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SOME RESEARCH RESULTS ON THE SPRAY DRYING STAGES OF PROCESS TECHNOLOGY FOR PRODUCING SOLUBLE GREEN TEA POWDER FROM FRESH TEA LEAVES[3]

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ABSTRACT

Soluble tea powder is produced by drying the concentrated extraction dried tea leaves (green tea, black tea or oolong). The products of this method have a good quality but are expensive and require lots of energy. This paper introduces some research results on the spray drying stages of process technology for producing soluble green tea powder from fresh old tea leaves. The effects of the spray drying process variables (spray drying temperature: 160 - 180^{0}C, drying agent velocity: 2 - 5m/s, and atomization air pressure: 5 - 20psi) on the total polyphenol, catechin, caffeine, and liquor sensory characteristics have been investigated. The quality of the soluble green tea powder was at an acceptable level for total polyphenol components (29.84 - 30.26% dry matter (DM)), caffeine (5.19 - 5.25%DM), total catechins (13.04 - 13.56%DM), and had good liquor sensory characteristics. The results of the study contribute to improving the process technology for producing soluble green tea powder from fresh old tea leaves, reducing production costs, and supplying materials for the food processing industry.

Keywords: Soluble tea powder, fresh tea, extraction, spray drying, old tea leaves.

Một số kết quả nghiên cứu công đoạn sấy phun trong quy trình công nghệ sản xuất bột chè xanh hòa tan từ lá chè tươi

TÓM TẮT

Chè hòa tan thường được sản xuất bằng cách sấy dịch trích ly từ chè khô (chè xanh, chè đen hoặc chè ô long) cho chất lượng tốt nhưng giá thành sản xuất cao, chi phí nhiều năng lượng. Trong bài báo này chúng tôi giới thiệu một số kết quả nghiên cứu công đoạn sấy phun trong quy trình công nghệ sản xuất bột chè xanh hòa tan từ lá chè tươi (chè già). Ảnh hưởng của các thông số trong quá trình sấy phun (nhiệt độ sấy phun: 160÷180^{0}C, tốc độ tác nhân sấy: 2-5m/s và áp suất tạo sương: 5-20psi) tới hàm lượng polyphenol, catechin tổng số, cafein và tính chất cảm quan đã được nghiên cứu. Chất lượng bột chè ở mức chấp nhận được, nước pha có tính chất cảm quan tốt, bột chè có thành phần polyphenol (29.84 ÷ 30.26% DM), cafein (5.19 ÷ 5.25% DM), catechin tổng số (13.04 ÷ 13.56% DM). Nghiên cứu công đoạn sấy phun góp phần hoàn thiện quy trình công nghệ chế biến bột chè xanh hòa tan từ lá chè tươi, cho phép giảm chi phí sản xuất, tạo nguyên liệu cho công nghiệp chế biến.

Từ khóa: Chè hòa tan, chè tươi, trích ly, sấy phun, chè già.

1. INTRODUCTION

Tea liquor is a favourite beverage of many Asian people as well as people around the world for its benefits for human health: limiting heart disease, cancer, diabetes, obesity, tooth decay, and increasing human life. Vietnam is ranked 5th in the world for tea production (FAO, 2012), and there are about 6 million people who rely on public - sector agricultural cultivation and processing of tea. The main products of tea processing are: green tea, black tea, and tea bags for domestic consumption and export. However, the value of tea products in Vietnam is low, only about 70 - 75% compared to similar

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products on the world market. Therefore, producing soluble tea powders directly from fresh old tea leaves as raw materials for the food processing industry is a new research trend. The technology will be a solution for old tea leaves processing, improving the living standard of tea farmers in Vietnam.

