Effect of Spray Drying Temperature on Quality of Instant Herbal Drinks

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Abstract

The aim of this research was to investigate the effect of the inlet temperatures on the quality of the instant herbal drink powders including instant laurel clock *(Thunbergia laurifolia* Lindl.) or rang-jeud drink, instant bamboo grass *(Tiliacora triandra* (Colebr.) Diels), or ya-nang drink and instant asiatic pennywort (*Centella asiatica* (L) Urb.) or bai-bua-bok drink. The inlet temperatures were varied from 120, 140 and 160°C, whereas other parameters including outlet temperature (90°C), maltodextrin concentration (15% w/v) and feed flow rate (10 mL/min) were kept constant. Physical properties of the instant herbal drink powder including moisture content, water activity, bulk density, solubility and color were analyzed. Microbiological properties and shelf stability of the spray-dried powder were also investigated. The results showed that at higher inlet temperature, moisture content, water activity, bulk density and solubility of the spray-dried powder were decreased significantly ($p<0.05$). The microbiological quantity analysis of the instant herbal drink powders were within standard range of Thai community product standard. Shelf stability of instant herbal drink produced from 120 and 140°C inlet temperature was less than one month. As the longer period of storage, water activity in spray dried powder increased significantly ($p<0.05$). Overall, satisfactory physical properties of instant herbal drink powder were obtained from 160°C inlet temperatures. Sensory properties of instant herbal drink was evaluated by two panel groups; age 18–25 (n=30) and age above 45 (n=30). The result indicated that the instant laurel clock drink received highest overall acceptance.

Keywords: Spray drying, Instant drinks, *Thunbergia laurifolia* Lindl. *Tiliacora triandra* (Colebr.) Diels, *Centella asiatica* (L) Urb.

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1. Introduction

Herbs have been utilized in foods and drinks for centuries. Adding herbs to fruit juice can greatly improve their flavor and add extra antioxidants that are pertinent for fighting off disease. The therapeutic benefit of herbal juice has gained much attention now especially in Asian countries. A lot of herbal juice nowadays served as a healthy drink for example Ginger, Lemon grass, Bael fruit which are widely popular products found in Thailand.

Laurel clock *(Thunbergia laurifolia*) locally known in Thailand as Rang-jeud is an ornamental plant which is native from India. In Thailand, leaves are used as an antipyretic, as well as an antidote for detoxifying poisons. *T. laurifolia* is traditionally used for anti-inflammation, antidiabetic (Kosai *et al*. 2015) and it has been also reported that Apigenin, one of flavonoid compound in laurel clock, has antioxidant and anticancer properties. (Ruela-de-Sousa *et al*., 2010, Chan and Lim, 2006). Several Thai herbal companies have started producing and exporting laurel clock tea. The tea has been claimed to be able to detoxify the harmful effects of drugs, alcohol and cigarettes. (Wonkchalee *et al*., 2012).

Bamboo grass (*Tiliacora triandra*) or Ya-nang in Thai is the native plant of Southeast Asia. Bamboo grass is not only used in the cuisines of northeast Thailand and Laos but also used as medicine in traditional folklore. According to the traditional medicine of many countries, it has been used as a herbal medicine for fever relief, anti-inflammation, anticancer, anti-pyretic antioxidant, antibacterial and immune modulator (Rattana *et al*., 2010). Phunchago *et al*. (2015) also reported that *T. triandra* has potential reagent for treating brain dysfunction induced by alcohol.

Asiatic Pennywort (*Centella asiatica*) or call in Thai as Bai-Bua-Bok has been used as a medicinal herb for thousands of years in India, China, Srilanka, Nepal and Thailand. Asiatic pennywort is one of the chief herbs for treating skin problems, to heal wounds, for revitalizing the nerves and brain cells (Singh *et al*. 2010). Several research have reported different biological activities of *C. asiatica* such as cardioprotective (Pragada *et al*., 2004), antidepressant (Chen *et al*. 2003), mental-retardation (Schaneberg *et al*., 2003).

