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# Effects of temperature and duration on extraction process utilising aqueous solvent towards quality of tea derived from dried roots of *Asparagus officinalis* L.

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## ABSTRACT

**Introduction:** The root of *Asparagus officinalis* L. stands out as a potential by-product source for creating value-added food products. Asparagus root is studied for the development of a new herbal tea. The water solvent extraction method is proposed to determine appropriate extraction parameters, including temperature and time, which are crucial and interdependent factors during the extraction process, requiring precise investigation to maximise yield and maintain the quality of the extracted compounds. **Methods**: This investigation focused on identifying an advanced extraction method applicable to the tea infusion of desiccated herbal products. The study delved into multiple extraction parameters, encompassing temperatures (80, 85, 90, and 95°C) and durations (15, 30, 45, and 60 minutes), utilising an aqueous solvent to scrutinise their impact on the tea's extracted solution quality. **Results:** The research determined that 85°C and 30 minutes were the proper parameters for tea infusion. The extracted solution from dried asparagus root tea exhibited ultimate nutrient contents (saccharose, vitamin C, phenolic compounds, flavonoid, and saponin) and antioxidant capacity (DPPH and FRAP) (in 100 g of dry matter) of 0.81 g, 1.23 g, 0.50 g TAE, 0.12 g QE, 1.10 g SE, 56.10%, and 1.12 M $Fe^{2+}$, respectively. **Conclusion:** This research effectively elucidated the impacts of extraction temperature and duration employing an aqueous solvent on desiccated agricultural commodity, particularly asparagus root. The findings yielded valuable insights aimed at discerning optimal parameters for the extraction procedure based on nutrient content and bioactivity in the extracted solution.

**Keywords:** aqueous solvent, asparagus roots, extraction process

## INTRODUCTION

Asparagus (*Asparagus officinalis* L.) is considered one of the world's top 20 valuable vegetable crops due to its exceptional nutritional attributes. Its unique flavour and fragrance stem from a variety of volatile components, including pyrazines and compounds containing sulphur (Pegiou *et al.*, 2019). With a history of cultivation spanning over two millennia across the globe, asparagus has firmly established itself as a cultivated plant. Asparagus is a perennial herb that typically takes 7-8 years to mature for commercial use. During harvest, the roots and rhizomes

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are often left in the fields as by-products (Viera-Alcaide *et al.*, 2022).

There are two main types of asparagus: green and white, both with high annual consumption. The global asparagus market is expected to grow at a consistent rate of 3% annually. Asparagus contains various phytochemicals, including saponin, flavonoid, vitamins, along with other polysaccharides, and dietary fibre (Zhang *et al.*, 2020). These compositions exhibit a spectrum of effects, such as anti-cancer, anti-tumour, antioxidant, immunomodulatory, hypoglycaemic, anti-hypertensive, and anti-epileptic actions, thereby elevating the crop's worth (Pegiou *et al.,* 2019; Guo *et al.*, 2020). Additionally, bioactive compound concentrations, such as polysaccharides, specifically fructans, are primarily stored in the roots, with a significant accumulation in the lower sections of the spears, surpassing other segments in content (Guo *et al.*, 2020). However, despite these attributes, few applications have been researched and developed for this specific component. Consequently, asparagus root remains a latent source material for the creation of value-added products, contributing to the amplification of the crop's value and the judicious utilisation of this by-product.

The process of obtaining desired natural products from raw materials is extraction. Various extraction methods, including solvent extraction, distillation, pressing, and sublimation, are employed based on the extraction principle. Among these, solvent extraction stands out as the most commonly utilised method (Zhang, Lin & Ye, 2018). Thoughtful selection of solvents plays a crucial role in determining the extraction of bioactive compounds from botanical sources. Desirable properties in an extraction solvent include low toxicity, easy evaporation at low temperatures, effective solubility of the target compound, and sufficient volatility. The selection of solvents is influenced by factors such as extraction rate, diversity of compounds extracted, ease of handling extracts, and the cost-effectiveness of both the extraction solvents and targeted compounds.

Plants contain a myriad of bioactive compounds with varying polarities. Numerous techniques have been developed to obtain pure compounds, elucidating their structure and biological activity (Sasidharan *et al.*, 2011). Aqueous extraction processing has emerged as an environmentally friendly alternative due to its advantages, such as eliminating organic solvent consumption, requiring lower investment costs, and having reduced energy demands. Furthermore, aqueous extraction processing eliminates the need for equipment related to drying, solvent recovery, and monitoring and controlling emissions of volatile organic compounds. Additionally, this process facilitates the simultaneous recovery of other compounds, including proteins, carbohydrates, fibres, and bioactive compounds. The efficiency of extraction is influenced by factors such as the properties of the extraction solvent, particle size of the raw materials, solvent-to-solid ratio, extraction temperature, and extraction duration (Zhang *et al.*, 2018; Guilherme *et al.*, 2023). Among these factors, both temperature and duration significantly impact the extraction process, with their effects being interdependent. Optimal extraction conditions need to be carefully calibrated to maximise yield and preserve the quality of the extracted compounds. In order to find these optimal conditions, balancing the benefits of increased temperature and duration against the risk of compound degradation, the extraction process of dried asparagus roots was carried out in this study.

