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EFFECTS OF HEAT PUMP DRYING CONDITIONS ON SAPONIN CONTENT IN HYDROPONIC *CENTELLA ASIATICA* (L.) URB TUBER POWDER

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ABSTRACT

Addressing the global food crisis, climate change, and environmental pollution necessitates the immediate and long-term development of sustainable food systems. Hydroponics is a soil-free cultivation method that offers a promising solution to global food demands and used to grow vegetables such as *Centella asiatica* (L.) Urban. *Centella asiatica* (L.) Urban is commonly known as one of the traditional herbal medicines widely used in Southeast Asia. *Centella asiatica* contains bioactive compounds like triterpenoids, flavonoids, and alkaloids, which offer antimicrobial, antioxidant, wound-healing, and memory-enhancing properties. They also aid in treating cardiovascular diseases, diabetes, cancer, and gynecological disorders. *Centella asiatica* contains a significant amount of triterpenoid saponins, primarily asiaticoside, madecassoside, centelloside, and sceffoleoside, collectively known as centelloids. Among them, the biological activity of saponins is believed to be attributed to these characteristics, making them a valuable raw material with significant and unique medicinal properties. Utilizing by-products from the production of hydroponic *Centella asiatica* in products with valuable biological properties will contribute to the sustainable development of food systems worldwide. Heat pump drying, a highly efficient and eco-friendly technology, operates based on thermodynamic principles with transferring heat between environments and enabling precise temperature control. Heat pump drying ensures minimal alteration of bioactive compounds, retains nutritional quality, and maintains desirable characteristics such as color and flavor. Additionally, it offers low energy consumption and enhanced storage stability of the dried product. Despite these benefits, initial investment and maintenance costs of this technology are high. Moreover, the operating temperature ranges were restricted to specifical initial materials, et cetera. In this study, *Centella asiatica* tubers cultivated hydroponically were harvested six months post-planting, achieving a peak saponin content of 3.17%. These tubers were processed into powder using heat pump drying, fine grinding and sieving. The drying conditions, set at 60°C for 420 minutes, collected *Centella asiatica* tuber powder with a high saponin concentration of 6.30% and notable antioxidant activity, demonstrated by an IC_{50} value of 8.13 mg/mL.

Key words: *Centella asiatica*, tuber powder, heat pump drying, hydroponics, saponin, polyphenol, antioxidant, biological activity

INTRODUCTION

The disruption of food system resilience and the deterioration of global food security due to climate change and environmental degradation are critical global challenges [1]. Hydroponics is a soil-free cultivation technique that offers a promising solution to global food demand. It enhances food sustainability and ensures a reliable food supply through an innovative, efficient, and low-maintenance approach. Notably, hydroponic systems play a vital role in alleviating the escalating threat of global hunger [2]. The development of sustainable food systems is an essential requirement for both the present and the future, driven by the global food crisis, climate change, and environmental pollution.

Centella asiatica (L.) Urban, commonly known Gotu kola as one of the traditional herbal medicines widely used in Southeast Asia [3]. *Centella asiatica* contains bioactive compounds such as triterpenoids, carotenoids, glycosides, flavonoids, alkaloids, essential oils, and fatty acids. These compounds have antimicrobial, antiviral, antioxidant, wound-healing, and memory-enhancing properties and support the treatment of cardiovascular, digestive, diabetic, cancerous, and gynecological diseases [4].

Centella asiatica contains a significant amount of triterpenoid saponins, primarily asiaticoside, madecassoside, centelloside, and sceffoleoside, collectively known as centelloids [5]. These secondary metabolites commonly were found in plants and synthesized through the isoprenoid pathway to form hydrophobic triterpenoid aglycones, which are attached to hydrophilic sugar chains (glycones), the biological activity of saponins is believed to be attributed to these double structural characteristic, making them a valuable raw material with significant and unique medicinal properties [6].

Fresh *Centella asiatica* has a short shelf life, is prone to wilting when exposed to sunlight, and undergoes degradation due to oxidation, leading to physical changes [7]. Drying of *Centella asiatica* is a method used to achieve products with desired quality, reduce storage space requirements, and extend shelf life, and prepare the raw material for pharmaceutical processing [8 - 10].