In present, instant drink powders are worldwide produced. Most of instant drink powders of fruit juice and vegetable are claimed for health benefits that are convenient to consume. By dissolving into water in a minute, is easy for handling and storage with longer shelf-life. Therefore, the instant drink powders were highly interested by consumer than plant extract juice. Spray drying technique is a powerful tool for transforming liquid extract into the dry powder. In spray drying application different drying conditions and carrier materials are used in order to obtain good product recover and stability. Santhalakshmy *et al*. (2015) and Tonon *et al*. (2011) reported that air temperature affected the physicochemical properties of the spray dried powder. The quality of reconstituted spray dried powder is good because the product temperature is rarely elevated above 100°C (Adhikari *et al.*, 2004). Higher inlet temperature increased the moisture content of powder and led to the formation of larger particles. There are considerably substantial amount of works on spray drying of fruit juice up-to-date for example Jamun fruit juice (Santhalakshmy *et al*., 2015), Green tea extract (Susantikarn and Donlao, 2016), *Satureja montana* extract (Vidović *et al*., 2014), Watermelon powder (Quek *et al*., 2007), Indian gooseberry powder (Thankitsunthorn *et al.*, 2009), Longan beverage powder (Kunapornsujarit and Intipunya, 2013), Black mulberry juice powder (Fazaeli *et al*., 2012), Gac fruit aril powder (Kha *et al*., 2010), Pitaya fruit powder (Tze *et al*., 2012). However, in Thailand there have been limited scientific literatures concerning drying herbal juice. Therefore, the objective of this study was to investigate the effect of drying temperature on physical and microbiological properties of herbal drink powders and determine the suitable drying temperature for producing instant herbal drink powder including laurel clock drink powder, bamboo grass drink powder and asiatic pennywort drink powder.

2. Materials and Methods

2.1 Material

Laurel clock or in Thai calls Rang-jeud (*Thunbergia laurifolia* Lindl), Bamboo grass or Ya-nang *(Tiliacora triandra* (Colebr.) Diels) and Asiatic pennywort or Bai-Bua Bok (*Centella asiatica* (L) Urb.) were purchased from local market in Ayutthaya, Prachinburi and Sakaew province. Pandan leaves (*Pandanus amaryllifolius* Roxb.) was purchased from Talaad-thai, Pathumtani province. Maltodextrin DE 10 was purchased from Chemipan Corporation, Co.Ltd.

2.1 Herbal juice preparation

All herbal leaves were soaked and dried at 50°C for 2 h before use. Dried Laurel clock leaves, Bamboo grass leaves and Asiatic pennywort leaves were separate chopped and blended with Pandan (*Pandanus amaryllifolius* Roxb.) leaves and water using ratio of 4:1:3. The herbal juices then were filtered, boiled and sugar added to obtain final concentration of 16°Brix. The carrier agent, maltodextrin (DE 10), was added into the juices at concentration of 15% (w/v) and kept under agitation until complete dissolution. This concentration was selected in preliminary test, as the most adequate to recover a representative amount of powder of spray drying.

2.2 Spray drying

Instant herbal drink powders were performed by using a Mini Spray dryer (BUCHI, B-191, Laboratory-Techniques LTD, Flawil – Switzerland). The spray dryer was operated concurrently using a spray nozzle with an orifice of 1 mm in diameter. Three inlet air temperatures of 120, 140 and 160°C were investigated for all the herbal drink solutions. The outlet air temperature was maintained at 90°C by controlling the feed flow rate (Jirayucharoensak *et al*., 2015). The liquid feed was fed into the spray chamber through a peristaltic pump with flow rate of 10 mL/min. Pressure was in the range of 0.8–1.2 kg/cm^2. Dried herbal drink powder samples were collected into the aluminum foil bags and double packed into plastic bags. The samples were kept in desiccator containing silica gel at room temperature until further analysis.

2.3 Analysis of the spray-dried herbal drink powder

2.3.1 Physical properties

The spray-dried powders were analyzed for moisture content, water activity, bulk density, solubility and color characteristics as following. All analytical measurements were carried out in triplicate.

Moisture content

The moisture content was determined based on AOAC method (AOAC, 2000). Samples of herbal drink powders (2 g) were weighed and dried in oven at 105°C until a constant weight was obtained.

Water activity (a_w)

The water activity meter (AquaLab TE3, Decagon Device, Inc., USA) was used to measure a_w of the spray-dried powers.

Bulk density

Bulk density (g/mL) was determined according to Kha *et al* (2010). Herbal drink powders (2 g) were gently added into an empty 10 mL graduated cylinder which was held on a vortex vibrator for 1 min. The ratio of mass of the powder and the volume occupied in the cylinder determined the density value.

