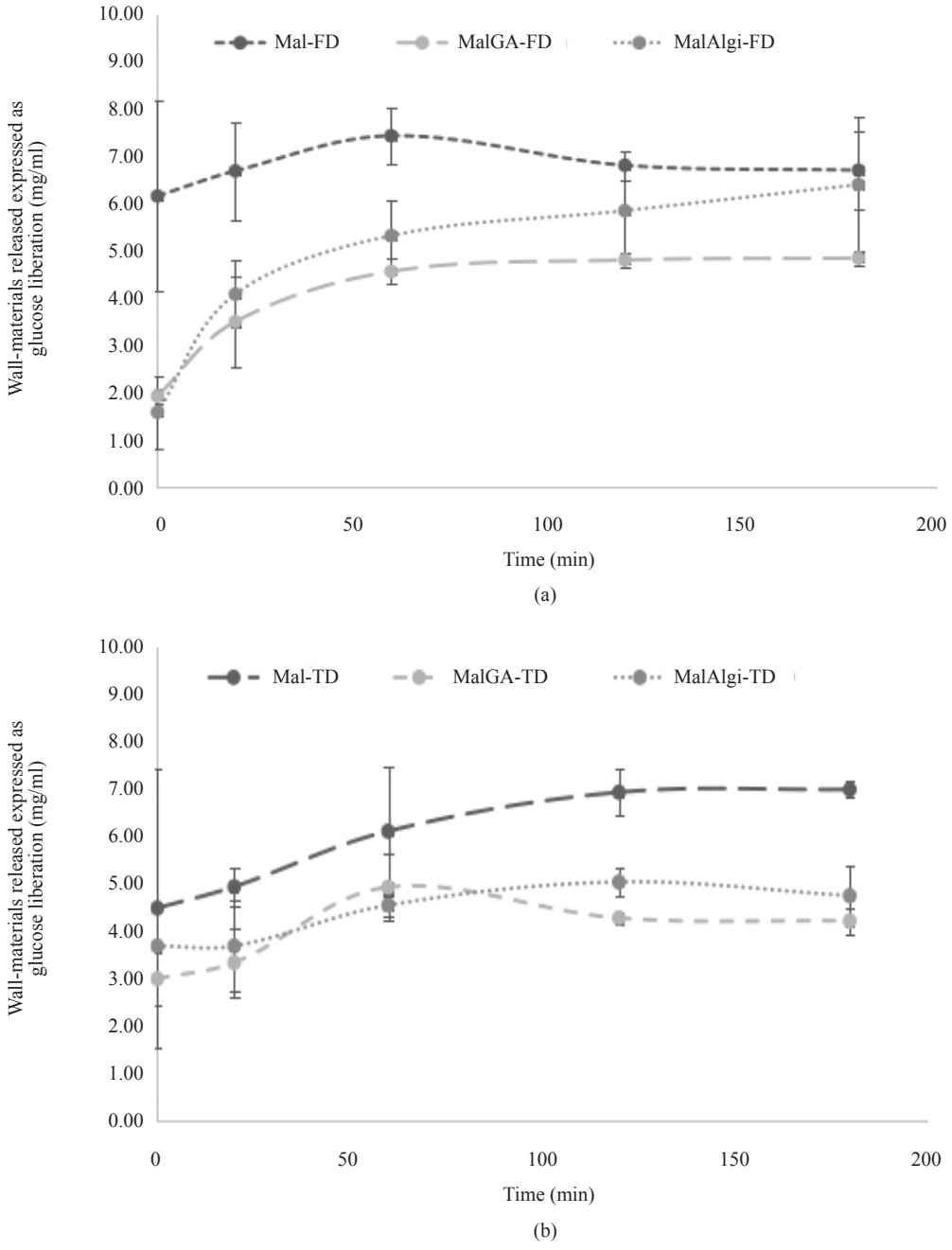


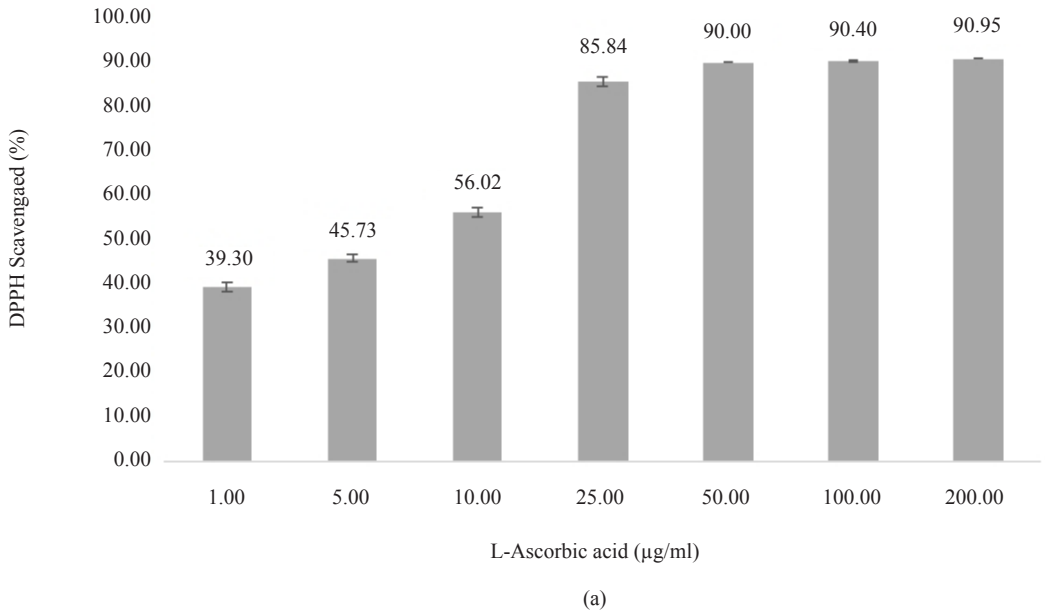
Figure 2. Wall material releasing expressed in glucose content of encapsulated chayote and kohlrabi extracts powder after amylolytic enzyme digestion. The drying methods are a) freeze-drying and b) tray-drying method; GA: Gum Arabic; Algi: Alginate; FD: Freeze Dry; TD: Tray Dry

To mimic the wall material susceptibility to amylolytic digestion of the encapsulated chayote and kohlrabi extracts powder, all samples were subjected to combine amylolytic enzymes treatment. Generally, the wall material releasing which was expressed in glucose content of encapsulated chayote and kohlrabi extracts powder after amylolytic enzyme digestion, was measured in *in vitro* gastrointestinal digestion. As shown in Figure 2, Mal-FD and Mal-TD samples provided higher wall material releasing than the other samples. The combination of maltodextrin and 1) gum arabic or 2) alginate displayed less susceptibility to amylolytic enzymes digestion compared to pure maltodextrin. Moreover, a higher solubility of the wall-materials (Table 3, pure maltodextrin) has an influence on the releasing of encapsulated compounds, which affects their bioaccessibility. The link between bioaccessibility and wall-material releasing is that the encapsulation wall-materials provided an effective in protecting those extracts during gastrointestinal conditions, controlling their delivery, and enhancing its bio accessibility. Types of encapsulation wall-materials were able to protect these extracts against the acidic condition in the stomach, allowing protecting and appropriately delivering the active compounds through the gastrointestinal tract. This finding broadly supports the work of other studies in this area linking the types of wall materials