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Developing a Herbal Drink from Green Asparagus (*Asparagus officinalis* L.): Effect of Process Parameters on the Quality of the Product

Quang Vinh Nguyen[1,*], Dang Pha Le[2], Minh Trung Nguyen[1], Thi Yen Nhi Tran[3], Truong Dang Le[3]

[1] *Institute of Biotechnology and Environment, Tay Nguyen University, Buon Ma Thuot, Vietnam*

[2] *Department of Science and Technology in Dak Lak, Buon Ma Thuot, Vietnam*

[3] *Nguyen Tat Thanh University, Ho Chi Minh, Vietnam*

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**Quang Vinh Nguyen: nqvinh@ttn.edu.vn, https://orcid.org/0000-0003-2584-1466*
Dang Pha Le: https://orcid.org/0000-0001-8575-3009
Minh Trung Nguyen: https://orcid.org/0000-0002-6665-4213
Thi Yen Nhi Tran: https://orcid.org/0000-0001-7522-1471
Truong Dang Le: https://orcid.org/0000-0003-0335-1140

Abstract.
Green asparagus is widely consumed fresh due to its high nutritional value and a low calorie content. However, its short shelf-life due to a high water content causes high postharvest losses. In this study, we aimed to develop an innovative asparagus herbal drink to ease postharvest losses and diversify asparagus-derived products.

We investigated the effects of process parameters on the quality of the herbal drink from green asparagus. In particular, we determined the optimal length and grinding size for asparagus and selected suitable blanching and drying methods. Analytical responses included the contents of total soluble solids, polyphenol, carbohydrates, and vitamin C, as well as the visual appearance of asparagus samples.

The length of 5 mm was found suitable for subsequent steps as it facilitated an increase in solute in the asparagus infusion. Microwave blanching and convective drying were selected to achieve high contents of total soluble solids, polyphenol, carbohydrates, and vitamin C in the asparagus infusion. Dried asparagus ground into 1.5–2.0 mm particles was packaged into tea bags. The asparagus infusion subjected to sensory evaluation had a yellowish color, a characteristic asparagus flavor, and a relatively sweet taste. Total soluble solids in the infusion amounted to 26%.

Our results showed a possibility of developing an asparagus herbal drink which could be a potent product in the commercial market. Therefore, further large-scale studies of the asparagus herbal drink should be carried out to enhance its feasibility in the food industry.

Keywords. Green asparagus, herbal drink, total soluble solids, total polyphenol content, blanching, convective drying

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Влияние технологических параметров на качество травяного напитка из зеленой спаржи (*Asparagus officinalis* L.)

Quang Vinh Nguyen[1,*], Dang Pha Le[2], Minh Trung Nguyen[1], Thi Yen Nhi Tran[3], Truong Dang Le[3]

[1] *Institute of Biotechnology and Environment, Tay Nguyen University, Buon Ma Thuot, Vietnam*

[2] *Department of Science and Technology in Dak Lak, Buon Ma Thuot, Vietnam*

[3] *Nguyen Tat Thanh University, Ho Chi Minh, Vietnam*

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**Quang Vinh Nguyen: nqvinh@ttn.edu.vn, https://orcid.org/0000-0003-2584-1466*
Dang Pha Le: https://orcid.org/0000-0001-8575-3009
Minh Trung Nguyen: https://orcid.org/0000-0002-6665-4213
Thi Yen Nhi Tran: https://orcid.org/0000-0001-7522-1471
Truong Dang Le: https://orcid.org/0000-0003-0335-1140

