



Volatile Components in the Extracts from 20 Herbaceous Plant Flowers

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Abstract

In this study, thermal stability analysis (TG-DTG) was employed to investigate the thermal decomposition process from 20 herbaceous plant flowers. The results indicated that the decomposition of the majority of the flowers commenced at approximately 150°C and was completed by around 600°C, with carbonization typically initiating around 300°C. In this research, X-ray fluorescence spectroscopy (XRF) was utilized to analyze the elemental composition of 20 herbaceous plant flowers. The results showed that *Paeonia lactiflora* Pall. Flowers and so on have higher inorganic content, while *Cyperus rotundus* L. flowers and so on have higher carbon content. In this study, Fourier transform infrared spectroscopy (FTIR) was utilized to explore the functional groups in the ethanol extracts of 20 herbaceous plant flowers. The results demonstrated that the ethanol extracts of these 20 herbaceous plant flowers displayed characteristic C=C stretching vibrations in the range of 1700-1610 cm⁻¹. This spectral characteristic implies the potential presence of valuable bioactive compounds, including flavonoids, amino acids, and alkaloids. Gas chromatography-mass spectrometry (GC-MS) analysis of the flower extracts from 20 herbaceous plant flowers unveiled that these extracts encompass compounds with diverse bioactivities. These provide a basis for its resource utilization.

Keywords: TG-DTG; FTIR; XRF; GC-MS; Anticancer active substance.

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1. Introduction

Plant biomass is made up of lignin, hemicellulose, cellulose, moisture, ash, and extractable substances. The separation of biomass from plant materials and the determination of biomass content are of great help in realizing its resource-oriented utilization.^[1] Thermogravimetric analysis finds applications in diverse fields, including energy storage, biofuels, food science, and pharmaceuticals.^[2] Thermogravimetric analysis (TGA) can be efficiently utilized to characterize organic polyoxometalates synthesized from the active components of traditional Chinese medicine.^[3] For instance, thermogravimetric analysis can be used to characterize the enhancement of berberine cinnamate over berberine salts.^[4] Thermogravimetric analysis can offer specific selectivity and recognition capabilities for

chlorogenic acid extraction using molecularly imprinted polymers.^[5] Plants with medicinal applications are occasionally subject to adulteration. Thermogravimetric analysis, by revealing the thermal decomposition processes of these plants, furnishes a foundation for drug identification and comprehensive utilization. Extracts derived from medicinal plants exhibit antibacterial and anticancer activities.^[6] The ethanol-water vapor thermal reduction method is capable of enhancing lithium recovery. During this process, it reduces LiCoO₂, resulting in the formation of water-soluble LiOH and water-insoluble transition-metal oxides.^[7] By measuring the contents of flavonoids, total phenols, and hydroxytyrosol in ethanol and ethanol-aqueous solutions of olive leaves, this research can contribute to the economic exploitation of olive leaves in the food, cosmetics, and drug-related industries.^[8] The ethanol-water extract of defatted seeds, which contains acidic substances such as chlorogenic acid, exhibits antioxidant and antibacterial activities,^[9] while ethanol, water, and glycerol extracts of red grape pomace display antioxidant and anti-pigmentation activities.^[10] The water extract from the wild plant *Eupatorium adenophorum* has the potential to induce apoptosis in cervical cancer cells,^[11] and the ethanol