with wall materials releasing during *in vitro* digestion. Velderrain-Rodríguez et al., [27] reported the data of *in vitro* digestibility and releasing properties of a mango peel extract encapsulated within water-in-oil-in-water emulsions containing sodium Carboxymethyl Cellulose, (CMC). The results showed that a slower lipid digestion rate was observed in emulsions containing CMC which also accords with our observations. In addition, Ferreira-Santos et al., [30] studied the encapsulated pine bark extract by spray-drying using maltodextrin. The results showed that pine bark extracts can be effectively encapsulated in maltodextrin through spray-drying, resulting in a protective effect on the phenolic compounds degradation (increased stability and bioaccessibility) during the digestion process. In the case of the combination of maltodextrin and gum arabic or alginate in this study, the MalAlgi-FD (Figure 2a) and MalAlgi-TD (Figure 2b) samples showed similar wall materials releasing pattern. This result can imply that there was no difference between drying methods (freeze-drying and tray-drying methods) during the encapsulation process. These results interpreted that the type of wall material affected both and digestibility. Thus, the behavior of the encapsulated chayote and kohlrabi extracts in an emulated gastrointestinal medium was dependent on their type and properties of the wall material which were used for encapsulation and their susceptibility to amylolytic enzymes. Moreover, it is known that the gut microbiota which is mainly found in the colon, provided several functions that the host cannot accomplish on its own. Thus, choosing of wall materials are contributed to an increase in the bioaccessibility of the encapsulated chayote and kohlrabi extracts powder in the intestine.