(a) (b) (c)

**Figure 1.** Green asparagus roots (a), green asparagus roots after blanching (b), and asparagus roots tea (c) (Nguyen *et al.*, 2024)

## MATERIALS AND METHODS

### Materials and equipment

The roots of *Asparagus officinalis* L. with excellent quality and no signs of physical damage or infestation were harvested in My Thoi Ward, Long Xuyen City, An Giang Province, Vietnam. The heat-resistant variety UC 157 F2 supplied by Walker Brothers (USA) was used. The green asparagus shoots were harvested when they reached 25-30 cm (Ba, Thuy & Tho, 2014). The roots were cut from the shoots, with a length approximately one-third of the shoot's length.

The drying process was carried out using the Forced Convection Drying Oven (ESCO, OFA-110-8, Indonesia).

### Experimental design

Every sample comprised 2 kg of green asparagus roots, cut into approximately 1 cm pieces. The roots underwent sorting and washing, followed by a preliminary treatment of blanching, involving immersion in hot water at 85°C for 2 minutes in order to ensure better quality and stability of the material (Nguyen *et al.*, 2024). After blanching, the samples were dried using a Forced Convection Oven (ESCO, OFA-110-8, Indonesia) at 70°C with an air flow velocity of 1 m/s. The dried samples were crushed finely and sieved through a mesh with a diameter of 1 mm (Nguyen *et al.*, 2023) (Figure 1). Each sample contained 100 g of finely ground dried material and was extracted in a triangular flask with a water/material ratio of 20/1. The aqueous extraction was set up at various temperatures (80, 85, 90, and 95°C) for different durations (15, 30, 45, and 60 minutes) in the Water Bath BK500 (Yamoto, Japan). The extracted solution was collected for the following analysis and evaluation.

*Determination of colour*

Colour assessment was conducted by analysing *L, a,* and *b* values of the extracted solutions using a colorimeter (Konica Minolta CR400).

*Determination of Brix*

Brix was performed by measuring the dissolved solids using a refractometer (Atago hand-held refractometer, Japan) with a detection level range of 0-53°Brix in the extracted solution of dried sample.

*Determination of saccharose*

Saccharose content (g/100 g of dry matter) was measured by the dinitrosalicylic acid (DNS) method with some modifications. This method is based on the oxidation of the C=O group by 3,5-dinitrosalicylic acid from yellow to orange-red in an

alkaline medium (Nielsen, 2010). An aliquot (1 mL) of sample was put in a test tube and then added with 2 mL of reagent DNS. The tubes of blank, solution of standard glucose, and samples were put in boiling water for 10 minutes. Next, 7 mL of distilled water was added. The solution was analysed at an absorbance of 575 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan). The concentration of total sugar was based on a standard curve of glucose, y=23885x + 0.126 ($R^2$=0.9999), where y is the absorbance and x is the concentration of the solution in the tube.

*Determination of vitamin C*

Ascorbic acid was detected based on the 2,4-dinitrophenyl hydrazine colorimetric method described by Sharaa & Mussa (2019) with some modifications. Approximately 1 g of sample with 5 mL of solution containing 3% meta-phosphoric acid (w/v) and 8% glacial acetic acid (v/v) were taken in a 15 mL centrifuge tube. The centrifuge tube was placed on the reciprocating shaker (Stuart, UK) for 1 hour. One mL of supernatant after centrifugation was mixed with 0.5 mL of 3% bromine, 0.25 mL of 10% thiourea, and 0.25 mL of 2,4-dinitrophenyl hydrazine. The mixture was incubated for 3 hours at 37°C. After that, 10 mL of 85% $H_2SO_4$ was added to the tube to form a red complex. The solution was cooled to room temperature and analysed at an absorbance of 521 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan). The concentration of vitamin C was calculated with a standard ascorbic acid graph, y=0.2253x + 0.0024 ($R^2$=0.9999), where y is the absorbance and x is the concentration of solution in the tube.

