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LE PHAM TAN QUOC[1,2]
NGUYEN VAN MUOI[1]

[1]Departement of Food Technology, College of Agriculture and Applied Biology, Can Tho University, Ninh Kieu District, Can Tho City, Vietnam
[2]Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, Go Vap District, Ho Chi Minh City, Vietnam

SCIENTIFIC PAPER

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PHYSICOCHEMICAL PROPERTIES OF *Polygonum multiflorum* THUNB. ROOT POWDER PRODUCED WITH DIFFERENT CARRIER AGENTS

Article Highlights

- Spray dried powder remains, *TPC* and *AC* of *Polygonum multiflorum* Thunb. root extract
- *TPC* and *AC* values of GA after spray drying process were higher than that of MD
- Physicochemical properties of spray dried powder were absolutely different with the initial material

Abstract

Polyphenol is a valuable compound found in plants. Unfortunately, it is quite sensitive to heat, light and oxygen in the air. This is a disadvantage making the storage of these compounds for longer periods of time difficult. However, this problem can be overcome by encapsulation with carrier agents as maltodextrin, gum arabic, modified starch, etc. The efficiency of maltodextrin (MD, DE16-19) and gum arabic (GA) on spray drying of Polygonum multiflorum Thunb. root extract was investigated. The incorporation of gum arabic to the extract had the total polyphenol content (TPC) and antioxidant capacity (AC) higher than maltodextrin. The obtained powders from gum arabic and maltodextrin were analyzed for encapsulation yield, moisture content, color parameters, total phenolic content, antioxidant capacity, bulk density, wettability, hygroscopicity, water solubility index, particle size and microstructure. The results showed the types of carrier agents which significantly affected the physicochemical properties of powders produced by spray drying.

Keywords: carrier agent, gum arabic, maltodextrin, Polygonum multiflorum Thunb., spray drying.

It is well known that polyphenol from plant based foods and medicines has an important role in human health. Polyphenols in plants are antioxidant compounds which can combat many syndromes such as cancer, cardiovascular diseases, diabetes, intellectual disability, neurodegenerative disorders, etc. [1]. In addition, phenolic compounds are reducing agents and have high antioxidant capacity. There are many studies which have found these bioactive compounds safe and easy to use in medicine and food to replace synthetic antioxidants, especially natural antioxidants, in prevention of lipid oxidation in seafood [2].

Hà thủ ô đỏ (in Vietnamese), *Polygonum multiflorum* Thunb., is widely planted in Vietnam, China and Korea, and is one of the special herbal plants containing high levels of bioactive compounds in the root like polyphenol, gallic acid, resveratrol, catechin, physcion, rhein, emodin and more than 100 other compounds. For thousands of years, local people have used this wild plant as a traditional medicine for its anti-aging effects, hepatoprotective activities, effects against cancer, etc. [3]. In Vietnam, harvesting the root from this plant is quite difficult because *P. multiflorum* Thunb. is a wild herbal plant and is largely distributed in the mountainous region in the north of the country. Besides, it takes about 4 to 5 years for the plant to grow to be ready for harvesting [4].

Correspondence: L.P.T. Quoc, Departement of Food Technology, College of Agriculture and Applied Biology, Can Tho University, Campus II 3/2 street, Ninh Kieu District, Can Tho City, Vietnam.
E-mail: ephamtanquoc@iuh.edu.vn
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Nowadays, there are many methods to extract phenolic compounds from *P. multiflorum* Thunb., but the microwave-assisted extraction with acetone as solvent was used in this study because it can achieve high *TPC* and *TEAC* values and make the spray dried product good. Spray drying of the root extract may be a good method for these compounds to keep their quality and maintain low water activity and would make them easier to store and transport [5]. This method has been widely used for commercial production of dried vegetables, fruits and medicines. Moreover, spray drying is a highly suitable method for the oxygen- and light-sensitive components, especially polyphenol. This process has been successfully applied for polyphenol stability in plant foods, for instance *Morinda Citrifolia* L. [6], guava leaves [7] and *Emblica officinalis* [8].