Solubility

The solubility of the herbal drink powders was determined using the method described by Kunapornsujarit *et al.* (2013). The spray-dried powders (1 g) and distilled water (10 mL) were vigorously mixed at 30°C for 30 min and then centrifuged at 3000 rpm for 10 min. The supernatant was carefully collected in an aluminum can and oven dried at temperature of 105±2°C for 24 h. The solubility (%) was calculated as the percentage of dried supernatant with respect to the amount of the original 1 g of herbal drink powder.

Color characteristics

The color of herbal drink powders was determined using Minolta Colour reader Cr10, Japan. The results were expressed as Hunter color values of L*, a*, and b*, where L* was used to denote lightness, a* redness and greenness and b* yellowness and blueness.

2.3.2 Microbiological properties

The microbiological tests of the herbal drink powder were examined according to the Thai community product stand of instant mixed herbs drink #1441/2013 including total bacterial count, yeast and mold and total coliforms by method of FDA-BAM (2001A) and FDA-BAM (2002B). Briefly, one gram of each Instant herbal drink power was dissolved into 10 mL sterile 0.1% peptone water. This was taken as the 10^{-1} dilution and further serially dilution up to 10^{-4}. To obtain the total bacteria count were triplicate plated using Plate count agar (PCA). Yeast and mold count were obtained with Potato dextrose agar (PDA). Total coliform bacteria was determined by three-tube MPN procedure and calculated based on the number of positive tube according to MPN table.

2.3.3 Shelf stability test

Samples of spray-dried herbal drink powder which double packed in aluminum foil and plastic bags were stored for one month in room temperature (30–35°C). Samples were taken every week for water activity measurement.

2.3.4 Sensory evaluation

The sensory evaluations of the instant herbal drinks were conducted into two sessions of 30 panels each. Session one, panels were around 18–25 years old and those in the other session were above 45 years old. The instant herbal drink powders were dissolved in hot water and presented to each panelist in uniform plastic cups, labelled with 3-random digit code. A 7-point hedonic scale with ‘‘1’’ representing dislike very much and ‘‘7’’ representing like very much was used to assess preferences in odor, flavor, color, clarity and overall acceptability of the each type of herbal drinks.

2.3.5 Statistical analysis

Statistical analysis was carried out using SPSS software (version 19.0). Results are presented as mean value±S.D. Data were analyzed by analysis of variance (ANOVA) and Duncan’s multiple range test at p<0.05

3. Results and Discussion

3.1 Physical properties of the instant herbal drink

Table 1 showed the physical properties of the instant drink powders. The results revealed that the moisture content, water activity and solubility of the instant herbal juice were not significantly different (p>0.05) between air inlet temperature at 120°C and 140°C and significantly higher in produced from 160°C air inlet temperature (p<0.05). This is because at higher inlet temperature, the rate of heat transfer to the particle is greater, providing greater driving force for moisture evaporation. The average moisture content of powders in this study ranged from 2.7–5.2% that are within standard of Thai community product stand of instant mixed herbs drink #1441/2013.

Water activity is different from moisture content as it measures the availability of free water in a food system that is responsible for any biochemical reactions, whereas the moisture content represents the water composition in a food system. High water activity indicates more free water available for biochemical reactions and hence, shorter shelf-life. (Quek *et al*., 2007, Fazaeli *et al*., 2012). The average water activity of instant herbal drink powders in this study ranged from 0.15–0.32. The deterioration of dried powder caused by microorganisms and biochemical reactions can be prevented at a_w lower than 0.6 (Kha *et al*., 2010) and at 0.2 and 0.4 ensure the stability of the product against browning and hydrological reactions, lipid oxidation, auto-oxidation and enzymatic activity (Caliskan and Dirim, 2013). The result also showed that increasing inlet temperature, the water activity of all herbal powder was decreased.

Bulk density is one of food powder properties. It is an important parameter for the transport, storage, packaging and mixing processes. The bulk density of the instant herbal drink powder ranged between 0.69 and 0.78 g/mL. The results revealed that increasing inlet temperature caused the significantly decreasing bulk density (p<0.05). These results were in agreement with the result reported by Laokuldilok and Kanha (2015) and Kha *et al*. (2010). Reineccius (2004) explained that at higher inlet air temperatures, larger particle sizes were produced when compared to those at lower inlet air temperature. The larger particles also had a larger hollow structure than the smaller one. Moreover, the larger particles contained more entrapped air, which resulted in lowering the bulk density. Dried foods with low bulk density often show poor storage stability (Laokuldilok and Kanha, 2015).