*Determination of total phenolic*

Phenolic content (mg TAE/kg of dry matter) was indicated based on the Folin-Ciocalteu reaction (Sumaiyah, Masfria & Dalimunthe, 2015). Briefly, 0.15 mL of sample was mixed with 1.2 mL of distilled water and 0.45 mL of 5% (w/v) sodium carbonate ($Na_2CO_3$) in a test tube. The mixture was added to 0.1 mL of Folin-Ciocalteu reagent and left at room temperature for 90 minutes for reaction. Phenolic in the extract reacts with Folin-Ciocalteu to form a phosphomolybdenum complex with blue colour in the alkaline medium. The absorbance of the solution was measured at 750 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan). The concentration of phenolic was calculated equally to the standard tannic acid graph (TAE), y = 0.0021x + 0.0064 ($R^2$=0.9999), where y is the absorbance and x is the concentration of the solution in the tube.

*Determination of total flavonoid*

Flavonoid content was observed through colorimetric reaction using aluminium chloride, with some modifications from the method described by Sumaiyah, Masfria & Dalimunthe (2015). The reaction creates a stable acid complex by $AlCl_3$ with the C-4 keto groups and the hydroxyl C-3 or C-5 group of flavones and flavonols. Briefly, 0.1 mL of sample was mixed with 1.2 mL of distilled water and 30 µL of 5% (w/v) $NaNO_2$. After 5 minutes, the mixture was added with 10% (w/v) $AlCl_3.H_20$ (60 µL), 0.2 mL of 1 M NaOH, and 0.11 mL of water. The solution was then measured at 510 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan). The total flavonoid concentration was calculated based on the standard quercetin graph (QE), y= 8.2634x + 0.0182 ($R^2$=0.9999), where y is the absorbance and x is the concentration of the solution in the tube.

*Determination of saponin*

Saponin content was assessed based on the vanillin-sulphuric acid method (Le *et al.*, 2018). A red-violet reaction occurs from the oxidation of triterpene

saponins by sulphuric acid and vanillin. Approximately 0.25 mL of sample was added with 0.25 mL of 8% (w/v) vanillin in 96% ethanol and 2.5 mL of 72% sulphuric acid ($H_2SO_4$). The mixture was incubated for 30 minutes at 60°C and then cooled at room temperature. Solution was measured at 560 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan). The concentration of saponin was calculated by a standard saponin graph (SE), y= 0.1348x + 0.0075 ($R^2$ = 0.9999), where y is the absorbance and x is the concentration of the solution in the tube.

*Determination of DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging activity*

Antioxidant activity of the sample was determined by the free radical scavenging capacity of 2,2-diphenyl-1-picrylhydrazyl (DPPH). The DPPH assay was carried out based on Molyneux (2004) with slight modifications. The assay is based on the electron transfer that produces a purple solution in ethanol. Sample (1.5 mL) was mixed with DPPH solution at a ratio of 1:1 (v/v) and was analysed at 517 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan). Inhibition of DPPH free radicals was calculated using the equation below:

$$\text{Inhibition of DPPH radical (\%)} = 100 \times (A_c - A_s)/A_c$$

Where: $A_c$ is the absorbance of the control and $A_s$ is the absorbance of the sample.

*Determination of ferric reducing antioxidant power (FRAP)*

FRAP assay (mM of $FeSO_4$/g dry matter) was measured based on Sudha *et al.* (2012) with some modifications. This method is based on the reduction of tripyridyltriazine complex $Fe(TPTZ)^{3+}$ to blue coloured $Fe(TPTZ)^{2+}$ by antioxidants in an acidic medium. The FRAP reagent contained 100 mL of 200 mM acetate buffer (pH 3.6), 10 mL of 20 mM $FeCl_3.6H_2O$, and 10 mL of 10 mM TPTZ in 40 mM HCl. 0.05 mL of sample was added to 1.5 mL of FRAP reagent and 0.15 mL of distilled water. The mixture was incubated at 37°C for 8 minutes. It was later analysed at an absorbance of 593 nm, using a UV-visible spectrophotometer (V730, Jasco, Japan).

**Data analysis**

Data were collected and processed by STAGRAPHICS Centurion 16.1 software (Statistical Graphics Corp., USA). Analysis of variance (ANOVA) and least significant difference (LSD) test were used to conclude the difference between the average of experiments at 5% significance level ($p$=0.05), while Microsoft Excel 2016 software was used for calculating.

Results are presented using text, tables, and figures, which illustrate the data based on statistical analyses, including $p$-values, confidence intervals, and other relevant metrics.

## RESULTS AND DISCUSSION

Water is the most common solvent in food technology for extracting saccharose from sugar cane and sugar beets, compounds from tea and coffee, and bioactive compounds from herbs in non-alcoholic beverage production. The influence of temperature and extraction time using water as a solvent on the Brix degree, chemical composition, components of bioactive compounds, and antioxidant capacity of the extract from dried asparagus roots are illustrated through Table 1, Table 2, and Figure 2.