The changes of properties of the spray dried product depend on many factors of the spray drying process such as inlet/outlet temperature, feed flow rate, air flow speed, type of carrier agent, atomizer pressure, etc. However, we are interested in the physicochemical properties of the type of carrier agents in this study. There are many carrier agents, such as gum arabic, gelatin, modified starch, maltodextrin and whey protein isolate, which may serve as a drying aid to core encapsulation. Among them, gum arabic and maltodextrin are widely used for spray drying because they increase the stability of polyphenol and are commercially available and reasonably priced. Until now, there has been few published studies about the pharmaceutical values of *P. multiflorum* Thunb. root, no research studies about the spray drying process of its extract nor comparisons of physicochemical properties of the encapsulating agents. Hence, the main aim of this research was to investigate the different physicochemical properties of maltodextrin and gum arabic before and after spray drying and to investigate, under the same conditions of the spray drying process, the encapsulation yield, moisture content, colour parameters, total phenolic content, antioxidant capacity, bulk density, wettability, hygroscopicity, water solubility index, particle size and microstructure.

EXPERIMENTAL

Sample preparation

P. multiflorum Thunb. roots were harvested from the Cao Bang province, Vietnam. The roots were then washed with tap water, sliced and dried at 60 °C until the moisture level was less than 12%. The slices were then ground into fine powder (diameter less than 0.5 mm) and vacuum-packed.

Chemicals and reagents

Maltodextrin (MD, 16-19DE) was obtained from GPC, USA, and and gum arabic (GA) was supplied by Tianjin Dengfeng, China. Folin-Ciocalteu and DPPH (2,2-diphenyl-1-picrylhydrazyl, purity: ≥ 90%) reagents were purchased from Merck. A trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid, purity: 97%) reagent was purchased from Sigma-Aldrich, USA and all other chemicals and organic solvents were of analytical reagent grade.

Microwave-assisted extraction (MAE)

Polyphenols from dried powder of *P. multiflorum* Thunb. roots were extracted by a microwave system with acetone concentration of 57.35%, solid/solvent ratio of 1/39.98, extraction time of 289 s and microwave power of 127 W. The crude extract was filtered by Whatman paper. The filtered extract was evaporated at 45 °C to increase the extract concentration until a level of 4% of soluble solid was reached. The extract was then stored in a closed container at 4 °C [9].

Spray drying of *Polygonum multiflorum* Thunb. root extracts

Initial extracts after concentration by evaporation were at a level of 4 % of soluble solid. After that, gum arabic and maltodextrin were added into the extract with levels of soluble solid reaching 15 and 25%, respectively. The solution was well mixed and then fed into a Lab Plant SD-06 spray dryer. The feed flow rate, inlet/outlet temperature and air flow speed were approximately set at 500 mL/h, 160/70 °C and 5 m/s. After the spray drying process was completed, the dried powders were collected and vacuum-packed.

Encapsulation yield (*EY*)

EY was measured as the ratio of the dried mass of obtained powder to the dried mass of the initial substances, including the dried added carrier agent and the dried substances in the extract.

Determination of total polyphenol content (*TPC*)

The *TPC* in the extract was slightly modified and determined by the Folin-Ciocalteu colorimetric method [10]. The results were based on a standard curve obtained with gallic acid. *TPC* was expressed as mg of gallic acid equivalent per gram of dry weight (mg GAE/g DW).

Determination of antioxidant capacity (*AC*)

The *AC* of the extract was determined by DPPH assay which was adapted from Soto *et al.* (2014) [11] and slightly modified. Trolox was used as the standard. AC was expressed in TEAC (Trolox equivalent antioxidant capacity) determined as µmol of Trolox per gram of dry weight (µmol TE/g DW).

Bulk density

An amount of 2 g powder was added into an empty 10 mL graduated cylinder and shaked by a vortex vibrator for 1 min. The bulk density value was determined by the ratio of mass of the powder and the volume occupied in the cylinder [12].

Hygroscopicity

For hygroscopicity, 1.5 g of the powder was placed in a closed container containing the saturated solution of sodium carbonate. After 1 week, the powder sample was weighed and hygroscopicity was expressed as gram of adsorbed moisture per 100 g of powder [13].

Water solubility index (*WSI*)

Spray dried powder (2.0 g) and deionized water (25 mL) were vigorously mixed, incubated at 37 °C in a water bath for 30 min. Then the mixture was centrifuged for 20 min at 10000 rpm. The supernatant was separated and dried at 103±2 °C in an oven. The *WSI* (%) was expressed as the percentage of dried supernatant to the amount of the original powder [14].

Flowability

Flowability was determined by using measurement of angle of repose (AOR). The powder was poured slowly into the funnel which was held at a fixed height above the flat base. AOR was calculated by the height and radius of the powder on the flat base [15].