Solubility is an important parameter in the characterization of dry powders since it shows the ability of a powder to dissolve in water. The results showed that the solubility of instant herbal drinks is in the range of 64–66%. The higher solubility was found in the powder produced from 120°C inlet temperatures. These results revealed that inlet air temperature affected the solubility. Similar observations were also reported by of many articles

(Thankitsunthorn *et al*., 2009, Kha *et al*, 2010; Fazaeli *et al*., 2012). Quek *et al*. (2007) and Susantikarn and Donlao (2016) explained that at higher inlet air temperature, a hard surface layer might be formed over the powder particle that could prevent water molecules from diffusing through the particle. Consequently, wettability of the particle decreased and the dissolution of the powder was reduced. However, the solubility of the instant herbal drinks in this study was lower than that of spray-dried fruit powder report by other researchers (Kunapornsujarit and Intipunya, 2013, Susanitkan and Donlao, 2016). As a result, it is recommended that this instant herbal drink should be dissolved in hot water following by stirring moderately.

Color is one of the major parameter of dried food product. L* value defines the lightness of sample, a* denotes redness and greenness and b* denotes the yellowness and blueness. The results showed that the lightness of instant herbal drink was increased when inlet temperature increased. At the lowest inlet temperature (120°C) the darkest powder was obtained. Similar results were also found in spray-dried jamun juice powder (Santhalakshmy *et al*., 2015). Fritzen-Freire *et al*. (2012) explained the color scale that the L* parameter ranges from 0 to 100, indicating the color variation from black to white; the a* axis shows the variation from red (+a*) to green (-a*) while the b* axis shows the variation from yellow (+b*) to blue (-b*). Therefore, the data showed color of powder -a* and +b* means greenness and yellowness, hence the color of the instant herbal powders obtained from this experiment was greenish yellow color.

Table 1 Physical properties of instant herbal drink powders

Herbal drink powder	Inlet Temp (°C)	Moisture (%)	a_w	Bulk density (g/mL)	Solubility (%)	color L*	color a*	color b*
Laurel clock	120	4.8±0.4^{a}	0.32±0.05^{a}	0.78±0.04^{a}	66.69±0.16^{a}	90.76±0.04^{a}	-0.33±0.04^{a}	14.70±0.14^{a}
	140	4.6±0.2^{a}	0.25±0.05^{a}	0.74±0.03^{ab}	66.94±0.25^{a}	91.00±0.21^{ab}	-0.93±0.12^{b}	13.60±0.14^{ab}
	160	2.7±0.2^{b}	0.15±0.07^{b}	0.69±0.03^{b}	64.39±0.30^{b}	92.93±0.04^{b}	-1.30±0.00^{b}	12.33±0.12^{b}
Bamboo grass	120	5.2±0.5^{a}	0.32±0.04^{a}	0.77±0.05^{a}	66.44±0.12^{a}	89.50±0.08^{a}	-0.53±0.04^{a}	15.50±0.16^{a}
	140	4.2±0.5^{a}	0.27±0.03^{a}	0.73±0.02^{ab}	66.68±0.11^{a}	89.90±0.08^{a}	-0.93±0.04^{ab}	12.76±0.18^{b}
	160	3.2±0.3^{b}	0.17±0.01^{b}	0.70±0.03^{b}	64.86±0.45^{b}	92.93±0.04^{b}	-1.20±0.00^{b}	12.23±0.12^{b}
Asiatic pennywort	120	4.7±0.5^{a}	0.31±0.02^{a}	0.78±0.03^{a}	66.04±0.32^{a}	87.30±0.08^{a}	-0.16±0.12^{a}	15.36±0.04^{a}
	140	4.3±0.4^{a}	0.25±0.04^{a}	0.75±0.02^{ab}	65.98±0.96^{ab}	90.43±0.04^{ab}	-1.03±0.04^{b}	11.83±0.09^{b}
	160	3.1±0.1^{b}	0.18±0.04^{b}	0.70±0.02^{b}	64.98±0.18^{b}	91.76±0.40^{b}	-1.20±0.08^{b}	12.36±0.32^{b}

Note: Data is presented as mean ± standard deviation (n=3).

