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Instant tea from *Condonopsis javanica* L. root extract via spray drying

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Abstract:
Introduction. Codonopsis javanica L. root is a gingsen-like medicinal material with valuable bioactive compounds and alkaloids in its composition. However, the diversification of commercial products from *Codonopsis javanica* root extract is limited and poorly represented on the market. This study presents a new production process of an instant tea product from *Codonopsis javanica* root extract, which involved spray drying with maltodextrin as a drying additive.
Study objects and methods. The research featured different process parameters including a drying additive concentration, a drying temperature, and a feed flow rate. Moisture content and drying yield were selected as the main outcomes.
Results and discussion. In general, the improved drying yield was associated with an increased drying additive concentration, a lower drying temperature, and a higher feed flow rate. The best drying yield (78.35%) was obtained at the drying additive concentration of 30% (w/w), the drying temperature of 140°C, and the feed flow rate of 300 mL/h. The total saponin content in the product was 0.29% (w/w), and the ABTS free radical scavenging ability reached 59.48 µgAA/g. The obtained powder was spherical and exhibited fairly uniform particle morphology with shriveled and concave outer surface.
Conclusion. The research results justified the use of *Codonopsis javanica* as an ingredient in beverage industry and suggested maltodextrin as an appropriate substrate for spray-drying natural extracts.

Keywords: *Codonopsis javanica*, root extract, instant tea, spray drying, maltodextrin, process optimization, antioxidant activity, saponin

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INTRODUCTION

Codonopsis javanica L., known in Vietnamese as "Dangsam", is a member of the *Campanulaceae* family. It grows in the shade of trees and produces bell-shaped flowers [1–3]. *C. javanica* is a popular traditional herbal medicine in China. In Vietnam, it can be found in 14 mountainous Northern provinces, particularly in Lang Son, Cao Bang, Ha Giang, Lao Cai, and Son La, at the height of 500–1600 m above the sea level. It also grows in the highland areas of Southern provinces, including Quang Nam, Lam Dong, and Kon Tum, at an altitude of 1500 m [4, 5]. The habitats include pastureland, woodland edge in mountainous regions, hill slopes, and upland areas [6].

C. javanica contains valuable bioactive compounds and exhibits numerous pharmaceutical properties. Its root is known to contain glucose, essential oil, fatty substances, and alkaloids [7]. Past studies that employed nuclear magnetic resonance also registered codotubulosins A and B, adenosine and 5-(hydroxymethyl) furfural in quaternary ammonium alkaloids in the *C. javanica* roots [8]. Codonopsis roots contain such substances as polysaccharides, saponins, alkaloids, and phytosteroids, which significantly contribute to the pharmacological efficacy of the plant material [9, 10].

Extracts of *C. Javanica* or other species of codonopsis were used to treat diabetes and other illnesses [11–13]. They also possess strong antifatigue, antioxidant, antimicrobial, antitumor, and immune-boosting properties [14–17]. In *in vitro* experiments, *C. javanica* extract showed mutagenic, antimutagenic, anticancer, and antitumor properties against various human cell lines [18]. Polysaccharides from *C. javanica* were demonstrated to protect mice with cerebral ischemia-reperfusion injury [19]. Another experiment also proved the antilarval properties of *C. javanica* aqueous extract against *Aedes albopictus* pupae, a vector of Dengue fever [20].

In Vietnamese traditional medicine, *C. javanica* root is used to treat a number of disorders related to digestive and respiratory system [7]. Similar uses of *C. javanica* root were also reported in Chinese traditional medicine, the most popular preparation method being decoction or tea brewing [21]. As a result of the recent interest in health beneficial natural ingredients, plant extracts with functional properties are often included in instant tea formulations [22]. Instant tea formulation has the advantage of favorable aroma, stimulating effect, and convenience. To avoid degradation, the final moisture content of instant tea powder samples is approximately 3–5% [23].

The research objective was to investigate the parameters of instant tea production from *C. javanica* root extracts by spray drying. The parameters under analysis included moisture, drying yield, total saponin content, and antioxidant activity.