Wettability

The method to determine wettability was adapted from Freudig *et al.* (1999), with slight changes [16]. A volume of 100 mL water was first placed in a 250 mL beaker at room temperature. Then, 1 g of powder was gently tipped from a dish. The time for the whole amount of powder to visibly sink beneath the water surface was recorded as an indicator of wettability.

Color parameter

The color parameter consists of L^* (lightness), a^* (redness and greenness) and b^* (yellowness and blueness) values, which were determined using a Chroma Meter CR-400 (Minolta, Japan).

Particle size

A laser scattering particle size distribution analyzer (Horiba LA-960, Japan) was used to determine the particle sizes of the spray dried powder.

Scanning electron microscopy (SEM)

The morphology of the spray dried powder was examined by a Jeol JSM-7401F scanning electron microscope system. Samples were observed at 2000× magnification.

Data analysis

The experimental data was analyzed by the one-way analysis of variance (ANOVA) method and significant differences among the means from triplicate analysis at $p < 0.05$ were determined by Fisher's least significant difference (*LSD*) procedure using Statgraphics software (Centurion XV). The values obtained were expressed in the form of a mean±standard deviation (*SD*).

RESULTS AND DISCUSSION

Moisture, *TPC*, *TEAC* and *EY* of spray dried powder

Table 1 shows that the moisture of the two samples after spray drying significantly decreased in comparison with their corresponding initial materials ($p < 0.05$). The decrease of moisture depends on the properties of the carrier agent. Concentration of carrier agent increases with the decrease of the moisture of the spray dried product. This result is in agreement with Kha *et al.* who spray dried Gac powder and increased concentration of MD from 10 to 20%. It resulted in a decrease of moisture content of the samples from 4.87 to 4.06% [17]. In addition, the moisture of the product also depends on the drying temperature where increasing drying temperature results in a significant drop in moisture content and

Table 1. TPC, TEAC, EY and moisture of spray dried powder; different superscript letters in the same column denote significant differences (p < 0.05); MD-E: maltodextrin and extract after spray-drying; GA-E: gum arabic and extract after spray-drying

Sample	Moisture, %	*TPC* / mg GAE g^{-1} DW	*TEAC* / µmol TE g^{-1} DW	*EY* / %
Extract	-	47.53 ± 0.79^c	334.07 ± 3.04^c	-
MD	6.01 ± 0.16^c	-	-	-
GA	10.97 ± 0.03^d	-	-	-
MD-E	1.26 ± 0.15^a	20.54 ± 1.12^a	127.06 ± 3.76^a	60.4 ± 2.01^a
GA-E	4.01 ± 1.15^b	39.35 ± 0.23^b	146.97 ± 2.13^b	65.17 ± 1.34^b

the rate of heat transfer to the particle is greater. Besides, changes of moisture content are quite complicated when there are combinations of many carrier agents [18]. The moisture content of MD-E and GA-E in this study were 1.26 and 4.01%, respectively. This moisture is quite safe for storage because of low water activities.

High inlet temperature is a disadvantage for the spray drying process. It strongly affects *TPC* and *TEAC* of the received products. Compared with the initial extract, *TPC* and *TEAC* of MD-E retained approximately 43 and 38%; *TPC* and *TEAC* of GA-E retained 83 and 44%, respectively.

Although the sensitive bioactive compounds easily decomposed at high temperature, both of GA-E and MD-E retained *TPC* and *TEAC*. However, the received result shows that using GA as the carrier agent was more effective than MD because GA-E has the highest *TPC* and *TEAC* values. The reason for this is that the mean diameter of GA-E (19.17 μm) was higher than that of MD-E (17.52 μm); high diameter particles can contain a large amount of phenolic compounds. Tables 2 and 3 show the low *WSI* value and high wettability value of GA-E are advantages in protecting bioactive compounds inside the core. In other words, GA-E is more stable than MD-E. Therefore, the appearance of GA in the wall matrix can improve some properties of the product. Other research has yielded similar results, for instance *TPC* value of the wall matrix with 10% GA and 20% MD was higher than that of the wall matrix with 30% MD for spray drying process of guava leaf extract [7]. According to Tonon *et al.*, powders produced with GA had the greatest polyphenol retention after the spray drying process of *Euterpe oleraceae* Mart. extract, followed by the sample produced with MD 10 DE and 20 DE, while there was no significant difference in antioxidant capacity [19].