Different superscripts in each column represent significant difference between mean values at 95% statistical confidence ($p \leq 0.05$).

3.2 Microbiological properties of the instant herbal drink

The biological properties of the instant herbal drink powders are shown in Table 2. Yeast and mold were not found in all spray-dried condition. The total bacteria count of the instant herbal drink powder is in the range of 1.04–1.57 log CFU/mL and no bacteria growth in spray-dried powder obtained from 160°C inlet temperature. These result implied that increasing inlet temperature resulting in decreasing the total bacteria count. Total coliform was found less than 3 MPN/100 mL in all spray dried powder. Therefore, the instant herbal drink powders obtain in this experiment meet the Thai community product standard for biological aspect.

Table 2 Microbiological properties of the instant herbal drinks

Herbal drink powder	Inlet Temp (°C)	Total bacteria count Log CFU/mL	Yeast and Mold (CFU/g)	Total coliform bacteria (MPN/100 mL)
Laurel clock	120	1.57	none	<3
	140	1.08	none	<3
	160	none	none	<3
Bamboo grass	120	1.49	none	<3
	140	1.09	none	<3
	160	none	none	<3
Asiatic pennywort	120	1.51	none	<3
	140	1.04	none	<3
	160	none	none	<3

Note: Data is presented the average of triplicate measurement

3.3 Shelf stability determination

Water activity was selected as a criterion to determine the shelf stability of the spray-dried herbal drink powder. As long as the water activity remains below 0.6, the product is microbiologically stable. Figure 1 show that water activity was increased significantly (p<0.05) after storage for 4 weeks in all spray-dried powder. However, at the highest inlet temperature (160°C), the water activity was increased but not exceeded the safe storage limit (a_w<0.6) in the fourth week of storage. As our spray-dried powders contain sugar and has maltodextrin as a carrier, these influenced the hygroscopicity of the herbal drink powder. These results were consistent with other researchers (Thankitsunthorn *et al*., 2009, Quek *et al*., 2007).