Results showed that as the extraction temperature increased, the levels of saccharose and vitamin C decreased (Figures 2a and 2b). Specifically, when the material was extracted at 80°C, the saccharose content (per 100 g of dry matter) of the extracted solution

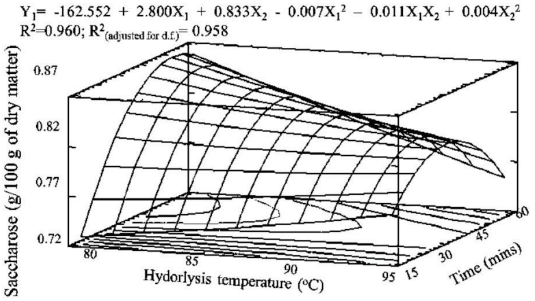
**Table 1**. Effects of temperature and extraction time using aqueous solvent on the extracted solution

| *Extraction temperature (°C)* | *°Bx* | *Extraction time (minutes)* | *°Bx* |
|---|---|---|---|
| 80 | 1.92±0.01*$^{c}$ | 15 | 2.00±0.00$^{a}$ |
| 85 | 2.03±0.01$^{a}$ | 30 | 2.01±0.00$^{a}$ |
| 90 | 2.01±0.00$^{ab}$ | 45 | 2.00±0.00$^{a}$ |
| 95 | 2.00±0.00$^{bc}$ | 60 | 1.93±0.01$^{b}$ |
| Level of significance | ** | | ** |
| Level of significance of the correlation | | ** | |

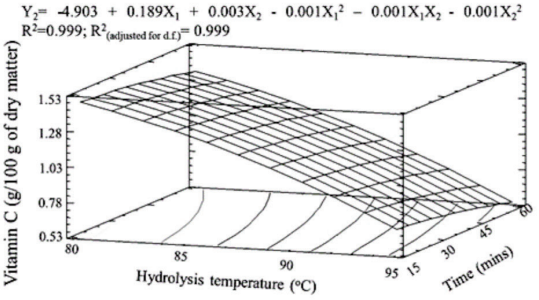
Values are expressed as means of triplicate testing. Values with a different superscript in each column are statistically significantly different, *$p$<0.05 and **$p$<0.01.

was 0.82 g, which decreased to 0.80 g when extracted at 95°C. However, at extraction temperatures of 80, 85, and 90°C, the differences in saccharose content were not statistically significant ($p$>0.05). Similarly, vitamin C content decreased from 1.42 g to 0.70 g per 100 g dry matter ($p$<0.05) as the extraction temperature increased from 80 to 95°C, which significantly declined more than 50% compared to the solution extracted at 80°C. In contrast, total soluble solids (TSS), also known as Brix, reached its highest value when extracted at 85 and 90°C, respectively, at 2.03 and 2.01, with no statistically significant difference between these two temperatures (Table 1). In terms of extraction time, saccharose levels peaked after 45 and 60 minutes of extraction with an aqueous solvent, reaching 0.840 g and 0.820 g per 100 g of dry matter, respectively, with no statistically significant difference at the 5% significance level. Conversely, increasing the extraction time tended to decrease vitamin C content. These phenomena can be caused by the oxidation and breakdown of biological compounds when extending the duration of the extraction process at high temperatures (Sasidharan *et al.*, 2011). Brix and saccharose are common measurements of sugar content in a solution. High temperatures generally enhance the extraction process, increasing Brix and saccharose content due to improved solubility and diffusion of substances. However, excessively high temperatures can cause degradation or caramelisation of some components, negatively affecting these components. Similarly, longer extraction times can also cause more substances to dissolve in the solvent. However, overly prolonged extraction can lead to the breakdown of some organic compounds, reducing Brix and saccharose (Adriana & Guy, 2016). Vitamin C (ascorbic acid) is a vital nutrient sensitive to temperature. High temperatures can decrease vitamin C content due to oxidation and thermal degradation; extended extraction times can also reduce vitamin C content due to prolonged exposure to heat and oxygen (Luzia *et al.*, 2015).

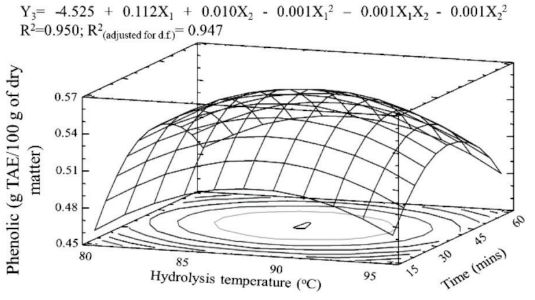
Results showed that the levels of phenolic and flavonoid increased to an optimal value and then gradually decreased as extraction temperature increased (Figures 2c and 2d). Specifically, the highest phenolic content was achieved at 85 and 90°C (0.530 g TAE/100 g dry matter), respectively, and the difference was not statistically significant ($p$>0.05). In contrast, saponin content decreased with increasing extraction temperature, from 1.20 g at 80°C to 1.01 g SE/100 g dry matter at 95°C ($p$<0.05) (Figure 2e). The reduction in DPPH free radical scavenging activity