Soluble tea around the world is produced mainly from processed tea leaves such as green tea, black tea, and oolong tea for beverage production (Clark et al., 1984; Mehta et al., 2001; Bavan & Bengal, 2009). The main stages are extraction, concentration, and spray drying to create tea powders. However, in the extraction process, many authors have applied different methods. Sato et al. (1984) used hot water for green tea extraction; tea extracts were mixed with dextrin and spray dried to produce tea powders. Bavan (2005) used hot water for a mixture of black tea and oolong tea extraction; tea extracts were then concentrated to produce spray - dried tea powders. Lunder and Nestec (1997) used hot water to extract a mixture of green tea and black tea at 2 bar pressure to obtain tea extracts.

Extraction of polyphenol from processed tea leaves has been examined in many projects in Vietnam. The extracted products are used as raw materials for the food processing and pharmaceutical industries. Water is mostly used as the polyphenol solvent extraction (Trinh Xuan Ngo 2009; Vu Hong Son & Ha Duyen Tu 2009). Ethanol combined with microwave was used in the study of Pham Thanh Quan et al. (2005).

It can be seen that the materials to produce tea powders for beverages are mainly from green tea, black tea, and oolong tea. The processing technology must ensure that the conventional taste and flavor of these products are kept. Production costs are relatively high, thus, it will not be economic if the tea powders are used in the food processing industry except in beverages. Recently, the study of Sinija et al. (2007) referred to the processing of tea powder directly from the fresh tea shoots by crushing and pressing. Tea extracts were fermented to produce soluble tea powder. Tea residues were fermented to produce black tea granules to increase economic efficiency. However, research about producing tea powder directly from fresh tea leaves is still limited.

Our research objectives are to examine the effect of the spray drying process variables on the quality of soluble green tea powder from fresh old tea leaves, contribute to providing raw materials for the food processing industry, improve the technology for producing soluble green tea powder, and lower production costs.

2. MATERIALS AND METHODS

2.1. Materials

Materials used for the study were old fresh tea leaves, Trung Du varieties, grown on farm land in Moc Chau, Son La.

2.2. Some main stages of the technological process

Fresh tea leaves were harvested and transported to the laboratory, selected to remove impurities, rinsed and drained. Tea leaves were boiled in water for 1 minute to inactivate enzymes, drained, and then preliminary milled by a cutting and grinding machine (CYF - AS22) in order to break up the organization of cells in the tea tissues, helping out the tea liquor leaves in the extraction process. The fine materials were extracted by adding distilled water heated to 90^0C with the ratio 1/2 (v/w) for 30 minutes and the mixture was mechanically pressed on the piston pressers with 350 N/cm^2 pressure to improve extraction efficiency. Tea extracts were then filtered by membrane filtration 125 μm - size to remove residues from the tea and concentrated to 30 Brix in a vacuum concentrator. Finally, the concentrated extracts were spray - dried to produce soluble green tea powder by spray dryer SD - 1500.

2.3. Research methods

- Total polyphenol content was determined by the method of ISO 14502 - 1 - 2005.

- Caffeine and total catechin contents were determined by the method of ISO 14502 - 2 - 2005. Total catechins were the total amount of catechins (C, EC, EGC, EGCG, and ECG) in the sample.

- The sensory evaluation by TCVN 3215 - 79. Tea tasters were trained to evaluate tea liquor sensory characteristics (colour, smell, taste and solubility) compared with traditional fresh tea liquor.

- The data were statistically processed by Excel 2007 and SAS 9.1.

3. RESULTS AND DISCUSSION

3.1. Technological process to produce soluble tea powder from fresh tea leaves

Experiments were conducted to examine the effects of spray drying parameters on the quality of the product in order to standardize the technology parameters in the spray drying stage. The technological process is shown in Figure 1.