ANOVA results showed that there was a significant difference between the *EY* of spray dried products ($p < 0.05$). Particularly, *EY* of GA-E was higher than MD-E. *EY* depends on many factors, for instance inlet/outlet temperature, type of carrier agent, feed flow rate, air flow speed, etc. This may be due to the volatilization of the active component [17]. *EY* of the spray drying process does not reach the maximum level because of the wet powder stuck to the upper part of the chamber wall. *EY* of product in this study was lower than encapsulation of passion fruit extract (75-78%) [20], higher than encapsulation of *Morinda citrifolia* L. leaf extract (39%) [6] and similar with encapsulation of *Lippia sidoides* leaf extract (66-69%) [21].

Bulk density, hygroscopicity, water solubility index and flowability of spray dried powder

There was a significant difference in the bulk density of the samples ($p < 0.05$). Bulk density of powder after spray drying process was lower than that of the initial powder. High inlet temperature results in the rapid formation of a dried layer at the droplet surface and case-hardening of the droplets occurs. Vapor bubbles and vapor-impermeable films appear on the drop surface. This leads to droplet expansion and decreases bulk density [22]. Besides, bulk density also depends on total solid feed, feed flow rate, air flow rate, atomizer pressure and especially on the type of carrier agents [23]. Table 2 shows that bulk density of GA-E was lower than MD-E. However, MD-E in this study was higher than the finding of Mishra *et al.* who used MD for spray drying *Emblica offi-*

Table 2. Bulk density, hygroscopicity, water solubility index and flowability of spray dried powder; different superscript letters in the same column denote significant differences (p < 0.05); MD-E: maltodextrin and extract after spray-drying; GA-E: gum arabic and extract after spray-drying

Sample	Bulk density, g/mL	Hygroscopicity, g/(100 g)	Water solubility index (*WSI* / %)	Flowability (repose of angle, °)
MD	0.71±0.01^{c}	26.34±0.47^{a}	93.50±0.71^{b}	31.66±0.82^{b}
GA	0.69±0.00^{b}	26.82±0.47^{a}	84.50±0.71^{a}	31.13±0.60^{b}
MD-E	0.69±0.00^{b}	29±1.41^{b}	94.50±0.71^{b}	26.13±0.78^{a}
GA-E	0.53±0.01^{a}	37.16±0.1^{c}	92.00±2.83^{b}	37.66±2.75^{c}

Table 3. Wettability and color parameter of spray dried powder; different superscript letters in the same column denote significant differences (p < 0.05); MD-E: maltodextrin and extract after spray-drying; GA-E: gum arabic and extract after spray-drying

Sample	Wettability, s	L^*	a^*	b^*
MD	57±1^{a}	99.44±0.43^{d}	-0.34±0.06^{a}	1.28±0.02^{a}
GA	365±12^{c}	84.72±0.25^{b}	2.84±0.11^{c}	18.34±0.05^{d}
MD-E	155±2^{b}	93.84±0.95^{c}	3.14±0.14^{d}	3.00±0.06^{b}
GA-E	461±11^{d}	81.83±0.44^{a}	2.26±0.03^{b}	17.32±0.03^{c}

cinalis fruit extract and obtained a bulk density of 0.52 g/mL [8]. In addition, dextrose equivalent value and moisture content increase with the increase of high bulk density due to its stickiness [5].

Hygroscopicity of spray dried powder increased strongly, especially GA-MS. The links between the hydrogen present in water molecules and the hydroxyl groups available in the amorphous and crystalline regions of subtract also affect hygroscopicity, especially MD-E. MD-E and GA-E consist of a high number of hydrophilic groups and thus easily bind water molecules from the surrounding air [5]. Hygroscopicity of MD-E and GA-E augmented approximately 10 and 39%, respectively. In addition, particle size significantly affects hygroscopicity; the smaller the particle size, the bigger the exposed surface and this leads to greater water adsorption from the surrounding air. The results were in agreement with Tonon *et al.* who spray dried *Euterpe oleraceae* Mart. fruit extract [19]. Besides, inlet air temperature increased with the decrease of the moisture of products. There is a great moisture gradient between the dried product and the surrounding air so it is quite easy for the product to absorb the moisture from the surrounding air. The high hygroscopicity is a disadvantage for storage but the result of this study was lower than that of other researchers such as Ersus and Yurdagel who spray dried carrot extract by MD and hygroscopicity achieved ranged from 72.83 to 83.33 g/(100 g) [24], while Mishra et al. used MD to encapsulate *Emblica officinalis* fruit extract and achieved hygroscopicity ranging from 46.03 to 53.01 g/(100 g) [8].

