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Original Research Article

Total Phenolics, Flavonoids Contents and Antioxidant Activity in Different Flavor Plants in Northeast (Isaan) Thailand: Enhancing Commercial Value

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ABSTRACT

This study focuses on the ethnobotanical and antioxidant properties of seasoning plants used in food, assessing 33 flavored plant species' total phenolic and flavonoid content, along with their antioxidant capabilities. The research employed the Folin-Ciocalteu method to determine total phenolic content (TPC), while total flavonoid content (TFC) was measured using the aluminum chloride colorimetric assay. Antioxidant capacity was gauged through DPPH assays, and seasoning plant flavors were categorized based on taste testing. The findings revealed 23 plant families and 33 distinct species employed in food flavoring, divided into 4 to 5 flavor categories encompassing 13 variations of highly spicy plants from the Lamiaceae family, 9 sweet-flavored varieties, 6 savory or delicious-flavored types, and 5 sour-flavored options. Among these, *Brassica juncea* displayed the most remarkable production of phenolic compounds and substantial flavonoid content, accompanied by the highest antioxidant activity (IC50 value of 66.08 ± 1.85 µg/ml) within the spicy category. *Allium ascalonicum* exhibited the highest antioxidant activity among sweet-tasting plants, featuring noteworthy phenolic compound and flavonoid concentrations (IC50 value of 126.70 µg/ml). Additionally, the study identified plants contributing to sour and salty or umami tastes, with *Bauhinia malabarica* and *Clochidion littorale* presenting significant concentrations of phenolic compounds and flavonoids, accompanied by notable IC50 values (95.31 ± 0.28 and 67.18 ± 2.15 µg/ml, respectively). This research offers valuable insights into the phytochemical constituents and therapeutic potential of seasoning plants used in traditional medicine and the food industry.

Keywords: Flavour plants, phenolics, flavonoids, antioxidant activity, commercial value, Northeast Thailand.

Introduction

The Northeast region of Thailand is known for its rich cultural heritage and unique culinary traditions. The use of plants as flavorings and seasonings in food has a long history and is a common practice in many cultures. These plants, known as flavor plants, are characterized by their fusion of taste and aroma, and they are used to enhance the flavor of food, making it more delicious [1]. The knowledge and use of plants as spices and condiments is widespread, and these plants are typically aromatic and pungent due to the presence of essential oils. Flavor plants are botanical marvels that enhance the taste and aroma of dishes, contributing to the unique and delectable flavors of Northeast Thai cuisine.

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These plants, including herbs and spices, have been valued since prehistory for their aromatic compounds that are released when eaten or heated. [2] They have been used in culinary practices for generations, driving exploration and trade. Aromatic compounds such as essential oils, terpenes, and phenolic compounds contribute to the taste and aroma of plants. These compounds are responsible for the distinct flavors of plants. [3]
Moreover, the plants that help flavor the food to be more delicious also contain important substances that promote a healthy body. Phytochemicals are biologically active, naturally occurring chemical compounds found in plants, which provide health benefits for humans. Polyphenols and flavonoids are important substances found in plants that give flavor. Flavonoids are a group of polyphenolic compounds that can be divided into six major classes: flavanones, anthocyanidins, flavan-3-ols, flavonols, isoflavones, and flavones.[4] These compounds have versatile health benefits, including cancer prevention, and are found in foods of plant origin. Plants used in traditional medicine are rich in polyphenols and flavonoids, which are also employed in human and animal health. Furthermore, they have high total phenol and flavonoid content, making them a potential medicinal source for the treatment and prevention of free radical-related diseases.[5] The role of free radicals in disease pathology is well established, and they are known to be involved in various acute and chronic disorders in humans, including diabetes, atherosclerosis, aging,