STUDY OBJECTS AND METHODS

Condonopsis javanica L. roots were purchased from the local farmers in the province of Kon Tum, Vietnam. They were harvested during the winter season at the age of two years. Then the roots were cut into smaller pieces, and their moisture content was reduced from 80.16% to 8.17% in a drying oven (Memmert UN110, Germany). The dried roots were mechanically powdered. Afterwards, 60% ethanol by volume was added to the powder in the amount of 40 mL per 1 g. The suspension was then subjected to hydrodistillation for 4 h at 60°C. Water was removed with a rotary evaporator until the weight of the solid in the extract was 40.3%. We obtained 65.75 g of dried extract from 100 g of input root powder. After multiple runs, the accumulated extract was stored in a cooler for spray drying.

To obtain instant tea, a drying additive (maltodextrin) was completely dissolved in 500 mL of distilled water and left at room temperature overnight. The solution was then mixed with the prepared *C. javanica* root extract at an appropriate ratio and then with Tween 80. The amount of the added Tween 80 equaled 5% of the weight of the prepared *C. javanica* root extract. After that, the mix was stirred at 6000 rpm for 20 min in a rotor-stator blender to allow emulsion formation. About 800 mL of the mix was then put into a lab-scale spray dryer (Pilotech YC-015 Mini Spray Dryer). The first single-factor investigation involved the effect of drying additive concentration on the properties of the product. The main spray drying parameters were the following: drying temperature = 140°C, feed rate = 120 mL/h. The dry powder collected was placed in the airtight glass bottle at 25°C for further examination.

The moisture content of the product was determined using the AOAC International (AOAC, 2007) method. The sample was dried in an oven at 105°C till constant weight. The dried sample was then measured for weight loss (%) and the moisture content (%) [24].

To determine drying yield, we used the following formula [25]:

$$DY(\%) = \frac{m_2 \times (1-y)}{m_1 \times x} \times 100$$

where m_1 is the weight of the feed solution, g; m_2 is the weight of the powder obtained by spray drying; x is solids, %; and y is the moisture content of the obtained powder product.

ABTS scavenging activity was determined using the method previously described by Pham *et al.* and Mradu *et al.* [26, 27]. To prepare the stock solution, 10 mL of 7.4 mM ABTS solution was dropped to 10 mL of 2.6 mM $K_2S_2O_8$ and kept at room temperature without exposure to light for 15 h for subsequent use. One milliliter of stock solution was diluted with 60 mL of methanol to get an absorbance value of 1.1 ± 0.02 at 734 nm to produce the working solution. Then 0.5 mL of the extract was added to 1.5 mL of the working solution and kept in darkness for 30 min at room temperature. A UV-VIS spectrophotometer recorded the absorbance of the mix at 734 nm. Ascorbic acid was used as a standard, and the results were expressed as µg ascorbic acid equivalents per gram of dried sample (µgAA/g).

To determine saponin content, 1 g of dried sample was finely powdered and solubilized in 20 mL of 20% isopropanol. The mixture was then heated in a microwave at 86°C for 20 min. The obtained mix was then filtered using Whatman paper for further quantitative purpose.

The saponin content was assessed spectrophotometrically as reported by Jennifer *et al.*, with minor modifications [28]. Briefly, 3.5 mL of the Liebermann – Burchards (LB) reagent, consisting of a 1:5 mix of acetic acid and sulfuric acid, was added to 1 mL of sample solution. If saponins were present, the sample solution fluoresced with yellow. The saponin content in the solution was then quantified by measuring its absorbance at 580 nm. The following calibration curve describes the relationship between absorbance and saponin concentration:

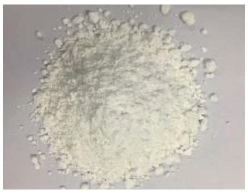
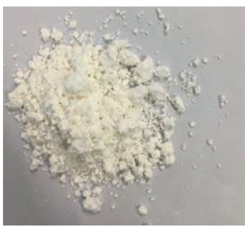
Absorbance (mg/mL) = 4.5725 × Concentration of saponins (mg/mL) + 0.0164.