Table 2 shows that WSI of MD and MD-E were not significantly different ($p<0.05$). Conversely, WSI of GA-E changed dramatically, increasing from 84.5 to 92%. WSI of GA was lower than MD because GA has high viscosity, which makes it difficult to dissolve in water. Bigger particle size resulted in the smaller exposed surface, reduced contact with the continuous phase and low value WSI. WSI increases with increasing concentration of the carrier agent and inlet temperature [25] or decreasing dry air flow rate [5]. Besides, the type of the carrier agent can significantly affect *WSI*. In general, *WSI* of dried products was quite high, from 92 to 94.5%; these values were higher than *WSI* of tomato powder (17.65-26.73%) [26], *WSI* of Gac powder (36.91-38.25%) [17] and similar to Ginger powder (93.82%) [25].

The measurement of the angle of repose (*AOR*) can determine the flowability of particles. *AOR* of MD dropped from 31.66 to 26.13° while *AOR* of GA increased from 31.13 to 37.66° (Table 2). *AOR* increases with a decrease in flowability and flowability of GA-E was lower than MD-E. According to Carr (1965, 1970), flowability of MD-E in this study was better (*AOR* < 30°) and GA-E was cohesive (*AOR*: 30-40°) [27,28]. The flowability of particles depends on many factors such as storage temperature, moisture of particle and relative humidity. The dried powder absorbed moisture from the surrounding air on particle surface. It tends to dissolve soluble components and form liquid bridges between particles making them more cohesive [29]. The shape and particle size also affect flowability; the particle size decreases with an increase in surface area per unit mass and leads to reduction in flowability. Frictional forces resist the flow and more surface area is available for cohesive forces [30].

Wettability and color parameter of spray dried powder

Table 3 shows that there was a significant difference among the wettability of the powder samples ($p < 0.05$). Carrier agents also had different wettability, but wettability of GA was quite higher than MD, reaching 365 s. After spray drying, wettability values of MD-E and GA-E increased sharply and achieved 155 and 461 s. Wettability depends on shape, particle size and type of carrier agent. Besides, the moisture of the powder also strongly affects wettability. Normally, the moisture of initial materials is higher than in spray drying produce and there is the aggregation of dispersed material to material units of larger size. Then, the water penetrates easily into the pores of the powder and shortens the wettability time [31]. This result was considerably different from Fernandes *et al.*, who used GA and modified starch to spray dry rosemary essential oil and obtained wettability ranging between 301 and 254 s [32]. This study was also different from Wu *et al.* who spray dried skim milk powder at various feed solid contents and obtained wettability ranged between 45 and 79 s [33].

The results of color analysis are described in Table 3. Color parameters (L^*, a^*, b^*) of carrier agents were the considerably different. MD was lighter than the rest of the samples; MD-E and GA-E were darker than initial MD and GA. The a^* and b^* value of samples also changed considerably. Changes were due to the color of the extract which was mixed with carrier agents. In addition, color parameters were affected by inlet temperature, feed flow rate, air flow rate and soluble solid content [34]. In addition, many phenolic compounds degrade at high inlet temperature but some phenolic compounds remain, such as tannins, which can react slowly with iron in the absence of oxygen and form dark-colored complexes [8].

Smaller particle size and the increased surface area cause rapid pigment oxidation [35]. This leads to changes in the color of the samples.

Microstructure and particle size of spray dried powder

MD-E and GA-E were the encapsulating agents enabling the formation of homogeneous particles. Dried powder particles have spherical shapes with many wrinkles on their surfaces, especially GA-E. The rest of GA-E particles have many indentions and wrinkles, while MD-E has smooth surfaces and less wrinkles (Figure 1). The formation of these indentations is usually attributed to particle shrinkage due to the drastic loss of moisture during the spray drying process which is followed by cooling in a cyclone [18,19]. In addition, concave wrinkled surfaces have high surface and increase frictional forces. They change physical properties of particles such as AOR, bulk density, hygroscopicity, water solubility index, etc. The microstructure of particles depends on the inlet temperature and the type of carrier agent. According to Phisut, when the inlet air temperature is high, the particles have a smooth surface, causing faster water evaporation which leads to the formation of a smooth and hard crust; decreasing drying temperature results in a larger number of particles with a shriveled surface [5]. Microstructure of the encapsulating agents in this study was found to be in agreement with Pham *et al.*, who used MD and the combined MD and GA to spray dry guava leaf extract [7], and Pang *et al.* who spray dried *Orthosiphon stamineus* extract by MD and whey protein isolate [36].