Research on the by heat pump drying of hydroponic *Centella asiatica* tubers to create value-added products will contribute to sustainable food systems and retains its bioactive compounds. The heat pump drying, a highly efficient and eco-friendly technology, operates based on thermodynamic principles with transferring heat between environments and enabling precise temperature control. The heat pump drying ensures minimal alteration of bioactive compounds, retains nutritional quality, and maintains desirable characteristics such as color and flavor. Additionally, it offers low energy consumption and enhanced storage stability of the dried product.

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Despite these benefits, initial investment and maintenance costs of this technology are high. Moreover, operating's temperature ranges were restricted with specifical initial materials [11].

This aims of the study was to investigate the effects of the heat pump drying for hydroponic *Centella asiatica* tubers- by-products of the hydroponic *Centella asiatica* cultivation to produce saponin-rich powder. The findings are intended to serve as a foundation for future research on utilizing hydroponic *Centella asiatica* tuber powder in the formulation of nutrient-rich food products with elevated bioactive compound levels.

MATERIALS AND METHODS

Materials and equipments

Materials: The study was conducted on the tubers of hydroponic *Centella asiatica* (L.) Urban collected from Dong Thap Province, Vietnam. Hydroponic *Centella asiatica* tubers were harvested within no more than 6 months from the planting start date. The tubers (a length of 40-50mm and a diameter of approximately 10 mm) were selected and excluded damaged or decayed tubers. Residual growth media and root hairs were carefully removed. The tubers were washed with clean water for 5 mins and allowed to drain. The clean tubers were then sliced into pieces approximately 2 mm thick, blanched in water at 70°C for 45 seconds, and subsequently dewatered using a centrifuger at 1,400 rpm for 5 mins. The sliced tubers were dried using a heat pump dryer under varying conditions. The dried tubers slices were then ground in a milling chamber for subsequent analyses.

A B C

Figure 1: Length (A) and diameter (B) of harvested *Centella asiatica* tubers; and thickness of sliced tuber pieces (C) before drying

Heat Pump Dryer: The drying process was performed in an HPTSASAKI020 cold dryer with an available drying temperature range of 20 - 60°C. The drying material load was approximately 200kg/batch, and the dryer was equipped with 36 trays made of 304 stainless steel.

Grinding and Sieving: The grinding and sieving process was carried out at room temperature of 18°C with air humidity maintained below 10%. The dried material

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was ground using a granite stone mill with a rotational speed of 60rpm and a capacity of 450 - 500kg/h. The ground material was then transferred to a 304 stainless steel sieving system with two levels and sieve hole sizes of 0.20 -0.30mm. The system operated with a vibration frequency of 1.400pcs/min and a capacity of 100kg/h. The sieved product had a moisture content of approximately 10%, with a particle size of around 0.10-0.20mm.

A **B** **C**

Figure 2: Equipments for powder making process: Heat pump dryer (A); Stone grinding equipment (B) and Sieving equipment (C)

Experimental Design

Harvesting Time of Fresh Hydroponic Centella asiatica Tubers: The hydroponic *Centella asiatica* tubers were harvested at different time points from the start of planting, specifically at 4, 5, and 6 months for the experiment. The harvested fresh tubers were analyzed for saponin content to determine the optimal harvesting time. The harvesting time of the tubers with highest saponin content would be selected for the next experiments.

A **B** **C**

Figure 3: Hydroponic *Centella asiatica* tubers were harvested at the following time points: 4 months (A), 5 months (B) and 6 months (C)

Drying Conditions: The factors investigated included temperature with 3 levels (30°C, 45°C and 60°C) and time with 3 levels (180 mins, 300 mins and 420 mins), to assess their impact on saponin content.

Extraction of Plant Material: *Centella asiatica* tubers (fresh and powdered), were processed for extraction according to the method described by Kumar and Kavita [12] with some modifications. Fresh tubers (50.0 g) were prepared by removing the roots, washing thoroughly, and cutting them into small pieces of 0.5–1.0 cm in size.

Both the fresh tuber pieces and powdered tubers (50.0 g) were separately mixed with an extraction solvent at a ratio of 1:1 (w/v) to obtain homogeneous mixtures. The solvent used for extraction was 60% ethanol. The solvent was then removed from the mixtures using a rotary vacuum evaporator. The resulting mixtures were filtered through Whatman filter paper No. 4 (pore size 20–25 μm) and subsequently centrifuged at 6000 rpm to collect the extracts.