Total saponins were calculated on the fresh weight basis.

The morphology of the spray-dried powder was studied by a scanning electron microscope (JSM 6300 SEM). The samples were mounted directly on aluminum SEM stubs in carbon conductive tape and covered by gold sputtering with a thin layer of gold.

Each measurement was carried out in triplicate. Statgraphic statistics software was used to evaluate the statistical data (Statpoint Technologies, version 20, Inc., Warrenton, VA, USA). The variance analysis (ANOVA) and the least significant difference (LSD) were calculated to compare the mean value of the film properties with $P = 0.05$.

Table 1 Moisture and texture of *C. javanica* instant tea at various maltodextrin concentrations

Maltodextrin concentration, %	Texture	Moisture, %
15		9.83 ± 0.087
20		9.27 ± 0.076
25		8.38 ± 0.066
30		7.09 ± 0.09
35		6.77 ± 0.05

RESULTS AND DISCUSSION

We determined the moisture and texture of powdered tea from *Condopopsis javanica* L. root extract obtained at various maltodextrin concentrations (Table 1). High concentrations seemed to result in the product with lower moisture and minor agglomerate formation.

Fig. 1 shows the dependence of drying yield on maltodextrin concentration. These impacts on drying yield were statistically significant ($P < 0.05$), as displayed by the one-way ANOVA analysis. Further LSD multiple range tests for drying yield values pointed out differences among the yields obtained at five distinct concentrations (15, 20, 25, 30, 35%). The highest drying yield (75.68%) was attained at the 30% concentration of maltodextrin. Generally, DY was directly proportional to the concentration that rose from 15% to 30%. This can be explained by the effect of exterior-active carbohydrates of maltodextrin, which attach with volatile compounds in the extracts [29]. As a result, higher concentrations of drying additives could support the remaining volatiles and simultaneously increase spray drying yield. As noted by Nunes and Mercadante, the high concentration of the drying additive (35% w/w) resulted in a caramelization reaction that produced furanones, furans, pyrones, and carbocyclic, thus reducing drying yield [30]. Due to the economical characteristic of maltodextrin, we used 30% of maltodextrin in the subsequent tests.

Table 2 shows the texture and moisture of the microcapsules obtained at different drying temperatures. Since an elevated temperature led to products with lower moisture content, we examined an effect of drying temperature on drying yield (Fig. 2). The results were statistically significant ($P < 0.05$), as displayed by

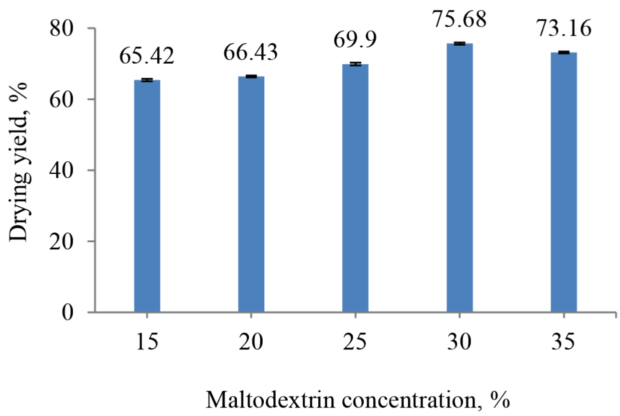


Figure 1 Drying yield of instant tea from *C. javanica* root extract at different maltodextrin concentrations

Table 2 Moisture and texture of instant tea from *C. javanica* root extract at different drying temperatures