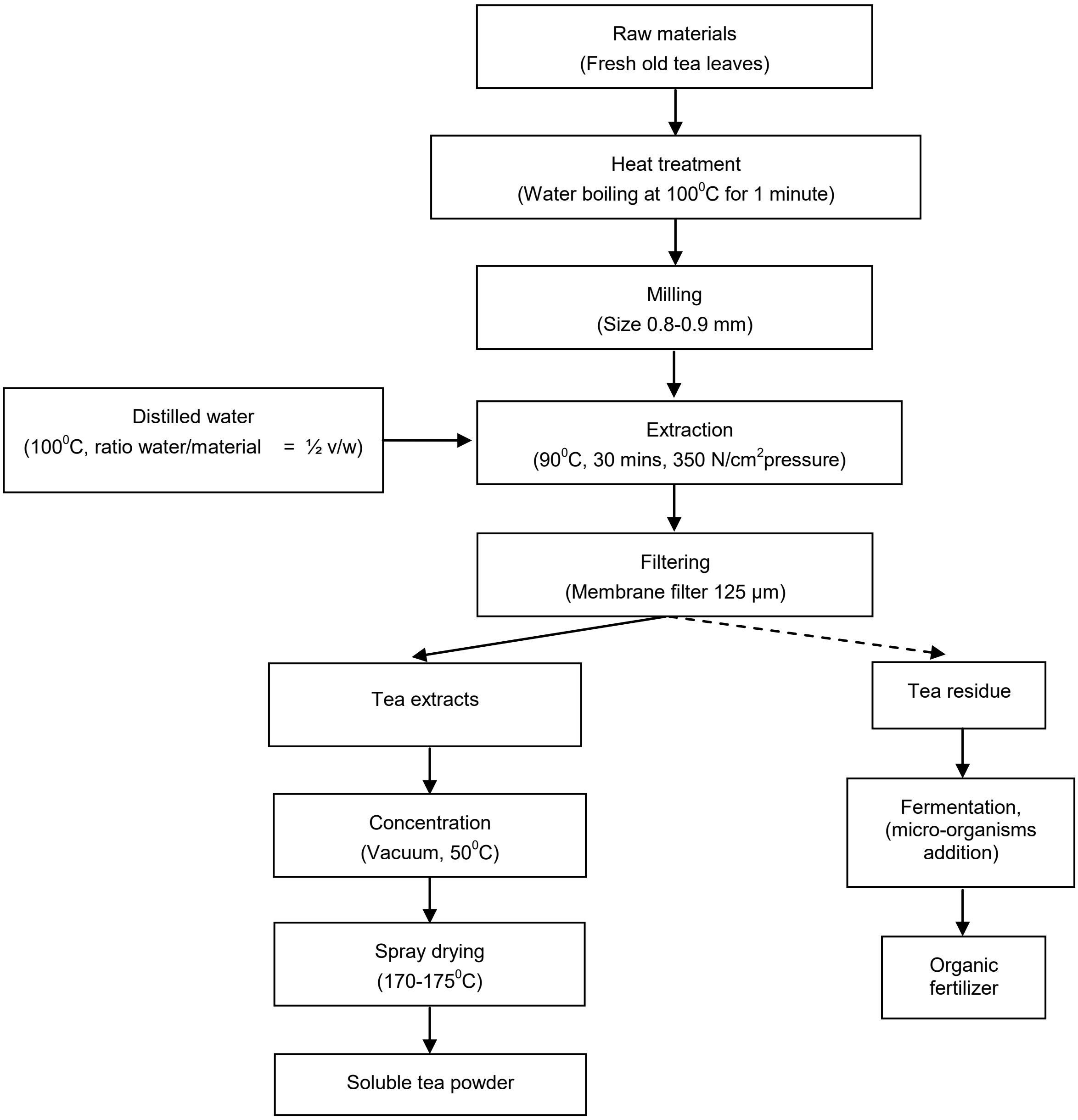

Figure 1. Flow chart for soluble green tea powder manufacturing

Table 1. Effect of spray drying temperature on total polyphenol, catechin and caffeine contents of the tea powder

Spray drying temperature	Polyphenol (%)	Catechin (%)	Caffeine (%)
160^0C	29.94[a]	13.17[a]	5.48[a]
165^0C	29.90[b]	13.11[b]	5.33[b]
170^0C	29.88[b]	13.08[c]	5.24[c]
175^0C	29.86[b]	13.06[c]	5.20[c]
180^0C	29.13[c]	10.43[d]	5.13[d]
$LSD_{5\%}$	0.0373	0.0297	0.0431

Note: In a column, different superscript letters indicate that mean values are significantly different at 5%.