Saponin content determination method: The quantification of total saponin content of the extract was conducted using a refined colorimetric method of Chen *et al.* [13]. Initially, 2.00 mL of hydroponic *Centella asiatica* tubers extract was evaporated to dryness. The resulting residue was combined with 0.40 mL of a 5% vanillin-acetic acid solution and 2.40 mL of perchloric acid ($HClO_4$). The mixture was heated at 80°C for 20 minutes in a thermostated water bath and subsequently cooled rapidly for 2 minutes. Ethyl acetate was added to bring the final volume to 10 mL. The saponin content was determined by measuring the absorbance at 550 nm, using a UV-Vis spectrophotometer. A standard curve of oleanolic acid (10~100 μg/mL) was employed to quantify the results, which were reported as grams of oleanolic acid equivalent per 100 grams of dry sample (%).

Polyphenol content determination method: The total polyphenol content (TPC) in the powder was quantified using a colorimetric approach based on the Folin-Ciocalteu reagent, with modifications to the method described by Haida *et al.* [14]. Diluted 1mg of hydroponic *Centella asiatica* tuber powder into 1mlL of distilled water to obtain a mixture. 1 mg of hydroponic *Centella asiatica* tuber powder was diluted in 1 mL of distilled water to prepare the mixture. Take 0.10 mL of the mixture and mix it with 1.50 ml of 10% Folin-Ciocalteu reagent, allowing it to react for 5 minutes. Subsequently, 4.00 mL of 20% sodium carbonate (Na_2CO_3) solution and 4.40 mL of distilled water were added, bringing the final volume to 10 mL. The reaction mixture was incubated in the dark for 30 minutes, and the absorbance was recorded at 738 nm. The TPC was quantified using a gallic acid standard calibration curve (0-100 μg/mL) and expressed as milligrams of gallic acid equivalents per gram of sample (mg GAE/g).

Antioxidant activity (DPPH) of hydroponic Centella asiatica tuber powder determination method: The free radical scavenging activity of the tubers powder was assessed using the DPPH method, following the protocol of Ye *et al.* [15] with modifications. A reaction mixture containing 200 μL of hydroponic *Centella asiatica* tuber powder at varying concentrations (0~10mg/mL) was combined with 1 mL of 0.10 mM DPPH solution and mixed thoroughly. The mixture was incubated in the dark for 30 minutes to allow the reaction to occur. The absorbance was measured at 517 nm by using a UV-Vis spectrophotometer. Ascorbic acid was used as a

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reference standard, with a calibration curve prepared over a concentration range of 0–100 ppm. The IC_{50} values for ascorbic acid and the powder were calculated based on their respective scavenging activities.

Statistical Data Processing: The data obtained from the study were processed by using Microsoft Excel 2016. Statistical analysis was conducted using ANOVA at a 95% confidence level, followed by Tukey's test to compare and differentiate means.

RESULTS AND DISCUSSION

Saponin content of the cultivation period

The saponin content (%) in fresh hydroponic *Centella asiatica* tubers at the different harvest times were presented in Table 1, which showed that the saponin contents of the first tubers at the harvest times of 4, 5, and 6 months were 1.77±0.01%, 2.82±0.01%, and 3.17±0.01%, respectively. At the harvest time of 6 months, the saponin content was the highest and significantly different ($p<0.05$) from the other harvest times. A comparison of the saponin content in fresh *Centella asiatica* tubers to some medicinal plants were listed in Table 1, showed that the hydroponic *Centella asiatica* tubers at 6 months had a relatively high saponin content, comparable to that of 5-year-old Panax fruticosus tubers (3.74%) [16]; lower than 7-year-old wild Ginseng (4.50%) [17] and 2-year-old Panax notoginseng (13.05%) [18].

Based on the analysis of the results in Table 1, the fresh *Centella asiatica* tubers harvested at 6 months were selected for the next experiments.

Effects of drying conditions on Saponin content of powder

The 6 months hydroponic *Centella asiatica* tubers were collected, selected, washed, sliced, dried, ground into powder and then sieved. The saponin content in the dried tuber slices was determined.