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immunosuppression, and neurodegeneration. [6,7] An imbalance between reactive oxygen species (ROS) and the body's antioxidant capacity has led to the use of dietary and medicinal supplements during disease attacks.[8] Studies have shown that herbal plants, vegetables, and fruits contain antioxidants such as phenolics, flavonoids, tannins, and proanthocyanidins, which contribute to their protective effects against diseases. [9] The ingestion of natural antioxidants has been associated with lower morbidity and mortality from degenerative disorders. The study explored the phytochemical contents of ethanol extracts from various indigenous plants commonly used for seasoning. These plants were found to contain a diverse array of phytochemicals, including flavonoids and phenols. These phytochemicals have been associated with positive therapeutic effects and antioxidant activity, suggesting potential health benefits. The study highlights the remarkable biodiversity of the region and the potential of these condiment plants as sources of natural bioactive ingredients for pharmaceutical and nutraceutical development. Plants containing antioxidants such as polyphenols, flavonoids, and tannins have been found to have preventive effects against diabetes, cancer, and other diseases. These antioxidants can interact with free radicals, preventing them from causing damage to biological macromolecules in healthy human cells, thus reducing the risk of cancer progression.[10] These bioactive compounds play a crucial role in human well-being and have pharmacological effects against microbial pathogens and diseases, including cancer. They also possess antidiabetic, anticancerous, anti-inflammatory, and antioxidant activities. Some examples of plants with high concentrations of bioactive compounds such as *Allium ascalonicum* L. is a sweet-tasting plant that has antioxidants. Additionally, the polar extracts of *A. ascalonicum* L. have been found to contain furostanol saponins, which have various biological activities. [11] Seasoning plants with different flavors contain distinct and important substances, including various aromatic compounds and phytochemicals. The specific compounds responsible for giving each plant its unique flavor can vary widely, and these differences can be attributed to the presence of unique phytochemicals, essential oils, as well as polyphenols and flavonoids. Plants used for sweet flavors, such as fruits and certain herbs, may contain compounds like fructose and natural sugars. Salty plants, like seaweed, are often rich in minerals. Meanwhile, spicy plants, like chili peppers, contain capsaicin, which imparts their characteristic heat. The presence of polyphenols and flavonoids, renowned for their antioxidant properties, can also differ among various plants, contributing to their individual health benefits. Comparing seasoning plants with different flavors reveals variations in their important substances.

A review of Lakshmi et al. (2021) and Shrinet et al. (2021) reveals findings that demonstrate high levels of polyphenols and flavonoids in plants, as well as strong antioxidant activity. These two groups of important substances are known for their antioxidant properties and potential health benefits, so consuming foods flavored with these plant sources can be beneficial.

The purpose of the present study was to quantitatively identify the total phenolics and flavonoids content in the ethanol extracts of 33 species of flavored plants, comprising sweet, sour, spicy, and salt varieties. The study also aimed to assess the in vitro antioxidant capacity of these extracts as a means of ascertaining their potential to protect against oxidative stress.

Materials and Methods

Plant collection

Thirty-three flavor plants were collected from their natural habitats and the regional market in Northeast (Isaan), Thailand, including locations in (1) Sakon Nakhon, (2) Nong Khai, (3) Bueng Kan, (4) Sisaket, (5) Roi Et, (6) Mahasarakham, (7) Khao Phanom, and (8) Mukdahan provinces in 2023 (Table 1). The collection was performed by Associate Professor Dr. Wannachai Chatan and then placed on deposit for research by the Plant and Innovation Research Unit at Mahasarakham University, located in Maha Sarakham Province, Thailand, with coordinates approximately at Latitude: 16.4414° N and Longitude: 102.8360° E."

Plant extraction

The samples were dried and ground to powders using a blender. Ten grams (10 g) of each plant sample were then extracted with 100 mL of 95% ethanol for 72 hours and subsequently filtered. The filtrate of each plant was concentrated using a rotary evaporator at 60 °C. All plant extracts were stored at 4 °C. The percentage of yield was calculated using the following equation (Equation 1):

% extractive value (yield%) = (Weight of dry extract / Weight taken for extraction) x 100 equation 1

Reagent

Folin–Ciocalteu reagent from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA), Sodium carbonate (Na_2CO_3) from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA), Gallic acid (Sigma-Aldrich Production GmbH, Switzerland), Sodium nitrite ($NaNO_2$) from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA), Aluminum chloride ($AlCl_3$) from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA), Sodium hydroxide (NaOH) from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA), Quercetin from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA), 2,2-Di (4-tert-octylphenyl)-1-picrylhydrazyl, free radical from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA) L-Ascorbic acid from Sigma-Aldrich Pte. Ltd. (St. Louis, MO, USA).