Figures 2 and 3 show that particle size of the initial carrier agent fluctuated strongly from 1.5 to 600 µm for MD (45 sizes) and from 7 to 500 µm for GA (32 sizes). Mean diameters of MD and GA were 99.66 and 123.71 µm, respectively. All sizes of MD and GA were under 6.2%.

Particle size of MD-E and GA-E changed significantly and were smaller than that of MD and GA. Diameters of MD-E ranged between 0.15 µm and 260 µm (56 sizes), mean diameter of 17.52 µm and each size was under 9%, while diameters of GA were separated into 2 areas; one area had particles size from 0.115 to 0.6 µm (13 sizes), cumulative percent of 26 and the other area has particle size from 2 to 260 µm (37 sizes), cumulative percent of 74%. Mean diameter of GA-E was 19.17 µm. The results show that the diameter of particle decreases after the spray drying process. Particles size depends on the type of carrier agent, inlet temperature, feed flow rate [22], atomizer pressure, feed total solids, air flow rate [23] and vis-

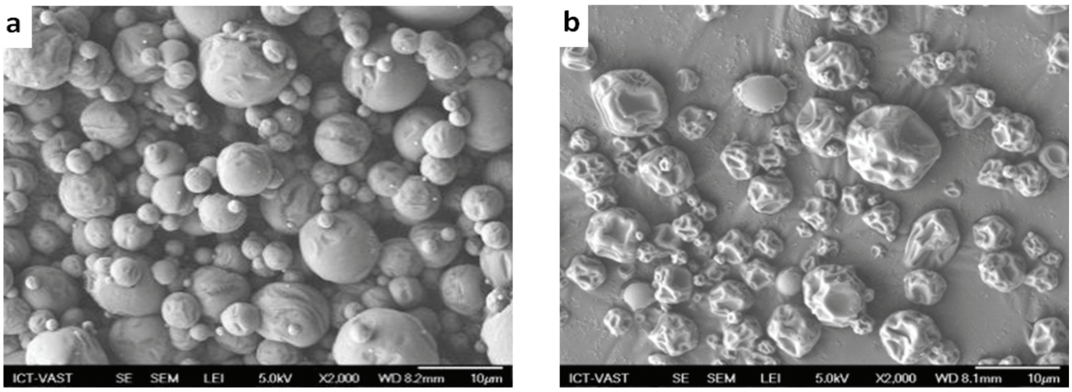

Figure 1. SEM microphotographs of MD-E (a) and GA-E (b) at 2000× magnification.

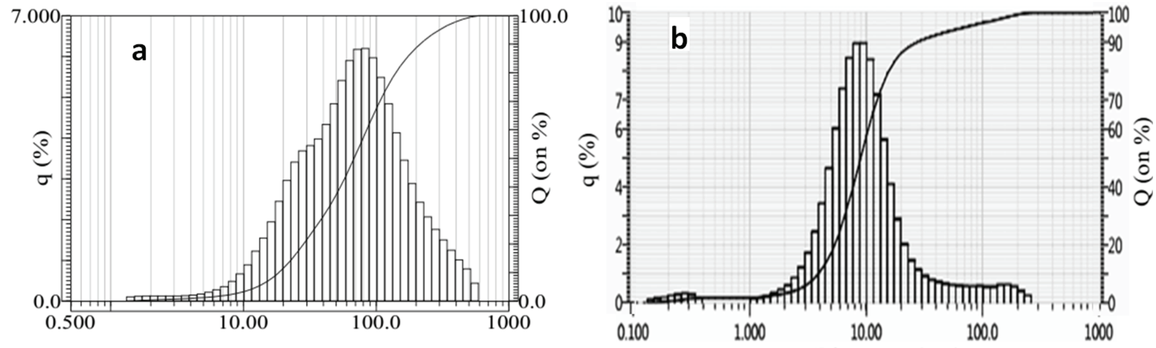

Figure 2. Particle size distribution curve of MD (a) and MD-E (b).