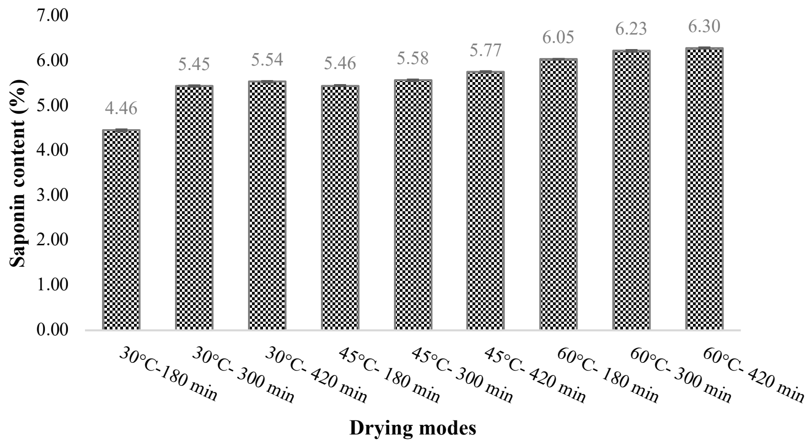

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Figure 4: Effects of drying modes (temperature and time) on powder's saponin content (%). Significant differences were analyzed with Tukey's test as means ± SD at $p < 0.05$

The saponin content progressively increased with both temperature and drying time. The saponin content of the powder obtained from the drying at 60°C was the highest and significantly different ($p<0.05$) from those dried (at 30°C and 45°C). At the same drying temperature, the sample dried for 420 minutes had the highest saponin content, and was significantly different ($p<0.05$) from the samples dried for 180 and 300 mins. In the investigated drying conditions, the highest saponin content of 6.30±0.01(%) was observed at the drying condition (60°C for 420 mins), while the lowest saponin content of 4.46±0.01 (%) was found at the drying condition (30°C for 180 mins).

According to the study by Eom *et al.* [19], *Centella asiatica* cultivated in Chungju, North Chungcheong Province, exhibited the highest triterpenoid saponin content when dried at a low temperature (35°C for 24 hours), reaching 68.8 mg/g dry weight (dw), equivalent to 6.88%. In contrast, drying with hot air at 60°C for 6 hours resulted in a significantly lower saponin content of 40.00 mg/g dw (4.00%). This suggests that higher drying temperatures can degrade or reduce saponin content in *Centella asiatica.* Therefore, in this study, the saponin content of hydroponic *Centella asiatica* tubers showed a linear increase with both temperature and drying time during heat pump drying. This unexpected trend could be attributed to several factors: (1) Reduction in moisture content: Heat pump drying efficiently removed moisture, which may concentrated the saponins in the dried material; (2) Protection of bioactive compounds: Heat pump drying operated at controlled temperatures and lower energy inputs, minimizing thermal degradation of heat-sensitive compounds like saponins, (3) Enhanced extraction efficiency: The drying process may disrupt cell walls, making saponins more accessible for extraction during analysis.

These findings contrast with Eom *et al.* [19], where higher temperatures led to saponin degradation. The difference may be due to the unique properties of hydroponically grown *Centella asiatica* tubers, which could have a different biochemical composition or structural integrity compared to soil-grown plants. Additionally, the precise temperature control and gentle drying conditions of heat pump drying may better preserve saponins compared to conventional hot air drying.

Effect of the drying conditions on total polyphenol contents

In addition to the determination of saponin content, the measurement of TPC in hydroponic *Centella asiatica* tubers dried under the established drying conditions was also conducted. The results of TPC determination were presented in Fig. 6.

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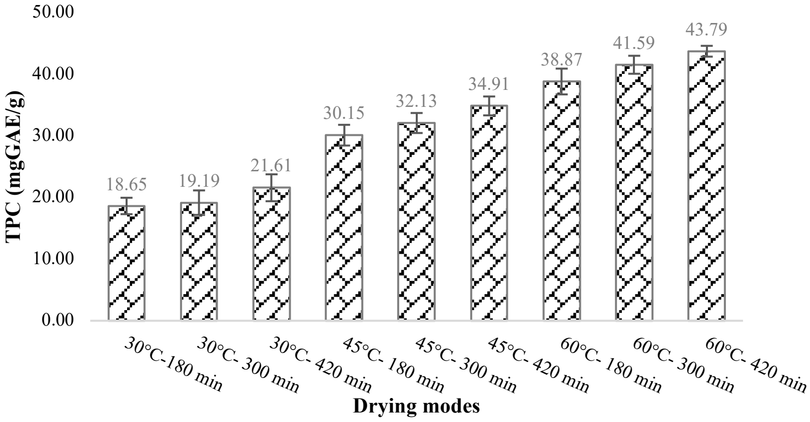