Antioxidant Properties

Total Phenolic Content

The total phenolic content (TPC) of a sample was determined using the Folin-Ciocalteu method. A sample solution was mixed with sodium carbonate and Folin-Ciocalteu's reagent, and the absorbance was measured at 750 nm after incubation. Gallic acid was used as a standard for calibration, and the TPC content of the sample was expressed as gallic acid equivalents per 100 g dry weight (mg GAE/g dw). [14]

Total Flavonoid Content

The total flavonoid content in the extracts was determined using the Aluminum chloride colorimetry method. The extracts were prepared by adding 200 µL of extract solution (50–1000 µg/mL) to 75 µL of NaNo3 (5%) for 5 minutes, followed by the addition of 150 µL of AlCl3 (10%) for 6 minutes. Then, 500 µL of 1M NaOH and 1075 µL of DI water were added to the mixture, which was kept at room temperature for 30 minutes. The absorbance of the mixture was measured at 415 nm using a UV Spectrophotometer. The total flavonoid content was expressed as mg/g of quercetin equivalents in milligrams per gram (mg QCE/g dw.) of dry extract .[15]

DPPH Radical Scavenging Activity

The DPPH (2,2-diphenyl-1-picrylhydrazyl) method was used to determine the free radical scavenging activity of the sample. The diluted sample was mixed with a 0.2 mM DPPH solution and allowed to stand in the dark at room temperature for 1 hour. The absorbance was measured at 520 nm using a spectrophotometer and expressed as IC50, which is the extract dose required to decrease the absorbance of DPPH by 50%. Ascorbic acid was used as a positive control.[16]

Statistical analysis

The results of Total phenolics cotent (mgGAE/100gdw), Total flavonoids content (mgCE/100gdw) and DPPH (IC_{50}mg/ml) were express as mean ± SD. The significant differences between means were calculated by one-way analysis of variance (ANOVA) using Duncan post hoc test at $P<0.05$.

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Figure 1: Study areas of the research.

Results and Discussion

Thailand is renowned for its rich biodiversity, including numerous tropical plants that are utilized to season food. A survey of plants in all 8 provinces in the northeastern region of Thailand revealed various plants used to season food, enhancing its flavor. Within this survey, it was discovered that there are 23 families and 33 plants species capable of imparting four to five distinct flavors. These flavors are categorized as salty, sweet, sour, spicy, and a delightful or umami taste. Table 1 and Figure 2 reveal that among the seasoning plants, 13 plant species contributed the spiciest flavors, 9 offered sweetness, 6 combined salty or mellow tastes, and 5 provided sour flavors. The spiciest flavors, commonly used for seasoning food, are found in the Lamiaceae family. Thai cuisine is renowned for its delicious flavors and subtle spiciness, which is enhanced by the use of plants from the Lamiaceae family. These plants are rich in essential oils and possess a spicy taste, greatly contributing to the overall taste and deliciousness of Thai food.[17,18] The family Lamiaceae comprises plants that are prominently employed as seasonings in Thai Isaan cuisine, imparting a distinctively fiery and spicy flavor profile. Thai Isaan cuisine is renowned for its fervent embrace of bold and fiery flavors, a culinary tradition that resonates deeply within the hearts of the Isaan people in Thailand. Furthermore, an assortment of spicy plants can be found in several plant families, including Apiaceae, Asteraceae, Brassicaceae, Polygonaceae, Rutaceae, Scrophulariaceae, and Piperaceae. In a 2008 study conducted by Arunrat Chaveerach et al. it was revealed that the pepper family holds a prominent position as a culinary ingredient within the local Thai culinary traditions. It imparts a delightful and spicy flavor to a wide range of dishes, and this culinary preference is observed throughout all regions of Thailand. Notably, two species from the pepper family, namely *P. nigrum and P. sarmentosum*, have garnered significant recognition as the most esteemed members within the Thai gastronomic landscape. Their usage underscores their importance and influence in Thai cuisine. Plants with sweet flavors can be found in various families such as Amaryllidaceae, Brassicaceae, Convolvulaceae, Fabaceae, Opiliaceae, Phyllanthaceae, and Cucurbitaceae. On the other hand, plants with sour tastes can be found in families like Anacardiaceae, Caesalpiniaceae, and Clusiaceae. For saltiness or umami, distinct plant characteristics can be found in families such as Acanthaceae, Athyriaceae, Euphorbiaceae, and Limnocharitaceae. The plants listed in Table 1 were utilized to quantify the presence of essential substances, specifically phenols and flavonoids, which are antioxidant compounds.