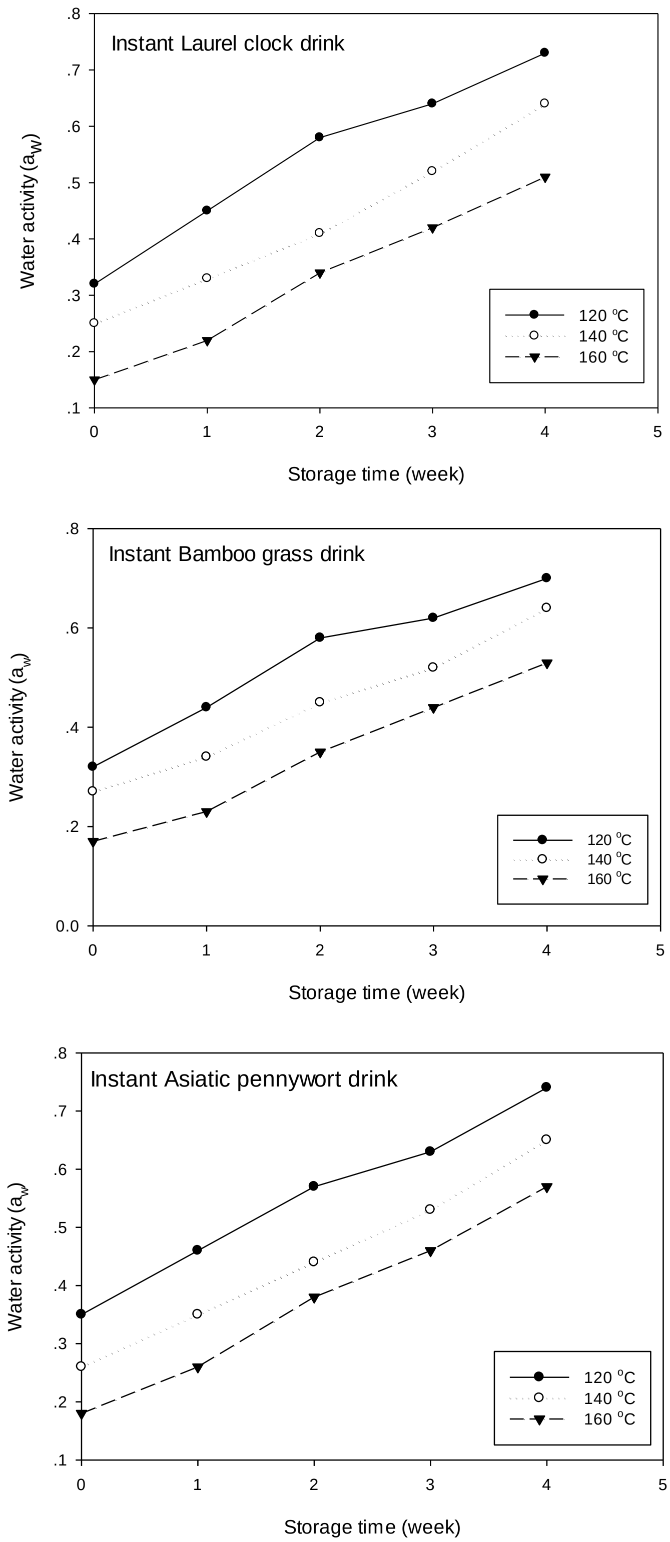

Figure 1 Water activity of the Instant herbal drinks during 4 weeks storage

3.4 Sensory properties

From the result of physical properties, biological properties and shelf-life determination, 160°C inlet temperatures showed the better properties than those from other inlet temperature. Thus, it was selected for sensory evaluation. The sensory test was conducted into two sessions of 30 panels each. Table 3 shows the sensory evaluation results of panelists who were around 18–25 years old whereas Table 4 shows the sensory evaluation result of panelist who has above 45 years old. The experiment was performed into two session of different age groups because it this known that sensory evaluation result is affected by age (Amerine *et al.*,1965). Then the target group of instant herbal drink nowadays slightly focuses in elderly consumer. The results from Table 3 and 4 showed that instant laurel clock drink is preferred the most in both panel groups. The overall acceptability, odor, flavor and clarity scores of instant laurel clock drink higher than instant bamboo grass and asiatic pennywort drinks significantly (P<0.05). The sensory scores of bamboo grass drink and asiatic pennywort drink were not significantly different (P>0.05) in all attributes as accessed by 18–25 years old panel group.The sensory score of overall acceptability of laurel clock drink in above 45 years old group is like moderately (6.00±0.587) follow by asiatic pennywort drink and bamboo grass drink (like slightly), respectively. Therefore, the result of the sensory evaluation implied that panelist age 18–25 years old and above 45 preferred the instant laurel clock drink. Thus, the taste of instant asiatic pennywort and bamboo grass drink should be improved to increase acceptability.

Table 3 Sensory evaluation of Instant herbal drinks by panelist at age of 18-25 years old

Herbal drink	**Sensory evaluation results**				
	Odor	**Color**	**Flavor**	**Clarity**	**Overall acceptability**
Laurel clock	$4.47±1.279^{b}$	$4.80±0.961^{b}$	$5.13±1.106^{b}$	$4.53±1.137^{b}$	$5.53±0.860^{b}$
Bamboo grass	$3.73±0.828^{a}$	$3.90±0.885^{a}$	$3.57±0.971^{a}$	$3.93±0.868^{a}$	$4.33±0.817^{a}$
Asiatic pennywort	$4.07±1.112^{ab}$	$3.97±0.890^{a}$	$4.17±0.950^{a}$	$4.03±1.273^{a}$	$4.57±0.802^{a}$

Note: Data is presented as mean ± standard deviation (n=30).

Sensory evaluation parameters were on a scale of 1–7 (Like very much = 7, like moderately =6, like slightly = 5, neither like nor dislike =4, dislike slightly = 3, dislike moderately =2 and dislike very much = 1).

Different superscripts in each column represent significant difference between mean values at 95% statistical confidence ($p \leq 0.05$).

Table 4 Sensory evaluation of Instant herbal by panelist age above 45 years old

Herbal drink	Sensory evaluation results				
	Odor	**Color**	**Flavor**	**Clarity**	**Overall acceptability**
Laurel clock	5.10±0.923[b]	4.10±0.845[b]	6.07±0.583[b]	5.03±0.809[b]	6.00±0.587[b]
Bamboo grass	4.60±0.968[ab]	4.53±0.629[a]	5.20±0.551[a]	4.17±0.874[a]	5.17±0.648[a]
Asiatic pennywort	4.27±0.944[a]	4.57±0.858[a]	4.90±0.607[a]	4.70±0.915[ab]	5.33±0.479[a]

Note: Data is presented as mean ± standard deviation (n=30).