Figure 6: Effects of temperature and time of the drying on TPC (mgGAE/g). Significant differences were analyzed with Tukey's test as means ± SD at p < 0.05

According to the results (Fig. 6), the TPC increased linearly with both temperature and time of the drying. Statistical analysis indicated that, at the same drying time, temperature had a significant impact on the TPC in the powdered samples. At a drying temperature of 60°C, the TPC was highest and statistically different ($p<0.05$) compared to the temperatures of 30°C and 45°C. When the drying occurred at the same temperature, no significant difference ($p>0.05$) in the TPC was found across the different drying times. This suggested that the drying time, at the same temperature, had little effect on the TPC in hydroponic *Centella asiatica* tubers during drying. The highest TPC (43.79±0.88 mgGAE/g) was observed under the drying condition of 60°C for 420 minutes, while the lowest TPC (18.65±1.33 mgGAE/g) was observed at 30°C for 180 minutes.

Polyphenols are known to be sensitive to high temperatures; therefore, the application of thermal processing can significantly reduce their content and antioxidant activity [20]. In this study, the TPC exhibited a linear increase with both the temperatures and times of the drying, which may be attributed to the evaporation of water during the drying process, resulting in reduced moisture content and increased dry mass of the final product.

The study by Eom *et al.* [19] also indicated that when using a cold drying method at 35°C for 24 hours, the highest TPC was achieved (16.36±0.31 mgGAE/g). In contrast, when dried with hot air at 60°C for 6 hours, the TPC was only 11.65±0.19 mgGAE/g. The TPC in the *Centella asiatica* leaf powder, according to the study by Quyen *et al.* [21], was only 2.14±0.29 mgGAE/g.

Based on the obtained results, it can be concluded that with the equipment and the drying conditions were tested, the TPC in hydroponic *Centella asiatica* tubers is

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minimally affected. The antioxidant activity is correlated with TPC, and further investigation should be conducted on the antioxidant activity of the hydroponic *Centella asiatica* powder dried under the optimal drying conditions. This should be compared with the antioxidant activity of the fresh tubers to determine the impacts of the drying process on the antioxidant activity of the *Centella asiatica* tubers powder.

Antioxidant capacity of *Centella asiatica* tubers powder

The hydroponic *Centella asiatica* tubers powder dried at 60°C for 420 minutes was tested for antioxidant activity. The DPPH IC_{50} antioxidant activity was presented in Table 2.

The antioxidant activity IC_{50} was represented by the ability to neutralize 50% of DPPH free radicals. A lower IC_{50} was value indicates higher antioxidant activity, and vice versa. Under the drying conditions (60°C for 420 minutes), the IC_{50} was value of the powder was 8.13 mg/mL, higher than the IC_{50} value of the fresh tuber extract at 6.85 mg/mL. The standard substance, vitamin C (ascorbic acid), had an IC_{50} at a concentration of 6.12 µg/mL (Table 2). The IC_{50} values of the hydroponic *Centella asiatica* tuber extract (both fresh and dried forms) were several times lower than that of vitamin C. According to the study by Mohapatra *et al.* [22], the IC_{50} value of dried *Centella asiatica* leaves, obtained by oven drying at 60°C until constant moisture content, was 115.49 µg/mL, which is higher than the IC_{50} of fresh leaves at 62.17 µg/mL.

CONCLUSION AND RECOMMENDATION FOR DEVELOPMENT

The results of the study indicated that the drying process did not reduce significantly the antioxidant activity of hydroponic *Centella asiatica* tubers compared to the fresh tubers. Therefore, the heat pump drying method was recommended to remain the antioxidant properties of the tubers, as this was a valuable medicinal resource for the extraction of primary and secondary bioactive compounds.

A B

Figure 7: Fresh tubers (A) and tuber powder (B) of hydroponic Centella asiatica

The utilization of by-products from the hydroponic *Centella asiatica* cultivation to create valuable biologically products was very important to increase the added value of agricultural products, reduce environmental pollution, and promote the sustainable development of the global food system.

The hydroponic *Centella asiatica* tubers harvested at 6 months from the planting start time contained the highest saponin content, reaching 3.17%, and were used for the heat pump drying. The heat pump drying conditions was set at a temperature of 60°C for 420 minutes to obtain hydroponic *Centella asiatica* tubers powder with a saponin content of 6.30%; TPC 43.79 mgGAE/g and an antioxidant activity IC_{50} of 8.13 mg/mL.