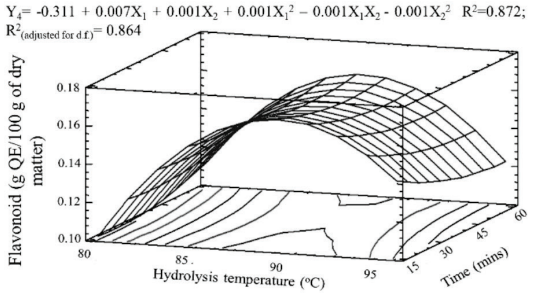

a. Saccharose



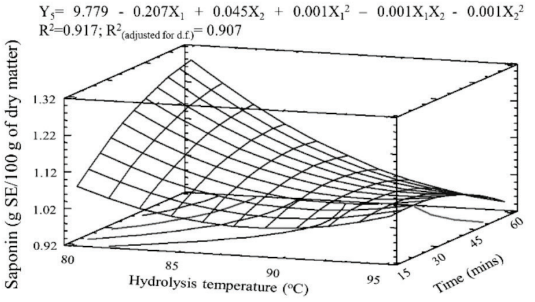

b. Vitamin C



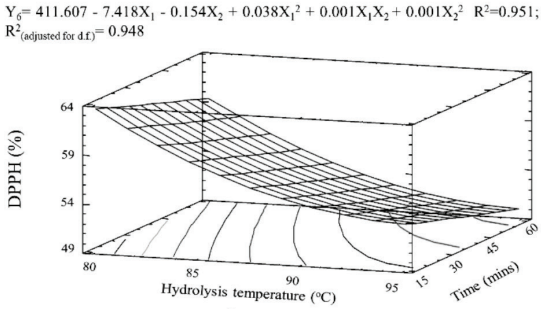

c. Phenolic



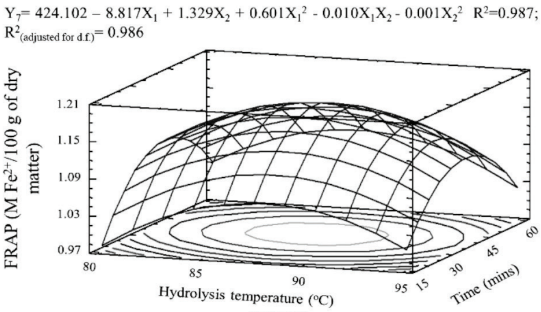

d. Flavonoid




e. Saponin




f. DPPH




g. FRAP

**Figure 2**. Effects of temperature and extraction time using an aqueous solvent on (a) Saccharose, (b) Vitamin C, (c) phenolic, (d) flavonoid, (e) saponin, (g) DPPH, and (h) FRAP of the extracted solution from dried asparagus roots using Response Surface Methodology (RSM) employing the STAGRAPHICS centurion software version 16.1

(Figure 2f) also occurred similarly to saponin, while changes in iron-reducing ability (FRAP) (Figure 2g) followed the same patterns as phenolic and flavonoid with increasing extraction temperature. Temperature is one of the significant factors affecting the solvent-based extraction process. At higher extraction temperatures, the material and compounds of plants become more flexible, creating favourable conditions for the extraction process (Akowuah, Mariam & Chin, 2009). As the extraction temperature increases, the solvent's viscosity decreases and molecular motion increases, making it easier for nutrients to be released from plant cells (Sheng *et al.*, 2013). Additionally, under the influence of temperature, plant tissues become softer, increasing the rate of mass transfer and therefore improving the solubility of nutrients (Amulya & Rayees, 2023). The initial decrease in phenolic content during the extraction process is attributed to the activity of polyphenoloxidase. However, at higher temperatures, these enzymes become inactive (Peterson *et al.*, 2007). Furthermore, biologically active compounds sensitive to temperature can undergo degradation due to intrinsic oxidation and polymerisation reactions (Jing, Dong & Tong, 2015). According to Gupta, Lakshmi & Prakash (2008), ascorbic acid is easily altered during heat processing. It not only dissolves readily in water but also oxidises rapidly, especially at high temperatures or in an alkaline environment over an extended period.