Sensory evaluation parameters were on a scale of 1–7 (Like very much = 7, like moderately =6, like slightly = 5, neither like nor dislike =4, dislike slightly = 3, dislike moderately =2 and dislike very much = 1).

Different superscripts in each column represent significant difference between mean values at 95% statistical confidence ($p \leq 0.05$).

4. Conclusion

In conclusion, inlet temperature has a great influence on physical and microbiological properties of the instant herbal drinks. As the inlet temperature increased, the moisture content, water activity, bulk density and solubility of the powder were decreased. Besides, the microbiological properties such as total bacteria count, yeast and mold and total coliform bacteria of instant herbal drinks were also meet the Thai community product standard. Overall, the inlet temperature of 160°C is considered appropriate for producing the instant herbal drinks. The water activities of instant herbal drinks were increased significantly during storage for 4 weeks. The sensory evaluation showed that the instant laurel clock drink was more accepted by both panelist groups than instant bamboo grass drink and instant asiatic pennywort drink. Further investigation is needed to improve the packaging and storage condition to prolong the shelf-life of the product.

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References

Adhikari, B., Howes, T., Bhandari, B.R. and Troung, V. 2004. Effect of addition of maltodextrin on drying kinetics and stickiness of sugar and acid-rich foods during convective drying: experiments and modelling. Journal of Food Engineering. 62:53–68.

Amerine, M.A., Pangborn, R.M. and Roessler, E.B. 1965. Principles of sensory evaluation of food. Academic Press, New York.

Association of Official Analytical Chemists (AOAC). 2000. Official methods of analysis of AOAC international (17^{th} edition). AOAC International, Gaithersburg, MD.

Caliskan, G. and Nur Dirim, S. 2013. The effects of the different drying conditions and the amounts of maltodextrin addition during spray drying of sumac extract. Food and Bioproduct Processing. 91:539–548.

Chan, E.WC and Lim, Y.Y. 2006. Antioxidant activity of Thunbergia laurifolia tea. Journal of Tropical forest Science. 18(2):130–136.

Chen, Y., Han, T, Qin, L, Rui, Y. and Zheng, H. 2003. Effect of total triterpenes from *Cenella asiatica* on the depression behavior and concentration of amino acid in forced swimming mice, Zhong Yao Cai, 25(12):870–873.

Fazeli, M., Emam-Djomeh, Z., Ashtari, A.K. and Omid, M. 2012. Effect of spray drying conditions and feed composition on the physical properties of black mulberry juice powder. Food and Bioproducts Processing. 90:667–675.

FDA- Bacteriological Analytical Manual (BAM). 2001A. “Aerobic plate count.” in Chapter 3. [Online]. Available:https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm063346.htm.

FDA- Bacteriological Analytical Manual (BAM). 2001B. “Yeasts Molds and Mycotoxins.” in Chapter 18. [Online]. Available: https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm071435.htm.

FDA- Bacteriological Analytical Manual (BAM). 2002. BAM 4: Enumeration of *Escherichia coli* and the Coliform Bacteria. [Online]. Available: https://www.fda.gov/Food/FoodScience Research/ LaboratoryMethods/ucm064948.htm.

Fritzen-Freire, C.B., Prudêncio, E.S., Amboni, R. DMC., Pinto, S.S., Megrão-Murakami, A.N. and Murakami, F.S. 2012. Microencapsulation of bifidobacteria by spray drying in the presence of prebiotics. Food Research International. 45:306–312.

Jirayucharoensak, R., Jittanit, W. and Sirisansaneeyakul, S. 2015. Spray-drying for inulin powder production from Jerusalem artichoke tuber extract and product qualities. Journal of Science and Technology, Ubon Ratchathani University. 17:13–18.

Kha, T.C., Nguyen, M.H. and Roach, P.D. 2010. Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (*Momordica cochinchinensis*) fruit aril powder. Journal of Food Engineering. 98:385–392.

Kosai, P., Jiraungkoorskul, K. and Jiraungkoorskul, W. 2015. Review of antidiabetic activity of "Rang Jeud" Thunbergia laurifolia. Journal of Applied Pharmaceutical Science. 5(suppl2):99–103.

Kunapornsujarit, D. and Intipunya, P. 2013. Effect of spray drying temperature on quality of longan beverage powder. Food and Applied Bioscience Journal. 1(2):81–89.