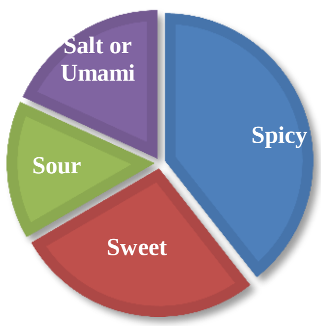

Figure 2: Food flavoring plants are categorized into (n=13 species of spicy flavors), (9 species of sweet flavors), (6 species of salty or umami flavors), and (5 species of sour plants).

Table 1: List of Botanical Plants Used for Seasoning Food in Northeast Thailand

Scientific name	English transliteration of local (Isaan) name	Part Use	Flavor/taste
Acanthaceae			
Acanthus ebracteatus Vahl	Ngueak plamo	Leaves	Salt
Amaryllidaceae			
Allium ascalonicum L.	Hom	Peducle	Sweet
Anacardiaceae			
Anacardium occidentale L.	Mamuang himmaphan	Leaves	Sour
Amarranthaceae	Cha khram		
Suaeda maritima (L.) Dumort.		Leaves	Salt
Apiaceae	Phak chi lao		
Anethum graveolens L.	Phak chi farang	Leaves/Stem	Spicy
Eryngium foetidum L.		Leaves/Stem	Spicy

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Asteraceae	Phak Khrat		
Acmella oleracea (L.) R.K.Jansen		Leaves	Spicy
Athyriaceae	Phak Kut		
Diplazium esculentum (Retz.) Sw.		Leaves	Umami
Brassicaceae	Phakkat-heen		
Brassica juncea (L.) Czern.	Chai thao	Leaves/Stem	Spicy
Raphanus sativus L.		Taber	Sweet
Caesalpiniaceae	Somsiao		
Bauhinia malabarica Roxb.		Leaves	Sour
Clusiaceae	Tio som		
Cratoxylum formosum (Jack) Benth. & Hook.f. ex		Leaves	Sour
Dyer ssp. *formosum*	Mak mok		
Garcinia cowa Roxb. ex DC.		Leaves	Sour
Convolvulaceae	Foi thong		
Cuscuta chinensis Lam.		Whole plant	Sweet
Cucurbitaceae	Buap Klom		
Luffa cylindrica M. Roem.	Buap khom	Fruit	Sweet
Trichosanthes cucumerina L.		Fruit	Sweet
Euphorbiaceae	Man pu		
Glochidion littorale Blume	Chaya	Leaves	Umami
Cnidoscolus chayamansa McVaugh		Leaves	Umami
Fabaceae	Ma klam ton		
Adenanthera pavonina L.	Thong kwao	Leaves	Sweet
Butea monosperma (Lam.) Taub.		Flower	Sweet
Lamiaceae	Saranae		
Mentha cordifolia Opiz ex Fresen. *Ocimum*	Maeng lak	Leaves	Spicy
americanum L.	Horapha	Leaves	Spicy
Ocimum basilicum L.	Ka phrao khon	Leaves	Spicy
Ocimum tenuiflorum L.	Niam hu suea	Leaves	Spicy
Plectranthus amboinicus (Lour.) Spreng.		Leaves	Spicy
Limnocharitaceae			
Limnocharis flava (L.) Buchenau.	Talapat ruesi		
		Petiole	Umami
Myrcinaceae			
Embelia subcoriacea Mez	Som kung		
		Leaves	Sour
Opiliaceae			
Melientha suavis Pierre	Phak wan		
		Leaves	Sweet
Phyllanthaceae			
Sauropus androgynus (L.) Merr.	Phak wan ban		
		Leaves	Sweet
Piperaceae			
Piper sarmentosum Roxb.	Cha phlu		
		Leaves	Spicy
Polygonaceae			
Polygonum odoratum Lour.	Phak paw		
		Leaves	Spicy
Rutaceae			
Feroniella lucida Swingle	Ma sang		
		Flower	Spicy
Scrophulariaceae			
Limnophila aromatica Merr.	Phak kha yaeng		
		Leaves	Spicy