Аннотация.
Зеленую спаржу употребляют в свежем виде из-за ее высокой питательной ценности и низкой калорийности. Однако высокое содержание воды укорачивает срок хранения данного продукта, что приводит к высоким послеуборочным потерям. В ходе данного исследования была разработана рецептура инновационного травяного напитка из спаржи, которая уменьшает послеуборочные потери и вносит разнообразие в ассортимент продуктов питания на основе спаржи.
Изучили влияние параметров обработки сырья на качество травяного напитка из зеленой спаржи. Была определена оптимальная длина и величина помола спаржи, а также рациональные методы бланширования и сушки. В образцах определяли общее содержание растворимых сухих веществ, полифенолов, углеводов и витамина С, а также провели органолептическую оценку внешнего вида напитка.
Наиболее оптимальной оказалась длина в 5 мм, поскольку она способствовала увеличению содержания растворенного вещества в настое спаржи. Бланширование в микроволновой печи и конвективная сушка позволили повысить содержание растворимых сухих веществ, полифенолов, углеводов и витамина С. Сушеную спаржу, измельченную до 1,5–2,0 мм, упаковывали в чайные пакетики. Органолептическое исследование готового напитка позволило выделить такие качества, как желтоватый цвет, характерный спаржевый привкус и умеренно сладкий вкус. Общее содержание растворимых сухих веществ в настое составило 26 %.
Результаты исследования доказали высокий коммерческий потенциал разработанного травяного напитка из спаржи. Дальнейшее изучение позволит повысить его рентабельность в пищевой промышленности.

Ключевые слова. Зеленая спаржа, травяной напиток, общее содержание растворимых сухих веществ, общее содержание полифенолов, бланширование, конвективная сушка

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Introduction

Green asparagus (*Asparagus officinalis* L.), belonging to the Asparagaceae family, is widely cultivated in subtropical and tropical regions around the world such as China, Peru, Thailand, Mexico, etc. [1]. Asparagus is commonly divided into two categories: green asparagus and white asparagus. The difference between them, however, is dependent on the growth of their spears. White stems are formed when growing below the soil, whereas green stems are developed when they are directly exposed to sunlight and become green via the chlorophyll function [2]. Besides, another rarely consumed asparagus is purple asparagus which has a higher anthocyanin content compared to green and white asparagus [3]. Asparagus is favorably consumed in many countries due to its high nutritional value and low calorie content [1].

Asparagus has a considerably higher protein content than many other vegetables, but it is low in carbohydrates and calories [4]. Besides, asparagus has been found to be a rich source of such bioactive compounds as vitamin C, flavonoids, polyphenols, and tannins, which lower cholesterol and have an anti-cancerous effect [4]. Many antioxidants have been identified in green asparagus including rutin, tocopherol, ferulic acid, and glutathione [5]. The asparagus aqueous extract was found to have a 7-fold higher inhibitory effect against α-glucosidase than that of acarbose used for a high-fructose diet-induced metabolic syndrome in mice [6]. Asparagus extracts were reported to have potential in immunomodulatory activities [7]. The effectiveness of antihyperglycemic treatment with an asparagus extract (500 mg/kg) on STZ-induced diabetic mice was found to be the same as that of an anti-diabetic drug (glibenclamide, 5 mg/kg) [8].

On the other hand, asparagus is a highly perishable product due to its high respiration rate, limiting its shelf-life [9]. Therefore, appropriate methods should be applied to better maintain the quality of fresh asparagus or to create innovative asparagus-based products for long-term use. Asparagus stems are currently commercialized as fresh, frozen, or canned products [2]. To date, many studies have aimed to develop innovative products from green asparagus. White asparagus was successfully employed to produce a spray-dried asparagus powder by Siccama *et al.* [10]. Asparagus powder was used as an additive to improve the elasticity and rigidity of cheeses and ensure enhanced bioactive compounds in the final cheese products [11]. Mazaheri Kalahrodi *et al.* showed a tendering effect of asparagus juice on the textural characteristics of beefsteak [12]. Adding asparagus powder into processed cheese was found to enhance the phenolic content, antioxidant activity, and proteolysis of the processed cheeses, as well as to improve the textural characteristics of processed cheese [11]. The term "herbal drink" is scarcely mentioned in the studies developing products from green asparagus. Therefore, we, for the first time, developed a herbal drink from green asparagus which serves as a healthy drink due to its nutritional value and bioactive compounds. Besides, we selected an appropriate drying method to ease the quality deterioration of fresh asparagus and prevent its harvest loss. Finally, we evaluated the process parameters for developing the asparagus herbal drink to obtain a tea extract with a high solute yield.

Study objects and methods

Materials. Asparagus spears (edible part) of different length were collected from a local farm in Ea Kar, Dak Lak province. Anthrone (9,10-Dihydro-9-oxoanthracene), gallic acid, and vitamin C were purchased from Sigma-Aldrich (St. Louis, Missouri, USA). Other analytical chemicals were purchased from standard commercial suppliers.