Effect of spray drying temperature on the content of total polyphenols, catechins and caffeine of soluble green tea powders and tea liquor sensory characteristics

The experiments were carried out in a range of spray drying temperatures to find out suitable drying temperatures that lead to high total polyphenols, catechin, and caffeine contenta while maintaining good sensory characteristics of tea powder and tea liquor.

Table 1 shows the highest polyphenol content was obtained when the drying temperature was set at 160^0C (29.94%DM). However, at the drying temperature range of 160 - 165^0C, the product formed a wet pulp that stuck on the walls of the drying chamber. When the temperature was increased, the polyphenol content was reduced due to the effect of a high temperature. At a temperature of 175^0C, the product formed dry, fine powders with the polyphenol content of 29.86%. This change in the polyphenol content when changing the temperature was insignificant in terms of mathematical statistics. As the temperature increased to 180^0C, the polyphenol content decreased (29.13%), a loss of 0.73% compared to the content at the temperature of 175^0C. Moreover, the color of the observed product turned golden brown, not as light yellow as it was at lower drying temperatures. Similar results were also noted in the content of catechins in tea powder because this component is heat sensitive. Table 2 shows catechin content fluctuated around 13.08% when the temperature changed from 160^0C to 175^0C. This result was significantly reduced to 10.43 % when the temperature increased to 180^0C.

For caffeine content, Table 1 indicates that when the drying temperature increased from 160^0C to 165^0C and then to 170^0C, the caffeine content decreased from 5.48% to 5.33% and 5.24%, respectively. When the drying temperature reached 175^0C, the caffeine content decreased to 5.20%. However, there was a slight change between the two temperatures 170^0C and 175^0C. The difference here is not high, insignificant in terms of mathematical statistics. This can be explained in that caffeine is heat resistant, and the difference was small when changing the drying temperature during the experiment. There was a minor caffeine loss as drying temperature was increased to 180^0C.

As it follows from our observations, drying at a low temperature (160 - 170^0C) produced a product color that was yellow - green in the early stages of the drying process. However, due to a low drying temperature, the products were wet and sticky, they adhered to the walls and the floor of the drying chamber and collector. Unless the product was immediately taken away, it became clotted and solidified, and turned black due to overheating. When increasing the drying temperature (175 - 180^0C), the products became more unconsolidated, and the powder flew out faster without the solidification phenomenon.

The liquor sensory characteristics of the soluble tea powder is shown in Table 2. It was

Table 2. Effect of spray drying temperature on tea liquor sensory characteristics

Drying temperature (^{0}C)	Tea liquor sensory characteristics			
	Color	Smell	Taste	Solubility
160	Bright golden green	Characteristic aroma	Slightly acrid, less characteristic	Pure, homogeneous
165	Bright golden green	Characteristic aroma	Slightly acrid, less characteristic	Pure, homogeneous
170	Bright golden green	Characteristic aroma	Slightly acrid, less characteristic	Pure, homogeneous
175	Bright golden green	Characteristic aroma	Slightly acrid, less characteristic	Pure, homogeneous
180	Bright golden	Light, less characteristic	Slightly acrid, less characteristic	Pure, homogeneous

clear that with drying temperatures less than 180^{0}C, the tea liquor remained green and retained its characteristic aroma. When the drying temperatures were greater than 180^{0}C, the liquor switched to golden green brown and it also lost its smell.

Thus, the spray drying temperature significantly affected the drying process, creating different powder and colors of tea liquor. The appropriate temperature for drying concentrated tea extracts in the study was 175^{0}C.