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This assessment serves to enhance the value of this category of seasoning plants. Plants used for flavoring and seasoning provide notable benefits due to the presence of secondary metabolites, such as phenolic and flavonoid compounds. These compounds have the potential to generate free radicals in the body, offering additional advantages to their utilization. [20,21] In Table 2, phenolic compounds are reported to range from 216.50 to 878.15 mg GAE/100 g dry weight, while flavonoids vary from 89.77 to 748.14 mg CE/100 g dry weight. Within the category of spicy plants, *B. juncea* (L.) Czern stands out for its substantial production of phenolic compounds (878.15 ± 2.3 15 mg GAE/100 g dry weight) and its high flavonoid content (748.14 ± 0.68 mg CE/100 g dry weight). Remarkably, it demonstrates the highest antioxidant activity, with an IC50 value of 66.08±1.85. It contains various phytochemical compounds, including phenolics, polyphenols, flavonoids, carotenoids, alkaloids, phytosterols, glucosinolates, terpenoids, and glycosides, which contribute to its antioxidant potential. [22] The antioxidant activities of *B. juncea* have been demonstrated through metal reducing, metal chelating, lipid reducing, and free radical scavenging activities. [23] In Table 3, the sweet-tasting plants show phenolic compound levels ranging from 277.05 to 444.27 mg GAE/100 g dry weight, with flavonoid concentrations varying from 103.36 to 359.00 mg CE/100 g dry weight. This table provides insightful data on the total phenolic and flavonoid contents, as well as the highest antioxidant activity observed in *A. ascalonicum* L. The results indicate significant concentrations of phenolic compounds (404.21±1.43 mg GAE/100 g dw) and flavonoids (359.00±0.8 mg CE/100 g dw), accompanied by a notable IC_{50} value of 126.70. These findings underscore the potent antioxidant properties and nutritional value of *A. ascalonicum* L., The extract of *A. ascalonicum* has shown radical scavenging activity, chain-breaking activity, and reducing capacity, which can be attributed to the high amounts of quercetin present in it.[24] Allium species, including *A. ascalonicum*, contain bioactive constituents such as sulfur compounds, steroidal saponins, flavonoids, and polysaccharides, which have various physiological functions including antioxidant effects.[25] The sour-tasting plants and salt or umami-tasting plant show phenolic compound levels ranging from 353.11 to 904.85 mg and 191.52 to 1,029.16 mg GAE/100 g dry weight with flavonoid concentrations varying from 122.31 to 747.48 and 269.97 to 933.06 mg CE/100 g dry weight. Tables 4 and 5 showed plants that contribute to sour and salty or umami tastes, result showed that, *B. malabarica* Roxb. and *C. littorale* Blume respectively, the results indicate significant concentrations of phenolic compounds (904.85±0.69, 1029.16±1.22mg GAE/100 g dw) and flavonoids (747.48±0.93, 993.06 ±0.69mg CE/100 g dw). Accompanied by a notable IC_{50} value of 95.31±0.28, and 67.18 ± 2.15 µg/ml. *B. malabarica* Roxb is a plant species that has been studied for its biological activity, specifically its antioxidant and phytochemical properties. The acetone extract of *B. malabarica* seed was found to have the highest antioxidant activity among the samples tested. [26] Additionally, the acetone extract of *B. malabarica* seed was found to contain substantial amounts of total phenolics, tannins, condensed tannins, flavonoids, and vitamin C. [27] These findings suggest that *B. malabarica* has the potential to be a valuable source of natural antioxidants and phytochemicals, with potential applications in health, food, and pharmaceutical industries.[28]
The leaf extract of *G. littorale* showed high values in total phenol and flavonoid content, as well as radical-scavenging activity. The extract exhibited neuroprotective effects against oxidative stress and neurodegeneration, possibly through the activation of the transcription factor DAF-16 [29]. Additionally, *G. littorale* has been shown to have antioxidant potential, with the presence of secondary metabolites such as flavonoids contributing to its radical scavenging and reducing abilities. [30] The plant *E. littorale*, which is closely related to *G. littorale*, has also been found to have strong antioxidant potential, particularly in its flowers. [31] Therefore, it can be inferred that *G. littorale* may also possess antioxidant properties. Among the plants we studied, those used for flavoring displayed the highest antioxidant capacity, marking a significant difference. Additionally, the extracts exhibited fluctuations in their antioxidant activity, highlighting the crucial role of flavonoids and phenolic compounds. These compounds, commonly found as secondary metabolites in plants, hold immense importance for their extraordinary ability to serve as potent antioxidants. [32]