Preparation of asparagus herbal drink. Asparagus spears were washed with distilled water to remove impurities and then sliced into specimens with varying lengths (2, 5, 10, 15, and 20 mm). The samples (500 g) were blanched in hot water (90–100°C), dried at 55°C to obtain the moisture content of 12%, and roasted at 100°C for 3 min (SCR301, Barwell, China). The samples with a suitable length were then used for further experiments.

To investigate the effect of heat pretreatment methods on the quality of the asparagus herbal drink, the selected specimens (500 g) were subjected to different heat pretreatments: without blanching (control sample), hot water blanching at 70–80°C for 3 min, hot water blanching at 90–100°C for 1.5 min, and microwave heating (R-G302VN-S, Sharp Coporation, Osaka, Japan) for 30 s at 440 W. The pretreated samples were dried at 55°C to the moisture content of 12% and then roasted at 100°C for 3 min. An appropriate pretreatment method was selected and the samples were prepared for subsequent evaluations.

The pretreated asparagus samples (500 g) were then subjected to different drying conditions (convective drying at 55°C, heat pump drying at 40°C, and microwave drying) until obtaining the moisture content of 12% followed by roasting at 100°C for 3 min. A proper drying method was selected for the herbal drink. Finally, the dried samples were ground into smaller pieces of different sizes (< 0.5, 0.5–1.0, 1.0–1.5, 1.5–2.0, and > 2 mm). The dried asparagus samples (2 g) were packaged into teabags made of filter paper. Analytical responses were determined to select the appropriate process parameters, including total soluble solids, total polyphenol content, total carbohydrate, vitamin C, and visual appearance of asparagus samples.

Total polyphenol determination. The total polyphenol content was determined according to a previous study by Nguyen *et al.* [13]. Each sample was extracted with distilled water at the ratio of 1:10. An aliquot (1 mL) of the extract was mixed with 5 mL of 10% Folin-Ciocalteu reagent and 1 mL of 7.5% Na_2CO_3. The mixture was kept for 30 min in the dark before reading absorbance values at 765 nm by using a 722-Visible spectrophotometer (Yangzhou Wandong Medical Co., China). Gallic acid served as a standard solution. The total polyphenol content was expressed as milligrams of gallic acid equivalent per gram of dry matter (mg GAE/g DM) by establishing a standard curve or varying concentrations of gallic acid (0.01–0.09 mg/mL) versus its absorbance.

Vitamin C determination. The content of vitamin C was determined by using a high-performance liquid chromatography (HPLC) system (Waters Corp., Milford, MA, USA) equipped with a Bischoff prontosil column (AQ 4×125 mm×5 μm). A gradient of the mobile phase consisting of methanol and 5 mmol/L KH_2PO_4 was programed at 0.75 mL/min for 30 min at 30°C. Each sample extract was injected to the column at the volume of 20 µL and vitamin C was used as a standard solution. The detector recorded the absorbance at 254 nm [14].

Total soluble solids and carbohydrate measurements. Total soluble solids were determined by using a digital refractometer (PR-101*α*, 0–45°Brix, Atago Co. Ltd., Japan). The carbohydrate content was measured following the Anthrone method [15]. Each sample extract (2 mL) was mixed with 4 mL of an anthrone solution and 5 mL of concentrated sulphuric acid. The mixture was boiled in a water bath for 8 min and immediately cooled to room temperature. The mixture was allowed to stand for 30 min in the dark before its absorbance was taken at 585 nm.

Sensory evaluation. The sensory evaluation of the asparagus herbal drink followed the Vietnamese standard TCVN 3218:2012. Four sensory attributes (appearance, color, flavor, and taste) of the asparagus infusion were evaluated according to a 5-point scale. For this, each teabag containing 2 g of dried asparagus was placed in a glass cup with 100 mL of boiled water and allowed to stand for 6 min. The sensory evaluation was conducted by 20 panelists who were assigned to score each attribute. The importance indexes were as follows: 1 for appearance, 0.6 for color, 1.2 for flavor, and 1.2 for taste.