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None

Conflict of interest

The authors declare no conflict of interest related to the manuscript.

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Table 1: Saponin content (%) of fresh *Centella asiatica* tubers at the different harvest time and some medicinal plants

Sort of plant	Saponin content (%)	References
Centella asiatica tuber - 4 months	$1.77^{c}\pm0.01$	
Centella asiatica tuber - 5 months	$2.82^{b}\pm0.01$	
Centella asiatica tuber - 6 months	$3.17^{a}\pm0.01$	
***Panax notoginseng* - 2 years**	**13.05**	**[14]**
***Panax fruticosum* - 5 years**	**3.74**	**[12]**
***Wild Ginseng* - 7 years**	**4.50**	**[13]**

The values were the average values of three repetitions. In the same column, values followed by a different letter represent statistically significant differences ($p<0.05$) by Tukey's multiple range test

Table 2: The DPPH IC_{50} antioxidant activity of tubers powder of the hydroponic Centella Asiatica

Sample	IC_{50}
Centella Asiatica fresh tubers extract (*)	6.85 mg/mL
Centella Asiatica tubers powder	8.13 (mg/mL)
Vitamin C	6.12 (μg/mL)

(*) IC_{50} of the hydroponic *Centella asiatica* fresh tuber extract according to the study by Thy *et al.* [23]

REFERENCES

1. **Mirzabaev A, Kerr RB, Hasegawa T, Pradhan P, Wreford A, von der Pahlen MCT and H Gurney-Smith** Severe climate change risks to food security and nutrition. *Climate Risk Management.* 2023; **39:**100473. https://doi.org/10.1016/j.crm.2022.100473

2. **Yee YS, Hum YC, Lee YL, Lai KW, Yap WS and YK Tee** A meta-analysis:Food production and vegetable crop yields of hydroponics. *Scientia Horticulturae.* 2023; **321:**112339. https://doi.org/10.1016/j.scienta.2023.112339

3. **Barge S, Jade D and NC Talukdar** *Centella asiatica* Linn. 1st ed. In: Pandita D, Pandita A(Eds). Potent Anticancer Medicinal Plants. Apple Academic Press. 2023:19-37. https://doi.org/10.1201/9781003431190-2

4. **Wiciński M, Fajkiel-Madajczyk A, Kurant Z, Gajewska S, Kurant D, Kurant M and M Sousak** Can Asiatic Acid from *Centella asiatica* be a Potential Remedy in Cancer Therapy? A Review. *Cancers.* 2024; **16(7):**1317. https://doi.org/10.3390/cancers16071317

5. **James JT and IA Dubery** Pentacyclic triterpenoids from the medicinal herb, *Centella asiatica* (L.) Urban. *Molecules.* 2009; **14(10):** 3922-3941. https://doi.org/10.3390/molecules14103922

6. **Azerad R** Chemical structures, production and enzymatic transformations of sapogenins and saponins from *Centella asiatica* (L.) Urban. *Fitoterapia.* 2016; **114:**168-187. https://doi.org/10.1016/j.fitote.2016.07.011

7. **Rahim MA, Baharudin NA, Nazri IA, Mohamad S and KAAR Muazzam** Effect of different drying methods on the antioxidant properties of leaves of *Centella asiatica*. IOP Conference series: Earth and Environmental Science Malaysia. 2021 9th March; **756:**012054. https://doi.org/10.1088/1755-1315/756/1/012054

8. **Niamnuy C, Charoenchaitrakool M, Mayachiew P and S Devahastin** Bioactive compounds and bioactivities of *Centella asiatica* (L.) Urban prepared by different drying methods and conditions. *Drying Technology.* 2013; **31(16):**2007-2015. https://doi.org/10.1080/07373937.2013.839563

9. **Rahimmalek M and SAH Goli** Evaluation of six drying treatments with respect to essential oil yield, composition and color characteristics of *Thymys daenensis subsp. daenensis*. *Celak* leaves. *Industrial Crops and Products.* 2013; **42:**613-619. https://doi.org/10.1016/j.indcrop.2012.06.012

10. **Kaur R, Kaur K and P Ahluwalia** Effect of drying temperatures and storage on chemical and bioactive attributes of dried tomato and sweet pepper. *LWT-Food Science and Technology.* 2020; **117:**108604. https://doi.org/10.1016/j.lwt.2019.108604

11. **Chua KJ, Hawlader MNA, Chou SK and JC Ho** On the study of time-varying temperature drying—Effect on drying kinetics and product quality. *Drying Technology.* 2002; **20(8):**1559-1577. https://doi.org/10.1081/DRT-120014052

12. **Kumar JP and T Kavita** Isolation and Phytochemical analysis of *Terpenoids* and *Asiaticosides* from *Centella asiatica* for their neuroprotective activities. *Res. J. Chem. Environ.* 2020; **24(3):**14-19.