Results indicated that as extraction time increased, the levels of phenolic, saponin, and FRAP also increased to an optimal value and then gradually decreased. Specifically, the highest phenolic content was achieved after 30 and 45 minutes of extraction, at 0.54 and 0.53 g TAE/100 g dry matter, respectively, with no statistically significant difference at the 5% level. The highest saponin content was reached after 30 and 45 minutes of extraction, at 1.11 and 1.08 g SE/100 g dry matter, respectively, with no significant difference. The highest FRAP value was obtained after 45 minutes of extraction (1.13 M $Fe^{2+}$/100 g dry matter). In contrast, the levels of flavonoid and DPPH tended to decrease as extraction time increased. The contents of flavonoid (g QE/100 g dry matter) and DPPH (%) decreased from 0.20 and 57.60 after 15 minutes to 0.14 and 54.02 after 60 minutes of extraction, respectively. Prolonged extraction time can initially boost the yield of flavonoids, enhancing the antioxidant capacity measured by DPPH scavenging activity. However, excessive extraction time may lead to the degradation of flavonoids and vitamin C, resulting in reduced antioxidant potential (Luzia *et al.*, 2015). Extraction time also affects the nutritional composition of the extract and is one of the essential factors in determining the efficiency of the extraction process and energy costs. If the extraction time is short, fewer substances are released and the extraction process may not be complete. If the extraction time is extended, energy is wasted, the production process is prolonged, and the quantity and quality of nutrients will decrease. Moreover, the efficiency of extracting bioactive compounds does not increase after a certain period of extraction time. The extraction time depends on the solvent, temperature, solvent-to-material ratio, the nature of the material, and the compounds to be extracted (Nguyen & Nguyen, 2021). When the extraction time is prolonged, polyphenolic compounds inside and outside the material nearly reach equilibrium, so total polyphenol content in the extract gradually increases.

**Table 2**. Effects of temperature and extraction time on the colour of the extracted solution from asparagus roots

| *Variable* | *L* | *a* | *b* |
|---|---|---|---|
| Extraction temperature (°C) | | | |
| 80 | 37.91±3.43$^{c}$ | -3.16±0.11$^{ab}$ | 4.61±0.24$^{b}$ |
| 85 | 38.72±3.90$^{b}$ | -3.30±0.12$^{b}$ | 5.01±0.12$^{a}$ |
| 90 | 39.00±3.21$^{a}$ | -2.64±0.23$^{a}$ | 4.70±0.30$^{b}$ |
| 95 | 38.62±3.20$^{b}$ | -3.14±0.21$^{ab}$ | 4.74±0.20$^{b}$ |
| Level of significance | ** | * | ** |
| Extraction time (mins) | | | |
| 15 | 38.40±2.92$^{b}$ | -2.91±0.11$^{a}$ | 4.80±0.13$^{a}$ |
| 30 | 38.60±3.10$^{a}$ | -3.20±0.13$^{a}$ | 4.70±0.21$^{a}$ |
| 45 | 38.64±3.23$^{a}$ | -2.91±0.12$^{a}$ | 4.83±0.20$^{a}$ |
| 60 | 38.60±2.91$^{a}$ | -3.21±0.20$^{a}$ | 4.80±0.20$^{a}$ |
| Level of significance | ** | * | * |
| Level of significance of the correlation | ** | * | * |

Values are expressed as means of triplicate testing. Values with a different superscript in each column are statistically significantly different, *$p$<0.05 and **$p$<0.01.

Additionally, phenolic and flavonoid can be oxidised by unfavourable factors from the extraction environment (temperature, light, and oxygen) (Naczk & Shahidi, 2004). Furthermore, at extraction temperatures ranging from 70 to 100°C, only short-chain polysaccharide molecules can be extracted. When extraction time is increased from 15 to 60 minutes, saccharose content does not increase further, but tends to decrease because the extraction process is almost complete. Prolonged extraction time can lead to the degradation of unstable short-chain polysaccharides (saccharose), especially the Maillard reaction, which results in reduced sugar content in the extract (Truong & Thuy, 2015). Additionally, increasing temperature and extraction time can either enhance or reduce the antioxidant capacity of a substance (Trung *et al.*, 2016). According to Rawson *et al.* (2013), the decrease in bioactive compounds when extracted at high temperatures for an extended period forms more stable compounds but with lower biological activity, thereby affecting antioxidant activity.

The colour of the extracted solution (expressed through *L, a,* and *b* values) is shown in Table 2. Results showed that the *L* value tended to increase to an optimal value, then gradually decreased, reaching its highest value when extracting the dried asparagus root tea solution at 90°C (39.00). Similarly, the highest *a* value was reached at 90°C (-2.64), while the highest *b* value was obtained when extracting at 85°C (5.01), indicating that the extract had a brighter yellowish-green colour compared to other samples extracted at 85-90°C. Results also showed that the extracted solution had a bright yellowish-green colour when extracted for a period ranging from 30-60 minutes. The darkening of an extract, indicated by a decrease in the *L* value, was primarily due to the oxidation of bioactive compounds and vitamin C, as well as the Maillard reaction. Oxidative processes degrade these compounds into coloured pigments, while the Maillard reaction further contributes to the darkening by forming brown pigments during thermal processing. These reactions highlight the importance of optimising extraction conditions to

minimise undesirable colour changes and preserve the quality of the extract (Buratti *et al.*, 2020).