Statistical analysis. Each experiment was conducted in triplicate and the data were presented as mean ± standard deviation. The results were analyzed by a one-way analysis of variance (ANOVA) with the SPSS software (IBM Corp., Armonk, New York, USA). The Tukey HSD test was utilized to compare mean values at the significant level of 5% ($P < 0.05$).

Results and discussion

Effect of asparagus size on the solute content in the extract. Prior to heat pretreatment, green asparagus needs to be reduced in size to facilitate further processes of blanching and drying. Table 1 presents the effects of asparagus lengths on the solute content in the extract. We found that longer samples had ineffective extraction yields of total soluble solids, total polyphenol content, and total carbohydrates. On the other hand, the total soluble solids, total polyphenol content, and total carbohydrate values of a 2 mm asparagus extract were the highest, amounting to 33.53 ± 0.21%, 0.74 ± 0.02 mg GAE/g DM, and 13.36 ± 0.32%, respectively. This was because smaller asparagus samples facilitated the diffusion of the blanching water to soften the plant tissues, increasing the extraction efficiency of solutes in green asparagus [16]. Our results were consistent with many previous reports that found smaller particle sizes to achieve higher extraction efficacy [16–18]. According to our analysis, there was no difference in the total soluble solids, total polyphenol content, and total carbohydrate values between the 2 and 5 mm samples. The content of vitamin C, however, showed an increasing trend at larger sample sizes. Vitamin C is highly susceptible to environmental conditions such as light, temperature, and oxygen [19]. The lowest content (83.57 ± 2.43 mg/100 g) of vitamin C was found in the 2 mm sample. This was because the small size contributed to a larger surface exposure to the hot blanching temperature, causing vitamin C to decay faster. Moreover, the loss in vitamin C could possibly be ascribed to the leakage to the blanching medium [20].

The visual appearance of asparagus specimens at different sizes is presented in Fig. 1a. As we can see, the 2 mm asparagus samples had a soft structure after blanching, with a dark brown color in some of the specimens. Meanwhile, the other samples showed harder structures with a greenish color, which were suitable for further processing. We found that the 5 mm sample could be suitable for further processing to develop an asparagus herbal drink.

Table 1. Effect of asparagus lengths on total soluble solids, polyphenol, carbohydrates, and vitamin C in the asparagus extract

Таблица 1. Зависимость общего содержания растворимых сухих веществ, полифенолов, углеводов и витамина С в экстракте от длины нарезанных образцов спаржи

Sample length, mm	Total soluble solids, %	Total polyphenol content, mg GAE/g DM	Total carbohydrate, %	Vitamin C, mg/100 g
2	33.53 ± 0.21^{c}	0.74 ± 0.02^{bc}	13.36 ± 0.32^{d}	83.57 ± 1.43^{a}
5	32.77 ± 0.59^{c}	0.72 ± 0.03^{b}	11.39 ± 1.67^{cd}	85.43 ± 1.21^{ab}
10	28.57 ± 0.34^{b}	0.67 ± 0.04^{ab}	10.56 ± 0.65^{bc}	86.33 ± 1.05^{b}
15	26.64 ± 0.82^{a}	0.63 ± 0.03^{a}	9.51 ± 0.34^{b}	88.53 ± 0.67^{b}
20	25.56 ± 0.48^{a}	0.61 ± 0.03^{a}	8.33 ± 0.24^{a}	90.78 ± 0.77^{c}

Values are expressed as mean ± SD. Different letters (a, b, c, d) show significant differences within the same column ($P < 0.05$).

Данные представлены как среднее значение ± стандартное отклонение. Буквами a, b, c, d обозначены значительные различия в пределах одного и того же столбца ($P < 0,05$).