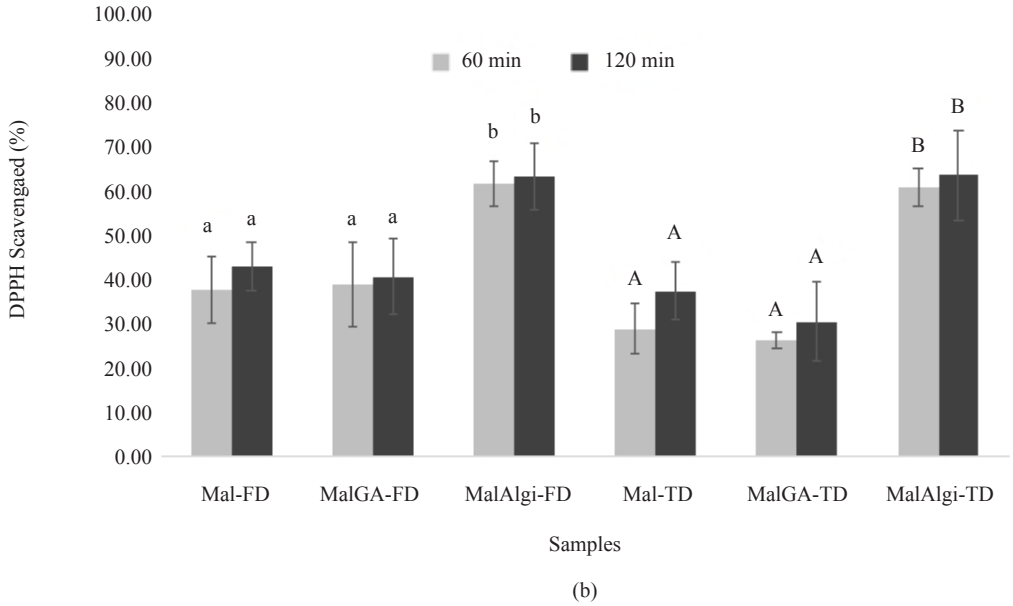
3.3 *Antioxidant activity of digested residue of encapsulated chayote and kohlrabi extracts by DPPH method*