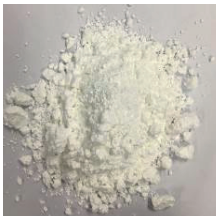
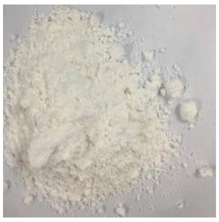
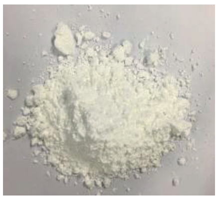
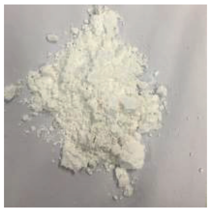
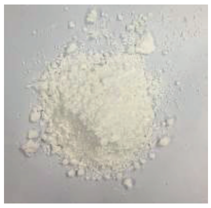
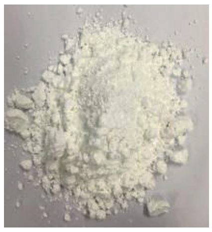
Drying temperature, °C	Texture	Moisture, %
140		6.77 ± 0.05
160		6.6 ± 0.075
180		6.01 ± 0.09
200		5.013 ± 0.1

Table 3 Moisture and texture of instant tea from *C. javanica* root extract at different feed flow rates

Feed flow rate, mL/h	Texture	Moisture, %
120		6.77 ± 0.05
180		7.05 ± 0.076
240		8.23 ± 0.112
300		8.71 ± 0.13

the one-way ANOVA analysis. Further LSD multiple range tests for drying yield pointed out well-defined differences among the yields obtained at different temperatures (140, 160, 180, 200°C). The greatest drying yield (75.68%) was achieved at 140°C. As the temperature rose from 140 to 200°C, drying yield decreased.

As previously mentioned, high inlet/outlet temperature (140°C) led to a caramelization reaction, thus decreasing drying yield [29]. Jafari *et al.* demonstrated that a relatively high inlet air temperature (160–220°C) may cause thermal damage to a dry substance, leading to a rapid development of semi-permeable membrane on the droplet surface [31]. These results are similar to the studies conducted by Fernandes *et al.* and Cortés-Camargo *et al.* [32, 33]. Considering the drying yield results, we decided to use the drying temperature of 140°C in out further experiments.

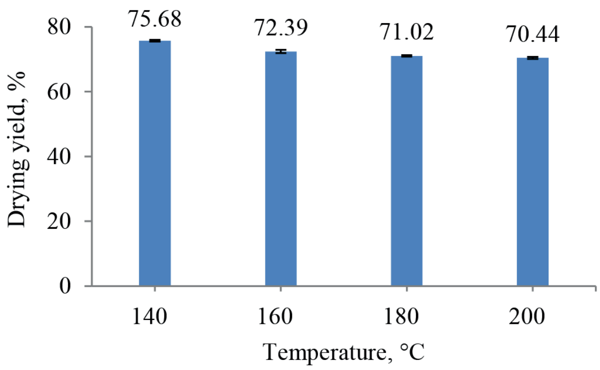


Figure 2 Drying yield of instant tea from *C. javanica* root extract at different drying temperatures

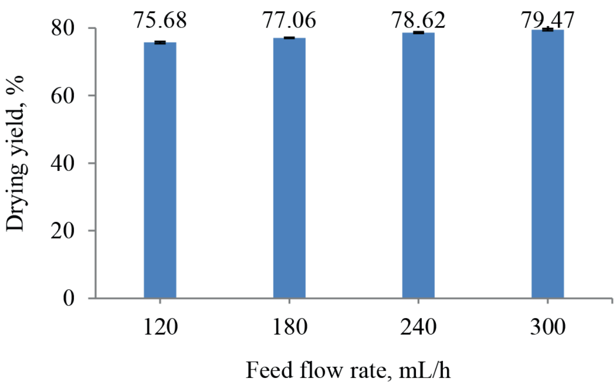


Figure 3 Drying yield of instant tea from *C. javanica* root extract at different feed flow rates

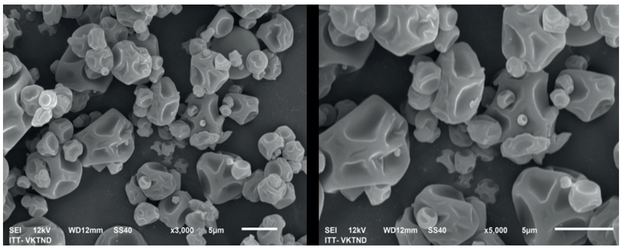


Figure 4 SEM images of instant tea from *C. javanica* root extract

Table 4 Total saponin content and free radical scavenging ability in instant tea from *C. javanica* root extract