13. **Chen Y, Xie MY and XF Gong** Microwave-assisted extraction used for the isolation of total triterpenoid saponins from Ganoderma atrum. *Journal of food engineering.* 2007; **81(1):**162-170. https://doi.org/10.1016/j.jfoodeng.2006.10.018

14. **Haida Z, Maziah M and M Hakiman** Primary metabolites, phenolics content and antioxidant activities of *Hydrocotyle bonariensis* and *Centella asiatica*. *Fundamental and Applied Agriculture.* 2021; **6(1):**27–34. https://doi.org/10.5455/faa.32251

15. **Ye M, Ren L, Wu Y, Wang Y and Y Liu** Quality characteristics and antioxidant activity of hickory-black soybean yogurt. *LWT-Food Science and Technology.* 2013; **51(1):**314-318. https://doi.org/10.1016/j.lwt.2012.09.027

16. **Son HL, Phuong VNL and TV Minh** Application of Response Surface Methodology for Optimizing the Extraction Conditions of Total Saponins from *Polyscias fruticosa* (L.) Harms Planted in Southern Vietnam. *Asian Journal of Biotechnology and Bioresource Technology.* 2023; **9(3):**20-30. https://doi.org/10.9734/ajb2t/2023/v9i3185

17. **Yang BW, Lee JB, Lee JM, Jo MS, Byun JK, Kim HC and SK Ko** The Comparison of Seasonal Ginsenoside Composition Contents in Korean Wild Simulated Ginseng (*Panax ginseng*) which were Cultivated in Different Areas and Various Ages. *Natural Product Sciences.* 2019; **25(1):**1-10. https://doi.org/10.20307/nps.2019.25.1.1

18. **Wei G, Dong L, Yang J, Zhang L, Xu J, Yang F, Cheng R, Xu R and S Chen** Integrated metabolomic and transcriptomic analyses revealed the distribution of saponins in Panax notoginseng. *Acta pharmaceutica sinica B.* 2018; **8(3):**458-465. https://doi.org/10.1016/j.apsb.2017.12.010

19. **Eom HJ, Shin HY, Ji YM, Kwon NR, Yoon HS, Kim IJ and KW Yu** Nutritional Components and Physiological Activity of *Centella asiatica* Cultured in Chungju by Drying Method. *The Korean Journal of Food and Nutrition.* 2021; **34(2):**165–173. https://doi.org/10.9799/ksfan.2021.34.2.165

20. **Guiné RP, Barroca MJ, Gonçalves FJ, Alves M, Oliveira S and PM Correia** Effect of drying on total phenolic compounds, antioxidant activity, and kinetics decay in pears. *International Journal of Fruit Science.* 2015; **15(2):**173-186. https://doi.org/10.1080/15538362.2015.1017073

21. **Quyen NTC, Quyen NTN, Quy NN and PM Quan** Evaluation of total polyphenol content, total flavonoid content, and antioxidant activity of *Centella asiatica*. IOP Conference Series: Materials Science and Engineering Malaysia. 2020 9-11 August; **991**:012020. https://doi.org/10.1088/1757-899X/991/1/012020

22. **Mohapatra P, Ray A, Jena S, Nayak S and S Mohanty** Influence of various drying methods on physicochemical characteristics, antioxidant activity, and bioactive compounds in *Centella asiatica* L. leaves: a comparative study. *Biotechnologia*. 2022; **103(3):**235-247. https://doi.org/10.5114/bta.2022.118666

23. **Thy VB, Beo VT, Huy THT and BT Vinh** Study on Antibacterial and Antioxidant Activity of Extracts from Hydroponic Pennywort Tubers (*Centella asiatica* (L.) Urban). *International Journal of Life Science and Agriculture Research.* 2024; **3(06):**497-502. https://doi.org/10.55677/ijlsar/V03I6Y2024-09