By studying the effects of spray drying temperature on the contents of total polyphenols, caffeine, catechin, and tea liquor sensory characteristics, it can be seen that the drying temperature should be maintained at 170 - 175^{0}C to ensure the contents of the chemical compositions are at acceptable levels and the tea liquor has good sensory characteristics. If the inlet temperature was higher than 175^{0}C, the contents of these components decreased rapidly, the sensory quality was reduced as well, the tea liquor turned golden brown, and its aroma also diminished. If the temperature was less than or equal to 170^{0}C, the heat supply was insufficient and the surface adhesion phenomenon appeared on the drying bins.

3.2. Effect of drying agent velocity on the content of total polyphenol, catechin, and caffeine of tea powder and tea liquor sensory characteristics

The change in drying agent velocity also affected the quality of the tea powder products. In the study, drying process variables were fixed at a drying temperature of 175^{0}C, an atomization air pressure of 10psi, and a feeding volume of 200ml/h, but the drying agent velocity varied among 2 m/s, 3 m/s, 4 m/s, and 5 m/s.

Table 3 shows that when the drying agent velocity was 5 m/s, the polyphenol content in the tea powder was higher than it was at the drying agent velocities of 4 m/s, 3 m/s, or 2 m/s. However, due to the high drying agent velocity, a part of the powder was quickly driven out of collecting system (through the drying chamber and the cyclone) by exhaust, leaving one part adhered to the bottom of the drying chamber. Moreover, the machine ran loudly and it was not safe to use. When the agent velocity was 4 m/s, it produced fine powders and the powder speed moving through cyclone was pretty fast. The content of total polyphenols decreased slightly compared to the content at the speed of 5m/s. Setting the drying agent velocity less than 4 m/s led to the total polyphenol content decreasing rapidly, from 29.81% at 4 m/s to 29.11% at 2 m/s. This velocity was an insufficient drying agent to move water out of the droplet, leading to deposition of the wet powder on the drying chamber and the powder latter turning brown due to overheating. Polyphenol content decreased as the wet powder clung to the hot walls of the drying chamber for a long time.

When reducing the drying agent velocity, caffeine loss was at a lower level than the polyphenol content. This may be explained by the fact that caffeine is heat resistant. The changes in catechin content when changing the drying agent velocity were similar to what

Table 3. Effect of drying agent velocity on total polyphenol, catechin, and caffeine content of the tea powder

Drying agent velocity	Polyphenol (%)	Catechin (%)	Caffeine (%)
2 m/s	29.11[a]	10.41[a]	5.02[a]
3 m/s	29.42[b]	11.25[b]	5.11[b]
4 m/s	29.81[c]	13.11[c]	5.21[c]
5 m/s	30.35[d]	13.55[d]	5.30[d]
$LSD_{5\%}$	0.0377	0.0552	0.0282

Note: In a column, different superscript letters indicate that mean values are significantly different at 5%.

Table 4. The impact of the drying agent velocity on tea liquor sensory characteristics

Drying agent velocity (m/s)	Tea liquor sensory characteristics			
	Color	Smell	Taste	Solubility
2	Bright golden green	Weak aroma, less characteristic	Slightly acrid, less characteristic	Pure, homogeneous
3	Bright golden green	Less characteristic	Slightly acrid, less characteristic	Pure, homogeneous
4	Bright golden green	Characteristic aroma	Slightly acrid, less characteristic	Pure, homogeneous
5	Bright golden green	Characteristic aroma	Slightly acrid, less characteristic	Pure, homogeneous

happened to the polyphenols. This content decreased as the drying agent reduced from 3m/s to 2m/s. When the drying agent velocity was higher than 4m/s, the catechin content was slightly higher. Evaluating of the sensory characteristics of tea powder dried at different drying agent velocity modes, it was found that if the drying agent velocity was set under 4m/s, the color, smell, and taste of the tea liquor was poor compared to when it was at a higher level (Table 4).