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extract of *Terminalia chebula* exhibits anti-inflammatory, antifungal, and antidiabetic activities.^[12] Therefore, the ethanol and water-alcohol extracts of medicinal plants possess anti-inflammatory, anticancer, antibacterial, antioxidant, and antidiabetic activities. As such, they hold potential for applications in the food, cosmetics and drug-related industries. Infrared spectroscopy combined with cluster analysis has emerged as a powerful tool for identifying different varieties of goji berries and can provide valuable insights for goji berry breeding.^[13] The therapeutic effects of traditional Chinese medicine rhubarb on ulcerative colitis is strongly contingent on the roasting degree. Unroasted rhubarb may induce diarrhea owing to its potent purgative properties, whereas over-roasted rhubarb may forfeit its therapeutic effectiveness. Mid-infrared spectroscopy in combination with principal component analysis (PCA) can be applied to identify properly roasted rhubarb, thereby ensuring optimal therapeutic outcomes in the treatment of ulcerative colitis.^[14] The FTIR spectrum has the ability to detect acids and esters in Chinese Baijiu. Moreover, it can be effectively utilized to differentiate the flavor profiles of various Chinese Baijiu products.^[15] Fourier transform spectroscopy is capable of detecting the active ingredients in unknown honeysuckle samples. This technique enables non-destructive testing, thereby contributing to the stable and controllable quality assurance of traditional Chinese medicine.^[16] Therefore, Fourier transform spectroscopy can be employed for the preliminary compositional analysis of medicinal plants. This application allows for the identification of the origin, authenticity, and quality assessment of plant-derived products. The traditional Chinese medicine formula Bu Shen Fang, known for its functions such as warming the kidneys, tonifying qi, strengthening the spleen, and invigorating yang, can have its active ingredients effectively analyzed using GC-MS.^[17] Patchouli, a traditional Chinese medicine, demonstrates antioxidant, antithrombotic, and anti-inflammatory properties. GC-MS can be applied to assess the pharmacokinetics of its essential oil extract.^[18] Traditional Chinese medicines are also susceptible to containing pesticide residues. GC-MS can effectively, sensitively, and accurately detect the organic phosphorus components present in honeysuckle samples.^[19] GC-MS can be employed to detect polycyclic aromatic hydrocarbons (originating from fossil fuel combustion) in Chinese herbal medicines like honeysuckle. It has been

discovered that honeysuckle may carry potential health risks, which necessitate meticulous detection and evaluation.^[20]

In this chapter, the thermal decomposition processes of 20 herbaceous plant flowers were analyzed by means of TG-DTG techniques, which are related to thermal stability and heat release characteristics. The obtained results provide a fundamental basis for the identification and comprehensive utilization of these 20 herbaceous plant flowers. FTIR was employed to analyze the functional groups in ethanol extracts of 20 herbaceous plant flowers. GC-MS was employed to determine the main compounds, unique compounds, and cancer cytotoxic compounds in ethanol extracts of flowers from 20 herbaceous plant species. This comprehensive analysis provides a basis for the utilization of herbaceous plant flowers resources and their potential cancer cytotoxicity.

2. Experimental design

2.1 Plant extraction

20 types of flower samples were collected from Longzi Lake in Zhengzhou City (medicinal plants under herbaceous forests that bloom from March to July), and immediately placed in the laboratory for pre-treatment of flower samples. Separate the entire flower sample, clean, air dry, and crush it. After the sample is crushed, it is extracted with anhydrous ethanol and water alcohol (ethanol: distilled water=1:1) in a water bath (65°C). After rotary evaporation, it is stored in a refrigerator at 4 degrees Celsius for later use.

2.2 Thermal stability test of herbaceous plant flowers

The processed flower powder was subjected to analysis using a PerkinElmer synchronous thermal analyzer (TG model: STA8000). The thermal analyzer is equipped with a platinum crucible, a balance, and a horizontal furnace, and has a sample capacity of approximately 200 mg. A 10-mg portion of the experimental sample flower powder was taken. High-purity nitrogen was introduced at a pressure of 0.1 MPa and a gas flow rate of 20 mL/min. The temperature was ramped up from 30°C to 800°C at a heating rate of 10°C/min and then held at 800°C for 5 minutes.

2.3 Elemental analysis of herbaceous plant flowers

The flower sample powder was evenly spread in a measuring container with a diameter of 40 mm and then placed in an XRF (Shimadzu EDX-7000, Japan) for elemental analysis. A sample irradiation area with a diameter of 10 mm was selected. After the testing process, the results were collected, organized, and used to generate elemental spectra.

2.4 Fourier transform infrared spectroscopy analysis of herbaceous plant flowers

The extraction solution of flower samples was analyzed using a potassium bromide (KBr)-based Fourier-transform infrared absorption spectrometer (Nicolet iS10, Thermo Fisher Scientific). A 15 µL aliquot of the liquid extract sample was dropped onto 200 mg of dried potassium bromide (KBr)

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powder. The KBr powder had been previously dried at 105°C for 24 hours and then mixed and ground evenly in an agate mortar. The mixture was subsequently pressed into a transparent pellet for analysis. Subsequently, each sample tablet was positioned within the sample holder of the Fourier-transform infrared (FTIR) spectrometer for analysis. The spectral range was configured as 4000–400 cm⁻¹, the scanning frequency was fixed at 32, and the spectral resolution was determined as 4 cm⁻¹. During the scanning process, the interference from water and carbon dioxide was subtracted. The infrared spectral standard spectra of different parts of the samples and their extracts were acquired using OMNIC 8.0 infrared operation software.