This research also developed regression equations to predict the levels of phenolic compounds, flavonoid, saponin, vitamin C, saccharose, and antioxidant capacity (DPPH and FRAP) of the extract based on different extraction temperatures and times (Figure 2). The obtained equations have correlation coefficients ($R^2$ and $R^2_{adj}$) greater than 0.86. Therefore, these equations can be used to predict variations in the levels of bioactive and chemical compounds, as well as antioxidant capacity in the extract, based on the studied extraction temperature and time.

## CONCLUSION

The study selected extraction at 85°C for 30 minutes as the appropriate parameters. With this temperature and extraction time, the extracted solution from dried asparagus root tea contained nutrient levels (saccharose, vitamin C, phenolic, flavonoid, and saponin) and antioxidant capacity (DPPH and FRAP) (calculated per 100 g of dry matter) of 0.81 g, 1.23 g, 0.50 g TAE, 0.12 g QE; 1.10 g SE, 56.10%, and 1.12 M $Fe^{2+}$, respectively. This study not only aimed to provide insights into the optimal extraction conditions for dried asparagus roots, but also to underscore the broader implications for nutrition, health, economic development, and sustainability. Optimised extraction process can lead to the development of nutritionally enriched, high-antioxidant products for future studies.

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**Authors' contributions**

Giang NTN, designed, carried out the experiment, analysed data, wrote, reviewed and edited the manuscript; Khai TV, carried out the experiment and analysed the data.

**Conflict of interest**

The authors declare no conflict of interest.

**References**

Adriana DTF & Guy AC (2016). A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes. *Int J Gastron Food Sci* 3:2-11. https://doi.org/10.1016/j.ijgfs.2015.11.00

Akowuah G, Mariam A & Chin J (2009). The effect of extraction temperature on total phenols and antioxidant activity of *Gynura procumbens* leaf. *Bangalore* 5(7):81-85. http://www.phcog.com/text.asp?2009/5/17/81/57991

Amulya PR & Rayees UI (2023). Optimization of enzyme-assisted extraction of antocyanins from eggplant (*Solanum melongena* L.) peel. *Food Chem X*(18):100643. https://doi.org/10.1016/j.fochx.2023.100643.

Ba TT, Thuy VTB & Tho TTN (2014). Effect of plastic mulch and superhume on growth and yield of green asparagus (*Asparagus officinalis* L.). *Can Tho University J Science* 14:99-104. https://ctujsvn.ctu.edu.vn/index.php/ctujsvn/article/view/2050

Buratti S, Cappa C, Benedetti S & Giovanelli G (2020). Influence of cooking conditions on nutritional properties and sensory characteristics interpreted by e-senses: case-study on selected vegetables. *Foods* 9(5):607. doi: 10.3390/foods9050607.

Guilherme DS, Simone PF, Alan A & Marco DL (2023). Aqueous extraction processing: An innovative and sustainable approach for recovery of unconventional oils. *Trends Food Sci Technol* 133:99-113. https://doi.org/10.1016/j.tifs.2023.01.019

Guo Q, Wang N, Liu H, Li Z, Lu L & Wang C (2020). The bioactive compounds and biological functions of *Asparagus officinalis* L. - A review. *J Funct Foods* 65:103727. https://doi.org/10.1016/j.jff.2019.103727

Gupta S, Lakshmi AJ & Prakash J (2008). Effect of different blanching treatments on ascorbic acid retention in green leafy vegetables. *Nat Prod Radiance* 7(2):111-116. http://nopr.niscpr.res.in/handle/123456789/5653

Jing CL, Dong, XF & Tong JM (2015). Optimization of ultrasonic-assisted extraction of flavonoid compounds and antioxidants from Alfalfa using response surface method. *Molecules* 20:15550-15571. Doi: 10.3390/molecules200915550

Le AV, Parks SE, Nguyen MH & Roach PD (2018). Improving the vanillin-sulphuric acid method for quantifying total saponins. *Technologies* 6(84):1-12. https://doi.org/10.3390/technologies6030084

Luzia CRDR, Viviani RDO, Martine EKH, André J, Simone HF & Alessandro DOR (2015). Effect of cooking on the concentration of bioactive compounds in broccoli (Brassica oleracea var. Avenger) and cauliflower (Brassica oleracea var. Alphina F1) grown in an organic system. *Food Chem* 172:770-777. https://doi.org/10.1016/j.foodchem.2014.09.124

Molyneux P (2004). The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. *Songklanakarin J Sci Technol* 26:211-219. http://rdo.psu.ac.th/sjstweb/index.php

Naczk M & Shahidi F (2004). Extraction and analysis of phenolics in food. *J Chromatogr A* 1054:95-111. https://doi.org/10.1016/j.chroma.2004.08.059