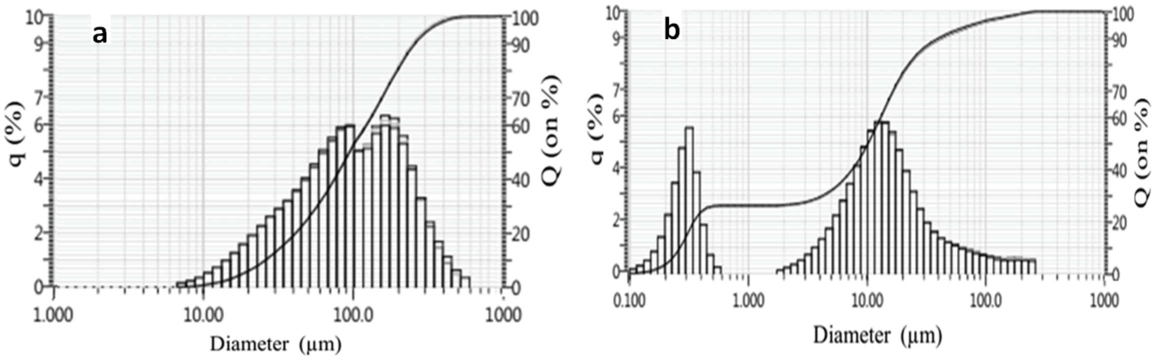

Figure 3. Particle size distribution curve of GA (a) and GA-E (b).

cosity of the encapsulated material [13,37]. Changes of particles size lead to changes in the physical properties of the powder such as bulk density, shape, flowability and dispensability.

CONCLUSION

All *P. multiflorum* Thunb. powder samples were produced by the spray drying method with different carrier agents which had low moisture content (1.26-−4.01%). This was an advantage for storage. MD-E had the highest bulk density and WSI, while GA-E had the highest encapsulation yield, hygroscopicity, flowability, wettability and mean diameter. The color of dried powder changed completely and the microstructures of the powder were spherical with many shriveled surfaces, especially GA-E. The TPC and TEAC retention of GA were higher than those of MD after the spray drying process. These results show that the type of carrier agent is a very important factor that strongly affects physicochemical properties of the dried product. Therefore, using GA as the carrier agent was the best choice in this study because there are three main factors that have the highest values: *TPC*, *TEAC* and *EY*.

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LE PHAM TAN QUOC[1,2]
NGUYEN VAN MUOI[1]

[1]Departement of Food Technology, College of Agriculture and Applied Biology, Can Tho University, Ninh Kieu District, Can Tho City, Vietnam
[2]Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, Go Vap District, Ho Chi Minh City, Vietnam

NAUČNI RAD

FIZIČKO-HEMIJSKE OSOBINE PRAHA KORENA *Polygonum multiflorum* THUNB. PROIZVEDENOG SA RAZLIČITIM NOSAČIMA

Polifenoli su vrlo važna jedinjenja za biljke. Nažalost, to su jedinjenja koja su prilično osetljiva na toplotu, svetlost i dejstvo kiseonika iz vazduha. Ovo je nedostatak o kome se mora voditi računa ako se ova jedinjenja skladište na duži vremenski period. Međutim, ovaj problem se može prevazići inkapsulacijom sa nosačima, kao što su: maltodekstrin, gumi arabika, modifikovani skrob, itd. U ovom radu analiziran je uticaj sprej sušenja na sastav ekstrakta korena Poligonum multiflorum Thunb. posle inkapsuliranja maltodekstrinom (MD, DE16-19) i gumi arabikom (GA). Inkorporacijom gumi arabike u ekstrakt dobija se veći ukupan sadržaj polifenola (TPC) i antioksidativnog kapaciteta (AC) nego kada se inkorporira maltodekstrin. Kod prahova koji su dobijeni sa gumi arabikom i maltodekstrinom analizirani su sledeći parametri: prinos inkapsulacije, sadržaj vlage, parametre boje, ukupan sadržaj fenola, antioksidativni kapacitet, ukupna gustina, omekšivost, higroskopnost, indeks rastvorljivosti vode, veličina čestica i mikrostruktura. Rezultati pokazuju koji nosači imaju značajan uticaj na fizičkohemijske osobine prahova proizvedenih sprej sušenjem.

Ključne reči: nosač, gumi arabika, maltodekstrin, Poligonum multiflorum Thunb., sprej sušenje.