According to the wall materials released by *in vitro* digestion analysis, the digested residue of encapsulated chayote and kohlrabi extracts powder were examined for antioxidant activity by the DPPH method. Basically, the peculiarity of the DPPH method was allowed for testing of both lipophilic and hydrophilic compounds which nitrogen-centered free radical produces violet/purple color in ethanol solution and fades to shades of yellow color in the presence of antioxidants [21]. Vitamin C was used as a positive control sample due to its antioxidant activity and the DPPH radical scavenging activities of vitamin C were 39.30-90.95% in a range of vitamin C from 1-200 µg/ml (Figure 3a). The DPPH scavenging activities of the digested residue of encapsulated chayote and kohlrabi extracts powder at 60 min and 120 min showed the highest activity ($p \leq 0.05$) when using the combination of maltodextrin and alginate (MalAlgi-FD and MalAlgi-TD) for both freeze-drying and tray-drying techniques. The DPPH scavenging activities of MalAlgi-FD and MalAlgi-TD provided approx. 60%, which was closed to the DPPH scavenging activities when using 10 µg/ml vitamin C (Figure 3b). The results were similar to the data of Suyalek et al., [28] reported that the combination of maltodextrin and hydrocolloids (gelatin and gum arabic) as wall materials could maintain higher antioxidant activity than only maltodextrin. In addition, longer digestion time (120 min) of all samples provided higher DPPH scavenging activities than shorter digestion time (60 min). These results indicated that all wall materials could protect the bioactive compounds in the extracts during digestion in the small intestine. This result was also related to the encapsulated morphology that affected the DPPH scavenging activities during digestion. In addition, several researchers reported the factor that influenced the antioxidant activity such as drying temperature and types of wall material [22, 29]. From the result of wall materials releasing and antioxidant activity, in each wall material, the results

showed a correlation ($p \leq 0.01$) between drying technique, wall materials releasing, and antioxidant activity at 0, 60, and 120 min. Moreover, the results in each drying technique correlated ($p \leq 0.05$) only with antioxidant activity at 0, 60, and 120 min. Thus, characteristics and antioxidant activity of encapsulated chayote and kohlrabi extracts powder after digestion were related to the drying technique and encapsulated wall materials types. This data can lead to a better understanding of wall materials types and releasing characteristics, which are used to control bioactive compounds liberation in the gastrointestinal tract.



(a)



(b)

* Different small letters indicate significant difference at $p \leq 0.05$ in freeze drying technique
** Different capital letters indicate significant difference at $p \leq 0.05$ in tray drying technique

Figure 3. Antioxidant activity of positive control (a), and digested residue of encapsulated chayote and kohlrabi extracts at 60 min and 120 min (b) by DPPH method.
Mal: Maltodextrin; GA: Gum Arabic; Algi: Alginate; FD: Freeze Dry; TD: Tray Dry

4. Conclusion

Chayote and kohlrabi extracts were encapsulated by maltodextrin and the combination of maltodextrin and gum arabic or guar gum with freeze-drying or tray-drying techniques. The morphology of all encapsulated extracts powder displayed irregular spherical shape, homo-dispersity, and smooth surface. Darkness and redness value were mostly found for the encapsulated chayote and kohlrabi extracts powder with tray-drying technique than that of freeze-drying technique. All samples showed high solubility, low moisture content, and Aw. Encapsulation by using maltodextrin as wall materials provided higher wall material releasing than that of the other samples. After digestion analysis, the digested residues were examined for the antioxidant activity and the results showed that the combination of maltodextrin and alginate as wall material for both freeze-drying and tray-drying techniques showed higher antioxidant activity after 60 and 120 min of digestion. The antioxidant activity of encapsulated chayote and kohlrabi extracts powder after digestion were related to the drying technique and encapsulated wall materials types. Thus, the combination of maltodextrin and alginate, and drying with freeze-drying technique in this experiment was the best treatment for the target activity in the small intestine. These data can lead to a better understanding of wall materials characteristics. However, the ratio of the combination of maltodextrin and alginate should be appended study in the future.

Conflict of interest

The authors declare that there are no conflicts of interest.

References

[1] Díaz-de-Cerio E, Verardo V, Fernández-Gutiérrez A, Gómez-Caravaca M. New insight into phenolic composition of chayote (*Sechium edule* (Jacq.) Sw). *Food Chemistry*. 2019; 295: 514-519.

[2] Ragasa CY, Biona K, Shen CC. Chemical constituents of *Sechium edule* (Jacq.) Swartz. *Der Pharma Chemica*. 2014; 6: 251-255.