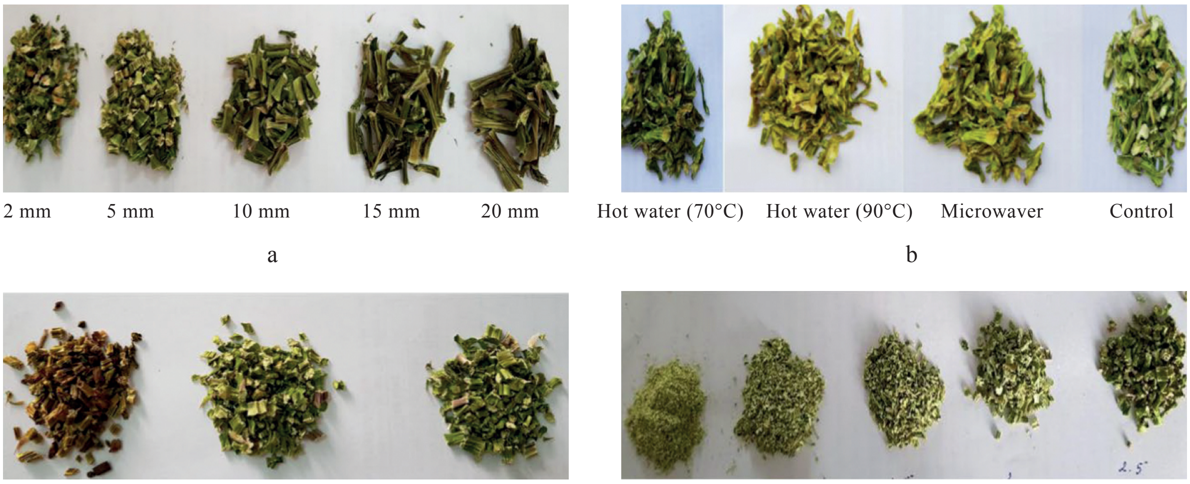

Figure 1. Visual appearance of asparagus samples: a) different lengths; b) blanching methods; c) drying methods; d) asparagus tea at different particle sizes

Рисунок 1. Внешний вид образцов спаржи: а) нарезки длины; б) методы бланширования; в) методы сушки; г) напиток из спаржи при разной величине помола

Effect of blanching methods on the quality of asparagus herbal drink. Heat pretreatment of the asparagus samples aims to inactivate the browning enzymes such as polyphenol oxidase and peroxidase, as well as to inhibit microbial growth on the material surfaces. It can also shorten the drying time as it softens the structure of the material, leading to a higher water evaporation rate [21]. According to our results, all the methods of heat pretreatment showed an increment in total soluble solids and total polyphenol content but a decline in vitamin C and total carbohydrates, compared to the control sample (without blanching). As previously discussed, high temperature might degrade vitamin C molecules. The decrease in total carbohydrates could be ascribed to the leakage to the blanching water, which was previously mentioned by Xanthakis *et al.* [20]. High Temperature Short Time (HTST). Heat treatment can increase the content of solutes and polyphenols by causing structural changes in plant cells. In particular, it can disrupt cell membranes and weaken hemicellulase and cellulase bonds, thus enhancing the extraction efficacy [22]. In our study, the microwave treatment showed the best extraction efficiency in the total soluble solids (32.67 ± 0.43%) and total polyphenol content (0.80 ± 0.05 mg GAE/g DM) of asparagus, while having a lesser effect on the vitamin C content and total carbohydrates in the extract. It was noted that the microwave treatment promoted a thermal gradient between the extracting medium and plant cells, facilitating the liberation of phenolic compounds [23]. A similar finding was reported in the study by Severini *et al.*, where the microwave blanching showed an increase in phenolic compounds and impaired the degradation of vitamin C in the sample, compared to hot water blanching and steam blanching [24].

As seen in Fig. 1b, the blanching processes caused noticeable impacts on the color of the dried asparagus samples. Hot water blanching at 70°C caused a browning effect, while blanching at 90°C and microwave heating gave the dried asparagus a yellow-greenish color. This could be explained by the fact that blanching at 90°C and microwave heating showed better efficiency in inactivating polyphenol oxidase compared to blanching at 70°C [13, 20]. High Temperature Short Time. Thus, microwave blanching could be a suitable option to develop a yellow-greenish color for asparagus tea, as well as to achieve higher total soluble solids, total polyphenol content, and vitamin C contents in the extract.