Product	Saponin, %	ABTS, μgAA/g
Condonopis javanica root extract	0.41	168.88
Instant tea	0.29	59.48
Performance recovery	69.00	35.22

Table 3 demonstrates the moisture and texture of the instant tea at different feed flow rates. An increased feed flow rate improved the moisture in the obtained product. We then examined these differences of feed flow rate with respect to drying yields, as shown in Fig. 3. These impacts on drying yield were statistically significant ($P < 0.05$), as indicated by the one-way ANOVA analysis. In addition, the yields obtained at different particular feed flow rates (120, 180, 240, 300 mL/h) were statistically different. The largest drying yield (79.47%) was achieved at 300 mL/h. Generally, as the feed flow rate rose from 120 to 300 mL/h, drying yield increased.

Jumah *et al.* showed that the feed flow rate was faster at droplet atomization stage, which led to larger droplets. These droplets contained a high content of water and, subsequently, resulted in high moisture content in the powdered product [33]. In addition, a higher feed flow rate increased drying yield. This could be explained by the fact that a higher feed flow rate and higher drying rates could reduce the dehydration time of the powder. On the other hand, a low moisture powder is usually mixed with exhaust air, presenting difficulties for cyclonic separation [35]. These results are similar to the studies conducted by Suzana F. Alves *et al.* and Tomazelli Júnior *et al.* [36, 37]. Considering the drying yield results, we chose the feed flow rate of 300 mL/h as optimal for further experiments.

Fig. 4 demonstrates the SEM photographs shrunk to microscopic scale of *C. javanica* instant tea obtained with 30% (w/w) concentration of maltodextrin at 140°C. The particles had a comparatively regular shape and no visible breaks or ruptures were observed, proposing a satisfactory core retention and barrier of the microcapsules. At low drying temperature, the shape of the obtained particles was typically spherical with a shriveled and concave outer surface, indicating that the low drying temperature clearly provides a better core ingredient protection [38, 39]. Some particles demonstrated a smooth and rigid outer surface due to quick evaporation. Therefore, the optimal drying temperature for instant tea production from *C. Javanica* root extracts using maltodextrin as a drying additive was 140°C.

We evaluated the saponin content and free radical scavenging ability of the *C. javanica* extract and its powder obtained by spray drying (Table 4). The results showed that the saponin content in the extract was higher than that in the powdered tea by 0.29%. The original extract appeared to exert more scavenging activity on ABTS free positive radicals with the total antioxidant value at 168.88 μgAA/g. Meanwhile, after spray drying, the total antioxidant value decreased, as expressed by the reduced free radical capture activity. This implies that saponin in the *C. Javanica* extract had the proton accept capacity and could serve as inhibitor of free radical and, probably, as a primary antioxidant [1].

CONCLUSION

In the present study, we produced instant tea from *Condopopsis javanica* L. root extract via spray drying. The maximum yield reached 78.35% at the concentration of maltodextrin used as a drying additive of 30% (w/w), the drying temperature of 140°C, and the feed rate of 300 mL/h. The resulting instant tea products had a high total saponin content (0.29%, w/w) and a good free radical scavenging ability (59.48 μgAA/g). Therefore, the using of *C. javanica* root extract to produce instant tea is beneficial to commercialize the products for the beverage market. Further studies are required to evaluate the sensory properties of the powdered product and examine the economic feasibility of the spray drying process.

CONTRIBUTION

Nguyen Phu Thuong Nhan and Nguyen Duong Vu conceived and designed the analysis. Le Van Thanh, Nguyen Phu Thuong Nhan, and Than Thi Minh Phuong performed the experiment and collected the data. Long Giang Bach and Tran Quoc Toan supervised the research and wrote the paper.

CONFLICTS OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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