Table 2: Total phenolics and flavonoids contents and antioxidant activities of spicy taste plant extracts

Scientific name	% yeild	Total phenolics cotent (mgGAE/100gdw)	Total flavonoids content (mgCE/100gdw)	DPPH (IC_{50}µg/ml)
Acmella oleracea (L.) R.K.Jansen	5.65 ± 0.07^{f}	324.25 ± 0.93^{j}	89.77 ± 1.09^{l}	451.89 ± 0.93^{m}
Anethum graveolens L.	3.94 ± 0.09^{i}	216.50 ± 0.69^{l}	214.21 ± 0.46^{i}	385.98 ± 1.16^{l}
Brassica juncea (L.) Czern.	8.64 ± 0.18^{b}	878.15 ± 2.31^{a}	748.14 ± 0.68^{a}	66.08 ± 1.85^{a}
Eryngium foetidum L.	6.56 ± 0.06^{d}	426.72 ± 0.46^{g}	197.50 ± 0.46^{j}	164.73 ± 0.67^{h}
Feroniella lucida Swingle	4.23 ± 0.12^{h}	714.71 ± 1.34^{c}	380.19 ± 0.39^{c}	108.58 ± 1.48^{c}
Limnophila aromatica Merr.	7.76 ± 0.20^{c}	553.38 ± 1.57^{d}	359.61 ± 2.31^{d}	117.27 ± 0.46^{d}
Mentha cordifolia Opiz ex Fresen.	9.29 ± 0.23^{a}	761.65 ± 1.70^{b}	585.19 ± 2.31^{b}	81.69 ± 0.46^{b}
Ocimum americanum L.	4.74 ± 0.13^{g}	311.07 ± 2.31^{k}	159.04 ± 0.71^{k}	341.39 ± 0.40^{k}
Ocimum basilicum L.	7.79 ± 0.23^{c}	543.31 ± 1.79^{e}	251.07 ± 1.19^{f}	196.72 ± 1.19^{i}
Ocimum tenuiflorum L.	5.76 ± 0.05^{f}	406.22 ± 0.79^{h}	237.90 ± 0.93^{g}	232.64 ± 1.16^{j}
***Piper sarmentosum* Roxb.**	3.38 ± 0.05^{j}	442.49 ± 1.99^{f}	281.72 ± 1.02^{e}	153.42 ± 0.71^{g}
***Plectranthus amboinicus* Lour.**	5.61 ± 0.17^{f}	363.40 ± 1.70^{i}	237.37 ± 0.69^{g}	126.44 ± 1.43^{f}
***Polygonum odoratum* Lour.**	6.02 ± 0.16^{e}	409.26 ± 1.44^{h}	231.43 ± 0.67^{h}	122.11 ± 0.46^{e}

$^{a, b, c,d,e,f,g,h,i, j ,k l, m}$ = Different superscripts in the same column indicate statistical significance (P < 0.05).

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Table 3: Total phenolics and flavonoids contents and antioxidant activities of sweet taste plant extracts

Scientific name	% yeild	Total phenolics cotent (mgGAE/100gdw)	Total flavonoids content (mgCE/100gdw)	DPPH (IC_{50}µg/ml)
Adenanthera pavonina L.	9.86 ± 0.05[b]	444.27 ± 1.31[a]	242.07 ± 1.13[e]	155.08 ± 0.93[b]
Allium ascalonicum L.	8.24 ± 0.09[d]	404.21 ± 1.43[b]	359.00 ± 0.86[a]	126.70 ± 0.23[a]
Butea monosperma (Lam.) Taub.	10.44 ± 0.14[a]	397.93 ± 0.28[c]	303.37 ± 0.93[b]	196.24 ± 0.93[c]
Cuscuta chinensis Lam.	10.52 ± 0.23[a]	347.43 ± 1.15[f]	274.48 ± 0.67[d]	241.13 ± 0.69[f]
Luffa cylindrica M. Roem.	9.55 ± 0.23b[c]	347.54 ± 1.79[f]	272.84 ± 2.23[d]	228.69 ± 0.61[e]
Melientha suavis Pierre	9.47 ± 0.16[c]	286.27 ± 0.71[g]	127.52 ± 0.71[g]	318.54 ± 2.31[h]
Raphanus sativus L.	8.12 ± 0.08[d]	359.91 ± 0.93[e]	103.36 ± 0.39[h]	296.54 ± 0.93[g]
Sauropus androgynous (L.) Merr.	9.77 ± 0.23[bc]	364.79 ± 0.93[d]	279.92 ± 1.16[c]	207.78 ± 1.16[d]
Trichosanthes anguina L.	10.43 ± 0.23[a]	277.05 ± 0.17[h]	178.81 ± 0.69[f]	869.95 ± 1.53[i]