Laokuldilok, T. and Kanha, N. 2015. Effects of processing conditions on powder properties of black glutinous rice (*Oryza saltiva* L.) bran anthocyanins produced by spray drying and freeze drying. LWT-Food Science and Technology. 64:405–411.

Phunchago, N., Wattanathorn, J. and Chaisiwamongkol, K. 2015. *Tilacora triandra*, an anti-intoxication plant, improves memory impairment, neurodegeneration, cholinergic function, and oxidative stress in Hippocampus of ethanol dependence rats. Oxidative Medicine and Cellular Longevity. http:// dx.doi.org/10.1155.2015/918426.

Pragada, R.R., Veeravalli, K.K., Chowdary, K.P. and Routhn, K.P. 2004. Cardioprotectiv activity of *Hydrocotyle asiatica* L. in ischemia-reperfusion induced myocardial infraction in rats. Journal of Ethnophamacology. 93(1):105–108.

Quek, S.Y., Chok, N.K. and Swedlund. P. 2007. The physicochemical properties of spray-dried watermelon powders. Chemical Engineering and Processing. 46:386–392.

Rattana, S. Padungkit, M. and Cushnie, B. 2010. Phytochemical screening, flavonoid content, and antioxidant activity of Tiliacora triandra leaf extracts. In Proceeding of the 2nd Annual International Conference of Northeast Pharmacy Research:60–63.

Reineccius, G.A. 2004. The spray drying of food flavours. Drying Technology. 22: 1289–1324.

Ruela-de-Sousa, R.R., Fuhler, G.M., Blom, N., Ferreira, C.V. Aoyama, H. and Peppelenbosch M.P. 2010. Cytotoxicity of apigenin on leukemia cell lines: implications for prevention and therapy. Cell Death and Disease. 1:19.

Santhalakshmy, S., Don Bosco, S., Francis, S. and Sabeena M. 2015. Effect of inlet temperature on physicochemical properties of spray-dried jamum fruit juice powder. Powder Technology. 274:37–43.

Schaneberg, B.T., Mikell, J.R., Bedir, E. and Khan, I.A. 2003. An improved HPLC method for quantitative determination of six triterpenes in *Centella asiatica* extracts and commercial products, Pharmazie. 58(6):381–384.

Singh, S., Gautam, A., Sharma, A., and Batra, A. 2010. *Centella asiatica* (L.): a plant with immense medicinal potential but threatened. International Journal of Pharmaceutical Sciences Review and Research. 4(2):9–17.

Susantikarn, P. and Donlao, N. 2016. Optimization of green tea extracts spray drying as affected by temperature and maltodextrin content. International Food Research Journal. 23(3):1327–1331.

Thankitsunthorn, S., Thawornphiphatdit, C., Laohaprasit, N. and Srzednicki, G. 2009. Effect of drying temperature on quality of dried Indian Gooseberry powder. International Food Research Journal. 16:355–361.

Tonon, R.V., Freitas, S.S. and Hubinger, M.D. 2011. Spray drying of acai (*Enterpe olevanceae* mart.) juice: effect of inlet air temperature and type of carrier agent. Journal of Food Processing and Preservation. 35(5):691–700.

Tze, N. L., Han, C.P., Yusuf, Y.A., Ling, C.N., Talib, R.A., Taip, F.S. and Aziz, M.G. 2012. Physicochemical and nutritional properties of spray-dried Pitaya fruit powder as natural colorant. Food Science and Biotechnology. 21(3):675–682.

Vidović, S.S., Vladić, J.Z., Vaštag, Z, G., Zeković, Z.P. and Popović, L.M. 2014. Maltodextrin as a carrier of health benefit compounds in *Satureja montana* dry powder extract obtained by spray drying technique. Powder Technology. 258:209–215.

Wonkchalee, O., Boonmars, T., Aromdee, C, Laummanunwai, P., Khunkitti, W., Vaeteewoottacharn, K., Sriraj, P., Aukkanimart, R., Loilone W., Chamgramol, Y., Pairojkul, C., Wu, Z., Juasook, A. and Sudsarn, P. 2012. Anti-inflammatory, antioxidant and hepatoprotective effects of *Thunbergia laurifolia* Linn. on experimental opisthorchiasis. Parasitology Research. 11:353–359.