2.5 GC-MS Examination of Flower Extracts from Herbaceous Plants

The analysis of 20 ethanol extracts was carried out using an Agilent GC-MS system (7890B/5977B). For the chromatographic conditions, the elastic quartz capillary column HP-5MS(60 m×250 μm×0.25 μm) was used. High-purity helium gas served as the carrier gas at a flow rate of 1.2 mL/min, with a split ratio of 5:1. The column was initially set at 40°C, then heated at 6°C/min to 250°C and held for 2 minutes. After that, the temperature was increased at 5°C/min to 280°C and kept constant for 5 minutes.

Mass spectrometry conditions: The electron ionization (EI) ion source was employed with the following parameters: the ion source temperature was 230 °C, the quadrupole temperature was 150 °C, the ionization voltage was 70 eV, and the ionization current was 150 μA, and a scanning range of 30–600 amu. The corresponding chemical components were retrieved by referencing the NIST17L standard spectral library. The relative content of compounds was determined through the peak-area normalization method.

3. Results and analysis

3.1 Analysis of volatile components in the flowers of herbaceous plants

Fig. 1(ab) illustrate that the thermal decomposition process of most plant flowers can be categorized into three separate stages. The initial stage, occurring from approximately 30°C to 150°C, is characterized by the loss of adsorbed water and crystalline water.^[21] In the second stage, ranging from approximately 150°C to 600°C, natural macromolecular compounds such as proteins, sugars, and fats undergo thermal decomposition,^[22] and the lowest point of the DTG curve commences the process of carbon formation at approximately 300°C. In the third stage, within the temperature span of 600°C to 800°C, the production of CO₂ and H₂O occurs, followed by their decomposition into ash. The natural macromolecular compounds, namely proteins, sugars, and fats, present in the 20 herbaceous plant flowers commence decomposition at 150°C. This finding suggests that the application temperature for these 20 herbaceous plant flowers should not surpass 150°C. In summary, from the thermal

decomposition profiles of the flowers of 20 herbaceous plants, it is evident that the onset and termination times of the three stages of flower thermal decomposition vary among different species. The majority of the flowers exhibit decomposition within the temperature span of approximately 150°C to 600°C, and the process of carbon formation commences at around 300°C. This indicates that the flowers of these 20 herbaceous plants possess the characteristic of easy degradation.^[23] The flowers of *Paeonia lactiflora* Pall., *Oxalis corymbosa* DC., *Orychophragmus violaceus* (L.) O. E. Schulz, and *Oenothera speciosa* Nutt show non-uniform thermal decomposition in the temperature span of 200–400 °C. Notably, the flowers of *Paeonia lactiflora* Pall. may contain a diverse array of natural macromolecular compounds. The thermal decomposition of *Iris tectorum* Maxim is non-uniform in the temperature span of 200–600°C. This may be attributed to the presence of high-molecular-weight substances, such as long-chain hydrocarbons, or inorganic substances like silicates and carbonates, within their natural macromolecular compounds. The decomposition rate of *Paeonia lactiflora* Pall. and *Iris tectorum* Maxim. is relatively rapid. It is also likely that *Paeonia lactiflora* Pall. and *Iris tectorum* Maxim. contain a higher proportion of low-molecular-weight volatile compounds.

Plants contain minerals and active substances, which enable them to be used as basic substances in the production and application of modern medicines.^[24] Fig. 1c reveals that the flowers of 20 herbaceous plant species contain elements including K, P, Ca, Cl, S, Fe, Cu, Mn, Zn, Si, Ti, Br, Rb, Sr, Cr, Co, Ni, and others. Among these elements, K and P are classified as abundant elements, Ca and S as moderate - level elements, while Fe, Zn, Mn, Cl, and Cu are considered trace elements. Furthermore, Si, Ti, and Co are beneficial elements for plants. The flowers of the 20 herbaceous plant species are capable of absorbing Ni, Br, Rb, and Sr elements. Through a comparison of the high contents of K, Ca, and Si, it can be inferred whether the content of silicates and carbonates is relatively high or low. Through thermal stability analysis and elemental analysis, it can be concluded that *Paeonia lactiflora* Pall. flowers, *Hemerocallis hybrida* Bergmans, *Trifolium repens* L., *Echinacea purpurea*, and *Hemisteptia lyrata* (Bunge) Fisch. & C. A. Mey. have higher inorganic content, while *Cyperus rotundus* L., *Hosta plantaginea* (Lam.) Aschers., *Oxalis corymbosa* DC., *Coreopsis basalis* (A. Dietr.) S. F. Blake, and *Erigeron annuus* (L.) Pers. have higher carbon content. A high Cl content is also detected in the majority of flowers. While Cl is an essential nutrient for plant growth, excessive accumulation thereof can give rise to cell toxicity.^[25] Sr plays a role in facilitating bone regeneration, promoting growth, and stimulating calcium signaling. Notably, the majority of flowers contain Sr, which can potentially be utilized in the synthesis of strontium nanoparticles endowed with antioxidant activity.^[26] Additionally, the flowers of these plants can be employed in the formation of strontium nanoparticles that possess antioxidant activity.