[a, b, c,d,e,f,g,h,i] = Different superscripts in the same column indicate statistical significance (P < 0.05).

Free radicals are well-established as key contributors to a range of health issues. Within this context, antioxidants play a vital role in combatting free radicals and shielding us from various diseases. Their function includes both the neutralization of reactive oxygen species and the preservation of our body's antioxidant defense mechanisms. [33] Furthermore, polyphenols have been the subject of extensive research and are widely recognized for their exceptional potential as natural antioxidant compounds. They contribute to human health by mitigating and preventing oxidative damage induced by free radicals. These findings underscore the significant role of polyphenols in guarding against oxidative stress and underscore their value as a promising avenue for promoting overall well-being.[34]

This research underscores that flavor-enhancing plants not only elevate the taste of food but also hold considerable potential for broader development across various domains. These seasoning plants can be further explored in the realms of nutrition, pharmacology, and processing, creating opportunities to enhance their overall value.

Conclusion

The current study performed an analysis to assess the free radical scavenging activity, total phenolic content, and flavonoid content of the thirty-three flavor plants. The results revealed that these flavor plants exhibit significant potential as a potent source of natural antioxidants. These findings emphasize the importance of utilizing flavor plants as a valuable and effective resource for obtaining natural antioxidants, which can have positive implications for human health. Additionally, it supplies valuable information for further application in the development of new drugs and alternative natural active ingredients for the food industry.

Table 4: Total phenolics and flavonoids contents and antioxidant activities of sour taste plant extracts

Scientific name	% yeild	Total phenolics cotent (mgGAE/100gdw)	Total flavonoids content (mgCE/100gdw)	DPPH (IC_{50}µg/ml)
Anacardium occidentale L.	8.82 ± 0.23[d]	697.11 ± 1.16[c]	342.37 ± 0.80[c]	106.13 ± 0.28[c]
Bauhinia malabarica Roxb.	10.67 ± 0.46[c]	904.85 ± 0.69[a]	747.48 ± 0.93[a]	95.31 ± 0.19[a]
Cratoxylum formosum (Jack) Benth. & Hook.f. ex Dyer ssp. formosum	10.53 ± 0.23[c]	874.78 ± 2.42[b]	346.64 ± 1.02[b]	104.31 ± 0.69[b]
Embelia subcoriacea Mez	11.95 ± 0.46[b]	353.11 ± 0.93[e]	180.27 ± 1.53[d]	212.73 ± 0.93[d]
Garcinia cowa Roxb. ex DC.	14.06 ± 0.19[a]	421.65 ± 0.46[d]	122.31 ± 0.46[e]	109.30 ± 1.46[e]

[a, b, c,d,e] = Different superscripts in the same column indicate statistical significance (P < 0.05).

Table 5: Total phenolics and flavonoids contents and antioxidant activities of salt or umami taste plant extracts

Scientific name	% yeild	Total phenolics cotent (mgGAE/100gdw)	Total flavonoids content (mgCE/100gdw)	DPPH (IC_{50}µg/ml)
Acanthus ebracteatus Vahl	14.20 ± 0.04[b]	162.66 ± 4.89[f]	626.35 ± 8.71[b]	83.48 ± 2.74[b]
Cnidoscolus chayamansa McVaugh	6.64 ± 0.05[e]	311.97 ± 0.57[c]	234.05 ± 0.53[f]	358.23 ± 0.7[e]
Diplazium esculentum (Retz.) Sw.	6.67 ± 0.09[e]	233.19 ± 0.31[d]	294.02 ± 1.16[d]	267.06 ± 0.69[d]
Glochidion littorale Blume	8.91 ± 0.17[c]	1029.16 ± 1.22[a]	993.06 ± 0.69[a]	67.18 ± 2.15[a]
Limnocharis flava (L.) Buchenau.	8.61 ± 0.09[d]	387.89 ± 0.75[b]	405.64 ± 1.34[c]	146.88 ± 1.36[c]
Suaeda maritima (L.) Dumort.	29.28 ± 0.04[a]	191.52 ± 3.18[e]	269.97 ± 8.66[e]	366.56 ± 3.91[f]