Nguyen GTN, Tran KV, Vo TTX & Nguyen TD (2024). The nutrient, colour and antioxidant capacity of asparagus (*Asparagus officinalis* L.) root tea after blanching. *Acta Sci Pol Technol Aliment* 23(2):209-219. http://doi.org/10.17306/J.AFS.001176

Nguyen GTN, Tran KV, Vo TTX & Nguyen TD (2023). The interactions between various drying temperatures and applied drying models of asparagus roots (*Asparagus officinalis* L.). *Acta Sci Pol Technol Aliment* 22(3):331-340. https://doi.org/10.17306/J.AFS.2023.1164

Nguyen GTN & Nguyen TM (2021). Effect of extraction conditions (temperature, pH and time) by cellulase on chemical properties of dried oyster mushroom (*Pleurotus sajor-caju*) extract. *Food Res* 5(3):351-358. https://www.myfoodresearch.com/uploads/8/4/8/5/84855864/_40__fr-2020-613_nguyen_2.pdf

Pegiou E, Mumm R, Acharya P, Vos RCH & Hall RD (2019). Green and white asparagus (*Asparagus officinalis*) a source of developmental, chemical and urinary intrigue. *Metabolites* 10(1):17. https://dx.doi.org/10.3390/metabo10010017

Peterson ME, Daniel RM, Danson MJ & Eisenthal R (2007). The dependence of enzyme activity on temperature: determination and validation of parameters. *Biochem J* 402(2):331-337. doi: 10.1042/BJ20061143

Rawson A, Hossain MB, Patras A, Tuohy M & Brunton N (2013). Effect of boiling and roasting on the polyacetylene and polyphenol content of fennel *(Foeniculum vulgare)* bulb. *Food Res Int* 50(2):513-518. https://doi.org/10.1016/j.foodres.2011.01.009

Sasidharan S, Chen Y, Saravanan D, Sundram KM & Latha LY (2011). Extraction, isolation and characterization of bioactive compounds from plants extracts. *Afr J Tradit complement Altern Med* 8:1-10. DOI:10.4314/ajtcam.v8i1.60483

Sharaa IES & Mussa SB (2019). Determination of vitamin C (Ascorbic acid) contents in vegetable samples by UV-Spectrophotometry and redox titration methods and estimation of effect of time, cooking and frozen on ascorbic acid contents. *International Journal of Progressive Sciences and Technologies* 15: 281-293. DOI: 10.52155

Sheng ZL, Wan PF, Dong CL & Li YH (2013). Optimization of total flavonoids content extracted from *Flos Populi* using response surface methodology. *Ind Crop Prod* 43: 778-786. https://doi.org/10.1016/j.indcrop.2012.08.020

Sudha G, Vadivukkarasi S, Indhu SRB & Lakshmanan P (2012). Antioxidant activity of various extracts from an edible mushroom *Pleurotus eous*. *Food Sci Biotechnol* 21(3):661-668. DOI:10.1007/s10068-012-0086-1

Sumaiyah, Masfria & Dalimunthe (2015). Determination of total phenolic content, total flavonoid content, and antimutagenic activity of ethanol extract nanoparticles of *Raphidophora pinnata* (L.F) schott. Leaves. *Rasayan J Chem* 11(2):505-510. DOI:10.31788/RJC.2018.1122068

Trung MT, Van NVT, Ha NC & Duy LND (2016). Factors affecting juice extraction ability of acerola fruit (*Magnolyophyta glabra*) by enzyme. *Can Tho University J Science* 42:11-18. https://sj.ctu.edu.vn/ql/docgia/tacgia-31273/baibao-26242/doi-ctu.jvn.2016.011.html

Truong PB & Thuy NM (2015). Effects of temperature and time on extraction of polysaccharide and tannins from red lingzhi (*Ganoderma lucidum*). *Can Tho University J Science* 6:21-28. https://sj.ctu.edu.vn/ql/docgia/tacgia-28617/baibao-9061.html

Viera-Alcaide I, Hamdi A, Guillén-Bejarano R, Rodríguez-Arcos R, Esperjo-Calvo JA & Jiménez-Araujo A (2022). Asparagus roots: from an agricultural by-product to a valuable source of fructans. *Foods* 11(5):1-13. DOI: 10.3390/foods11050652

Zhang H, Birch J, Pei J, Ma ZF & Bekhit AED (2020). Phytochemical compounds and biological activity in Asparagus roots: A review. *Int J Food Sci Technol* 54:966–977. Doi:10.1111/ijfs.13993

Zhang QW, Lin LG & Ye WC (2018). Techniques for extraction and isolation of natural products: a comprehensive review. *Chin Med* 13:20-45. DOI: 10.1186/s13020-018-0177-x