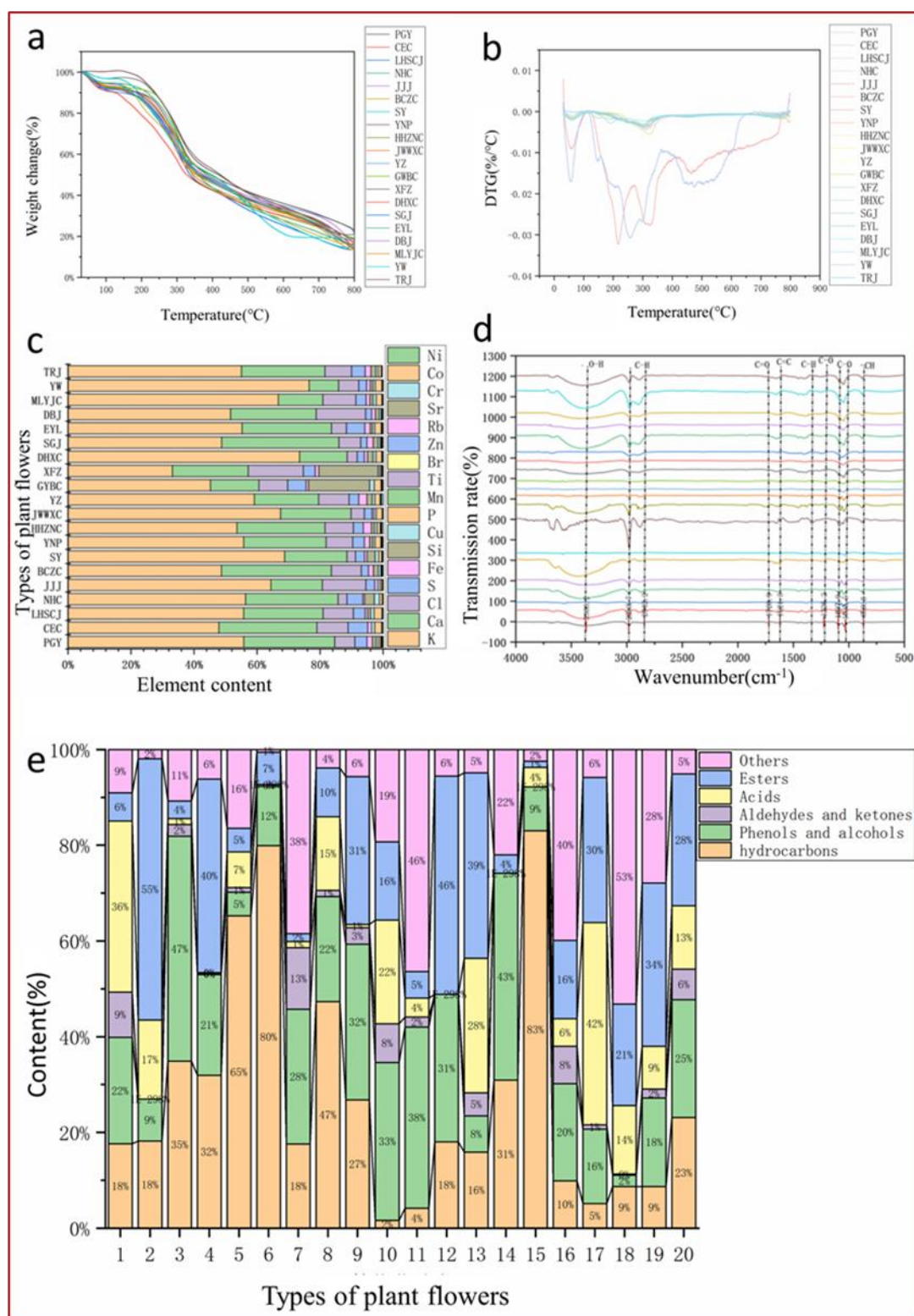


Fig. 1: TG (a) and DTG (b) curves of 20 herbaceous plant flowers; (c) The relative content of floral elements in 20 herbaceous plant species.; (d) Infrared spectra of ethanol extracts from the flowers of 20 herbaceous plant species ; (e) Column chart depicting the chemical composition and content of various categories of ethanol extracts from the flowers of 20 herbaceous plant species; The infrared spectra from top to bottom and 1-20 are as follows: *Taraxacum mongolicum* Hand.-Mazz., *Cirsium arvense* var. *integrifolium* Wimm. & Grab., *Cyanus segetum* Hill, *Hemisteptia lyrata* (Bunge) Fisch. & C. A. Mey., *Coreopsis basalis* (A. Dietr.) S. F. Blake, *Trifolium repens* L., *Paeonia lactiflora* Pall., *Erigeron annuus* (L.) Pers., *Oxalis corymbosa* DC., *Hemerocallis fulva* 'Golden Doll', *Hosta plantaginea* (Lam.) Aschers., *Setaria viridis* (L.) Beauv., *Cyperus rotundus* L., *Hemerocallis hybrida* Bergmans, *Echinacea purpurea*, *Orychophragmus violaceus* (L.) O. E. Schulz, *Leucanthemum maximum* (Ramoood) DC., *Oenothera speciosa* Nutt., *Iris tectorum* Maxim., *Gaillardia pulchella* Foug.

Fig. 1d shows that the infrared spectra of the ethanol extracts of *Taraxacum mongolicum* Hand.-Mazz., *Erigeron annuus* (L.) Pers., and *Oxalis corymbosa* DC. flowers have a large absorption peak at 3369.2 cm^{-1} and an O-H stretching vibration between $3600\text{--}3000\text{ cm}^{-1}$,^[27] indicating the possible presence of sugars, phenols, alcohols, and carboxylic acids.