Effect of drying conditions on the quality of asparagus herbal drink. The effects of different drying conditions on the extraction yield of the asparagus herbal drink are presented in Table 3. Microwave drying had the shortest drying time of 29 min. However, it considerably reduced the contents of vitamin C, carbohydrates, and total soluble solids in the asparagus drink. Meanwhile, convective drying and heat pump drying resulted in higher total soluble solids and vitamin C content in the extract. The rapid degradation of vitamin C by microwave heating was due to excessive heat generated in the internal molecular structures of asparagus. As shown in Fig. 1c,

Table 2. Effect of blanching methods on total soluble solids, polyphenol, carbohydrates, and vitamin C in the asparagus extract

Таблица 2. Зависимость общего содержания растворимых сухих веществ, полифенолов, углеводов и витамина С в экстракте спаржи от методов бланширования

Blanching method	Total soluble solids, %	Total polyphenol content, mg GAE/g DM	Total carbohydrate, %	Vitamin C, mg/100 g
Control sample (without blanching)	27.56 ± 0.32^{a}	0.60 ± 0.03^{a}	12.78 ± 0.54^{b}	72.10 ± 1.51^{c}
Hot water (70°C)	28.31 ± 0.21^{b}	0.68 ± 0.02^{b}	10.40 ± 0.43^{a}	63.52 ± 2.43^{a}
Hot water (90°C)	30.63 ± 0.18^{c}	0.74 ± 0.01^{c}	9.92 ± 0.67^{a}	65.29 ± 2.67^{a}
Microwave	32.67 ± 0.43^{d}	0.80 ± 0.02^{d}	11.56 ± 0.81^{ab}	68.61 ± 1.43^{ab}

Values are expressed as mean ± SD. Different superscripts (a, b, c, d) indicate significant differences within the same column ($P < 0.05$).

Данные представлены как среднее значение ± стандартное отклонение. Буквами a, b, c, d обозначены значительные различия в пределах одного и того же столбца ($P < 0{,}05$).

Table 3. Effect of drying methods on total soluble solids, polyphenol, carbohydrates, and vitamin C in the asparagus extract

Таблица 3. Зависимость общего содержания растворимых сухих веществ, полифенолов, углеводов и витамина С в экстракте спаржи от методов сушки

Drying method	Total soluble solids, %	Total polyphenol content, mg GAE/g DM	Total carbohydrate, %	Vitamin C, mg/100 g	Drying time
Microwave	26.93 ± 1.44^{a}	0.75 ± 0.04^{b}	11.53 ± 0.54^{a}	52.69 ± 2.54^{a}	29 min
Convection	30.46 ± 1.20^{b}	0.61 ± 0.02^{a}	13.58 ± 0.32^{b}	68.36 ± 2.45^{b}	17 h
Heat pump	29.62 ± 2.12^{b}	0.59 ± 0.03^{a}	12.47 ± 0.67^{b}	70.33 ± 3.12^{b}	22 h

Data are expressed as mean ± SD. Different superscripts (a, b, c, d) indicate significant differences within the same column ($P < 0.05$).

Данные представлены как среднее значение ± стандартное отклонение. Буквами a, b, c, d обозначены значительные различия в пределах одного и того же столбца ($P < 0{,}05$).

Table 4. Dried asparagus in the teabag and sensorial properties of asparagus infusion at different particle sizes

Таблица 4. Высушенная спаржа в пакетиках и органолептические свойства настоя спаржи при разной величине помола

Particle size, mm	Appearance of dried asparagus in the teabag	Color	Flavor	Taste	Sensory score
< 0.05	Fine powder	Light yellowish color, presence of many fine particles	Very light characteristic flavor of asparagus	Very light sweet	7.40 ± 0.32
0.5–1.0	Homogenous form	Presence of particles, light yellowish color	Light characteristic flavor of asparagus	Light sweet	9.00 ± 0.23
1.0–1.5	Homogenous form	Yellowish color	Intense characteristic flavor of asparagus	Relative sweet	15.40 ± 0.24
1.5–2.0	Homogenous form	Yellowish color	Intense characteristic flavor of asparagus	Relative sweet	16.00 ± 0.35
> 2.0	Inhomogeneous form	Light yellowish color	Very light characteristic flavor of asparagus	Very light sweet	9.60 ± 0.32

convective drying and heat pump drying gave dried asparagus a yellow-greenish color, whereas microwave drying induced a brown-yellowish color, reducing the sensorial attributes of the asparagus herbal drink. The lower total polyphenol content caused by convective drying and heat pump drying, as compared to the microwave-dried asparagus, could be attributed to the degradation of phenolic compounds when exposed to an extended drying time (17–22 h). The decrease in the total polyphenol content could also be due to the enzymatic processes that occurred during drying [25]. Although the heat generated by microwave drying was considerably higher than that in the other drying methods, the microwave drying time was not sufficient to cause a significant impact on phenolic compounds. As for sensorial properties, the asparagus samples