[3] Ordoñeza AAL, Ordoñez RM, Zampini IC, Isla MI. Design and quality control of a pharmaceutical formulation containing natural products with antibacterial, antifungal and antioxidant properties. *International Journal of Pharmacology*. 2009; 378: 51-58.

[4] Wu CH, Ou TT, Chang CH, Chang XZ, Yang MY, Wang CJ. The polyphenol extract from *Sechium edule* shoots inhibits lipogenesis and stimulates lipolysis via activation of AMPK Signals in HepG2 Cells. *Journal of Agricultural and Food Chemistry*. 2014; 62: 750-759.

[5] Trejo-Moreno C, Castro-Martínez G, Méndez-Martínez M, Jiménez-Ferrer JE, Pedraza-Chaverri J, Arrellín G, et al. Acetone fraction from *Sechium edule* (Jacq.) S.w. edible roots exhibits antiendothelial dysfunction activity. *Journal of Ethnopharmacology*. 2018; 220: 75-86.

[6] Branca F, Ragusa L, Scalzo RL, Picchi V, Argento S. Phytochemical profile of kohlrabi (*Brassica oleracea* l. var. gongylodes) cultivated in Italy. *Acta Horticulturae*. 2013; 1005: 285-292.

[7] Sassi AB, M′hamed AC, Chahdoura H, Tounsi MS, Mastouri M, Salem HB. Variation in biochemical profile and health beneficial compounds and biological activities of *Brassica oleracea* var gongylodes L. morphological parts. *Journal of Food Measurement and Characterization*. 2020; 14: 1192-1200.

[8] Goetz JK, Schraudolf H. Two natural indole glucosikclates from Brassicaceae. *Phytochemistry*. 1983; 22: 905-907.

[9] Sharma I, Aaradhya M, Kodikonda M, Naik PR. Antihyperglycemic, antihyperlipidemic and antioxidant activity of phenolic rich extract of Brassica oleraceae var gongylodes on streptozotocin induced Wistar rats. *SpringerPlus*. 2015; 4: 212.

[10] Park CH, Yeo HJ, Kim NS, Eun PY, Kim SJ, Arasu MV, et al. Metabolic profiling of pale green and purple kohlrabi (*Brassica oleracea* var. gongylodes). *Applied Biological Chemistry*. 2017; 60: 249-257.

[11] Lee JW, Lee DY, Baek DR, Jeong RH, Lee DS, Kim YC, et al. Phenylpropanoids from red kohlrabi sprouts inhibits nitric oxide production in RAW 264.7 macrophage cells. *Journal of Food Science and Biotechnology*. 2014; 23: 965-969.

[12] Lee JW, Lee DY, Cho JG, Baek NI, Lee YH. Isolation and identification of sterol compounds from the red kohlrabi (*Brassica oleracea* var. gongylodes) sprouts. *Journal of Applied Biological Chemistry*. 2010; 53: 207-211.