3.3. Effect of atomization air pressure on the content of total polyphenols, catechins, and caffeine of tea powders and tea liquor sensory characteristics

Besides the structural nozzle, atomization pressure plays a decisive role in the formation of the particle size generated in the drying chamber which affects the quality and size of the spray - dried product. Hence, selecting a suitable pressure in the experiment in accordance with each spray dryer is required. The experiment was carried out at a temperature of 175^0C, a feeding volume of 200ml/h, and a drying agent velocity of 4m/s, while the atomization air pressure ranged between 5 and 20psi.

It can be seen in Table 5 that when the atomizing air pressure increased from 5psi to 10psi, the polyphenol content decreased 0.3%. Increasing the atomization air pressure from 10psi to 15psi or 20psi, did not cause the polyphenol content to change significantly. However, at a 5psi injection mode, because the pressure was not strong enough to create fine droplets, there was not only insufficient heat to evaporate the moisture from the tea droplet but there were also deposits on the drying wall chamber due to the large particle concentration in the nozzle, which rapidly clogged the spraying nozzle. At 15psi and especially at the 20psi mode, due to high pressure, very small powders were created, which were unable to collect, following the exhaust.

The change in total caffeine content was insignificant when the atomization air pressure was set from 5psi to 20psi as the difference was only in the range of 0.02 - 0.04% DM. When the injection pressure was 5psi, the highest catechin

Table 5. Effect of atomization air pressure on total polyphenol, catechin and caffeine content of the tea powder

Atomization air pressure	Polyphenol (%)	Catechin (%)	Caffeine (%)
5 psi	30.26[a]	13.56[a]	5.25[a]
10 psi	29.96[b]	13.24[b]	5.23[ab]
15 psi	29.87[c]	13.09[c]	5.19[bc]
20 psi	29.84[c]	13.04[c]	5.21[c]
$LSD_{5\%}$	0.06	0.0489	0.0266

Note: In a column, different superscript letters indicate that mean values are significantly different at 5%.

Table 6. Effect of atomization air pressure on tea liquor sensory characteristics

Atomizing air pressure (psi)	Tea liquor sensory characteristics			
	Color	Smell	Taste	Solubility
5	Bright golden green	Sweet, characteristic aroma	Slightly acrid, less characteristic	Less pure, homogeneous
10	Bright golden green	Sweet, characteristic aroma	Slightly acrid, characteristic	pure, homogeneous
15	Bright golden green	Sweet, characteristic aroma	Slightly acrid, characteristic	pure, homogeneous
20	Golden green	Weak, less characteristic aroma	Slightly acrid, less characteristic	pure, homogeneous

content of 13.56% DM was obtained. However, the value at this pressure was instant as big droplets quickly collected in the nozzle, turning golden brown and creating a solid state and clogged nozzle. From pressures 10psi or higher, the powder was relatively stable and it achieved the best solubility at 15psi. At the pressure of 20psi, the powder turned golden brown, was less bright, and the catechin content decreased slightly.

The research results showed that when setting the atomization air pressure from 10 to 15psi, the tea liquor remained slightly acrid, had a characteristic taste, had pure solubility, green color, and a sweet aroma (Table 6). Flavor was reduced at pressures higher than 20psi. Organoleptic properties of the tea liquor were greatly affected by the atomizing air pressures below 10psi. Due to the low pressure, there were wet droplets, which created lumps in the drying chamber.

4. CONCLUSIONS

Drying temperature, drying agent velocity, and atomization air pressure are the main process parameters affecting the quality of soluble tea powder made from fresh old tea leaves. Powder products produced at a spray drying temperature of 1750C, a drying agent velocity of 4 m/s, and an atomization air pressure of 10psi, had acceptable quality levels and good liquor sensory characteristics. The tea powders retained their polyphenol components (29.84 - 30.26% dry matter (DM)), caffeine (5.19 - 5.25% DM), and total catechins (13.04 - 13.56% DM). The results of the study contribute to improving the process technology for producing soluble green tea powder from fresh old tea leaves, reducing production costs, and supplying materials for the food processing industry.

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