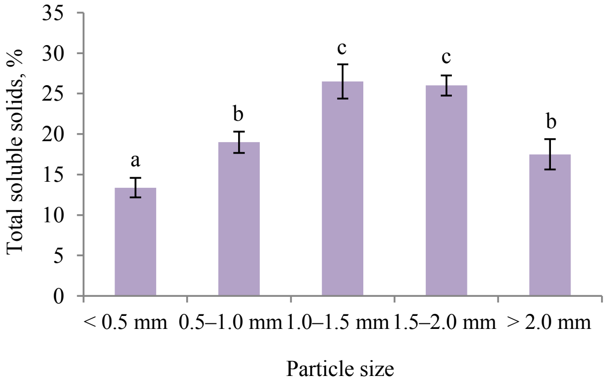

Figure 2. Effect of asparagus particle sizes on total soluble solids in the tea extract

Рисунок 2. Влияние величины помола на общее содержание растворимых сухих веществ в экстракте спаржи

acquired a yellow-greenish color from convective drying and heat pump drying and a dark brown color from microwave drying, which significantly affected their appearance. Both convective drying and heat pump drying produced the drinks with the same values of total soluble solids, total polyphenol content, total carbohydrate, and vitamin C. However, convective drying required a shorter time (17 h) to achieve the desired moisture content (12%) in the asparagus tea. Therefore, this method proved the most suitable for developing the asparagus herbal drink.

Effect of asparagus particle sizes on total soluble solids in the asparagus infusion. After drying, the asparagus samples were ground to different particle sizes and packaged into teabags. The effect of particle sizes on total soluble solids in the tea extract is illustrated in Fig. 2. We found that the grinding size from 1 to 2 mm produced the highest total soluble solids (> 26%), while very fine powder (< 0.5 mm) produced the lowest total soluble solids (13.37%) in the asparagus infusion. This agreed with many previous studies where the small particle size facilitated the extraction of solute in the solvent medium. However, very fine particles tended to agglomerate and deposit at the bottom of the teabag, preventing the diffusion of solute to the extracting medium sieving and selecting the optimal granulometry (0.15–0.74 mm) [16]. Table 4 shows a sensorial description of asparagus tea, while Fig. 1d features the appearance of dried asparagus at different particle sizes. According to the sensory evaluation, dried asparagus with 1.5–2.0 mm particles produced an asparagus infusion with the highest score (16) for color, intense taste, and characteristic flavor. Therefore, this size proved the most suitable for developing the asparagus herbal drink since it produced the highest soluble solids and good sensorial properties.

Conclusion

In this study, we developed an innovative asparagus herbal drink. The asparagus length of 5 mm was found to facilitate subsequent steps. Microwave blanching caused the dried asparagus to acquire a yellow-greenish color. Unlike hot water blanching, this method produced higher values of total soluble solids, total polyphenol, and total carbohydrate, while having a lesser effect on the content of vitamin C. Of all drying methods, convective drying proved suitable for higher total soluble solids and total carbohydrate, as well as better visual appearance of asparagus tea. Finally, the grinding size of asparagus was selected at 1.5–2.0 mm to obtain the highest total soluble solids in the asparagus infusion and the highest sensory score. The asparagus herbal drink had a yellowish color, an intense characteristic flavor of asparagus, and a relatively sweet taste. In addition, we selected the process parameters for the asparagus teabag to maintain a high content of total polyphenol and vitamin C in the asparagus herbal drink to enhance its nutritional value. Further investigations can be carried out to produce an asparagus herbal drink with a higher polyphenol content in the infusion. Besides, a pilot-scale study should be conducted to enhance the feasibility of the asparagus herbal drink as a commercial product.

Contribution

The authors were equally involved in writing the manuscript and are equally responsible for plagiarism.

Conflict of interest

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

Критерии авторства

Авторы были в равной степени вовлечены в написание рукописи и несут равную ответственность за плагиат.

Конфликт интересов

Авторы заявляют, что конфликта интересов нет.

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