[13] Castro-López C, Espinoza-González C, Ramos-González R, Boone-Villa VD, Aguilar-González MA, Martínez-Avila GCG, et al. Spray-drying encapsulation of microwave-assisted extracted polyphenols from *Moringa oleifera*: Influence of tragacanth, locust bean, and carboxymethyl-cellulose formulations. *International Food Research Journal*. 2021; 144: 110291.
[14] Grgić J, Šelo G, Planinić M, Tišma M, Bucić-Kojić A. Role of the encapsulation in bioavailability of phenolic compounds. *Antioxidants*. 2020; 9: 923.
[15] Misha S, Mat S, Ruslan MH, Sopian K, Salleh E. Review on the application of a tray dryerer system for agriculture products. *World Applied Sciences Journal*. 2013; 22(3): 424-433.
[16] Shukla, S. Freeze drying process: A review. *International Journal of Pharmaceutical Sciences and Research*. 2011; 2(12): 3061-3068.
[17] Muñoz-Shugulí C, Vidal CP, Cantero-López P, Lopez-Polo J. Encapsulation of plant extract compounds using cyclodextrin inclusion complexes, liposomes, electrospinning and their combinations for food purposes. *Trends in Food Science and Technology*. 2021; 108: 177-186.
[18] Sawale PD, Patil GR, Hussain SA, Singh AK, Singh RRB. Release characteristics of polyphenols from microencapsulated Terminalia arjuna extract: Effects of simulated gastric fluid. *International Journal of Food Properties*. 2017; 20(12): 3170-3178.
[19] Schoch TJ, Leach HW. Swelling power and solubility of granular starches. In: Whistler RL (Ed.) *Methods in Carbohydrate Chemistry*. New York, Academic Press. 1964; p. 107-108.
[20] Sopade PA, Gidley MJ. A rapid in-vitro digestibility assay based on glucometry for investigating kinetics of starch digestion. *Starch-Stärke*. 2009; 61(5): 245-255.
[21] Olugbami JO, Gbadegesin MA, Odunola OA. In vitro free radical scavenging and antioxidant properties of ethanol extract of terminalia glaucescens. *Pharmacognosy Research*. 2015; 7(1): 49.
[22] Yu Y, Lv Y. Degradation kinetic of anthocyanins from rose (*Rosa rugosa*) as prepared by microencapsulation in freeze-drying and spray-drying. *International Journal of Food Properties*. 2019; 22(1): 2009-2021.
[23] Ravichandran K, Palaniraj R, Saw NMMT, Gabr AMM, Ahmed AR, Knorr D, Smetanska I. Effects of different encapsulation agents and drying process on stability of betalains extract. *Journal of Food Science and Technology*. 2014; 51(9): 2216-2221. Available from: doi: 10.1007/s13197-012-0728-6.
[24] Zhang C, Quek SY, Fu N, Liu B, Kilmartin PA, Chen XD. A study on the structure formation and properties of noni juice microencapsulated with maltodextrin and gum acacia using single droplet drying. *Food Hydrocolloids*. 2019; 88: 199-209. Available from: doi: 10.1016/j.foodhyd.2018.10.002.
[25] Pudziuvelyte L, Marksa M, Sosnowska K, Winnicka K, Morkūnienė R, Bernatoniene J. Freeze-drying technique for microencapsulation of *Elsholtzia ciliata Ethanolic* extract using different coating materials. *Molecules*. 2020; 25: 2237.
[26] Borompichaichartkul C, Hamad A, Suriyarak S. Encapsulation of curcumin by spray drying using the combination of tween 80 and chitosan. *Journal of Food Technology, Siam University*. 2020; 15(2): 96-109.
[27] Velderrain-Rodríguez GR. Salvia-Trujillo L, Wall-Medrano A, González-Aguilar GA, Martín-Belloso O. In vitro digestibility and release of a mango peel extract encapsulated within water-in-oil-in-water (W1/O/W2) emulsions containing sodium carboxymethyl cellulose. *Food & Function*. 2019; 10(9): 6110-6120.
[28] Suyalek S, Jaturonglumlert S, Amornlerdpison D, Narkprasom N, Narkprasom K. Encapsulation of crude extracts from banana (*Musa X paradisca*) flowers by spray drying. *Burapha Science Journal*. 2020; 25(2): 448-463.
[29] Setiawan AP, Kumalaningsih S, Wignyanto W. The encapsulation of noni fruit using foam mat drying method. *Industria: Jurnal Teknologi Dan Manajemen Agroindustri*. 2020; 9(2): 91-98.
[30] Ferreira-Santos P, Ibarz R, Fernandes JM, Pinheiro AC, Botelho C, Rocha CMR, et al. Encapsulated pine bark polyphenolic extract during gastrointestinal digestion: Bioaccessibility, bioactivity and oxidative stress prevention. *Foods (Basel, Switzerland)*. 2021; 10(2): 328.