[a, b, c,d,e,f]= Different superscripts in the same column indicate statistical significance (P < 0.05).

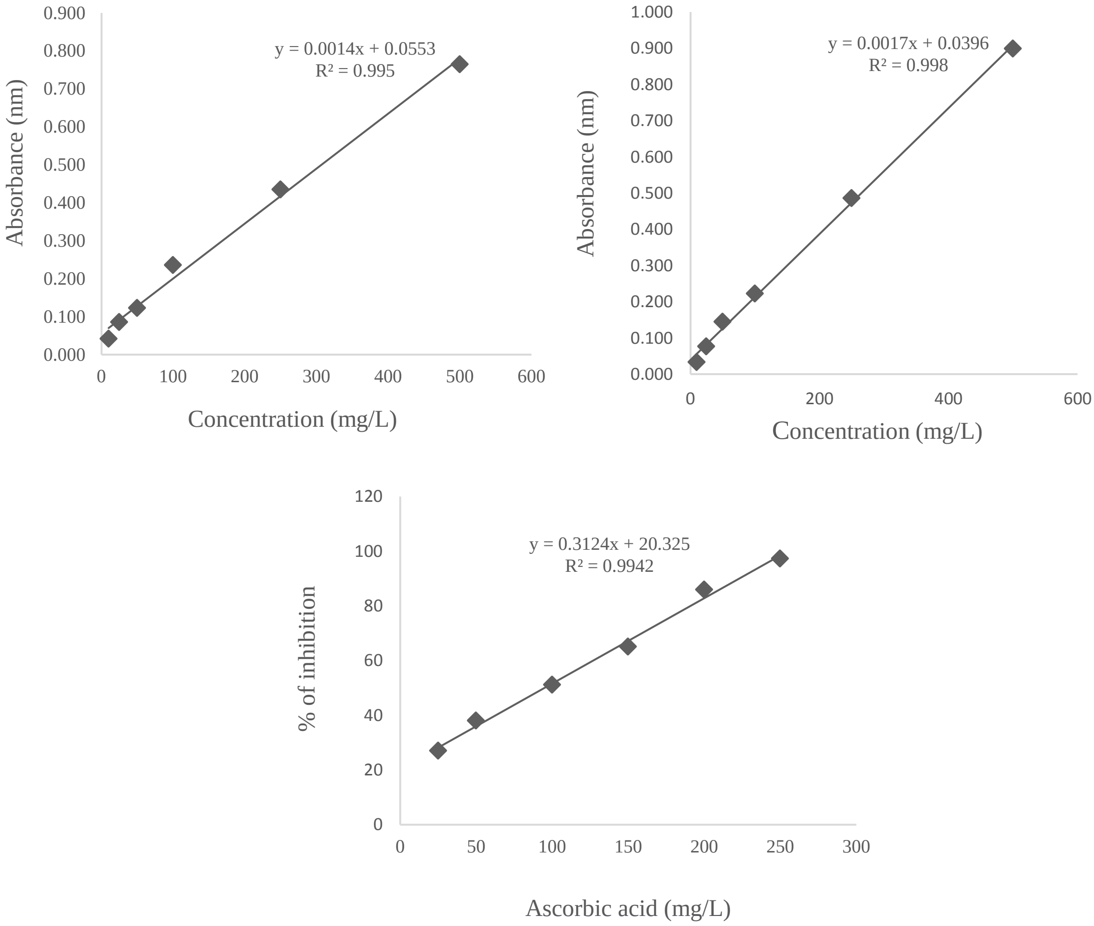

Figure 3: The calibration curves of gallic acid solutions for determination of tatal phenolic (a), quercetion solution for total flavonoid assay (b) and ascorbic acid solution for DPPH radical scavenging activity.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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