^[28] There are two absorption peaks around 2980.7 cm^{-1} , and between $3000\text{--}2800\text{ cm}^{-1}$, it is a C-H stretching vibration,^[31] which may indicate the presence of alkanes. There is an absorption peak around 1737.1 cm^{-1} , and between $1900\text{--}1600\text{ cm}^{-1}$, it is a C=O stretching vibration,^[29] which may indicate the presence of esters, carboxylic acids, and ketones. There is an absorption peak around 1640.1 cm^{-1} , and between $1700\text{--}1610\text{ cm}^{-1}$, it is a C=C stretching vibration,^[32] which may indicate the presence of olefins. There are several absorption peaks around 1374.2 cm^{-1} , and between $1480\text{--}1300\text{ cm}^{-1}$, they are C-H angular vibrations, which may indicate the presence of sugars. There are several absorption peaks around 1271.1 cm^{-1} , and between $1310\text{--}1000\text{ cm}^{-1}$, there are C-O stretching vibrations,^[33] which may indicate the presence of carboxylic acids, phenols, esters, ketones, and alcohols. There is an absorption peak around 1081.8 cm^{-1} , and between $1310\text{--}1000\text{ cm}^{-1}$, it is a C-O stretching vibration,^[29] which may contain carbohydrate substances. There is an absorption peak around 875.9 cm^{-1} , and between $900\text{--}780\text{ cm}^{-1}$, it is an out of plane bend of -CH, possibly indicating the presence of aldehydes. The ethanol extracts of flowers from 17 other herbaceous plants (such as *Cirsium arvense* var. *integrifolium* Wimm. & Grab., *Cyanus segetum* Hill, *Hemisteptia lyrata* (Bunge) Fisch. & C. A. Mey., *Coreopsis basalis* (A. Dietr.) S. F. Blake, *Trifolium repens* L., *Paeonia lactiflora* Pall., and *Paeonia lactiflora* Pall.) exhibit relatively small C=O stretching vibrations between $1900\text{--}1600\text{ cm}^{-1}$, and may contain fewer substances such as esters, carboxylic acids, and ketones. Moreover, the infrared spectra of ethanol extracts from *Cyanus segetum* Hill, *Paeonia lactiflora* Pall., *Hemerocallis fulva* 'Golden Doll', *Hosta plantaginea* (Lam.) Aschers., *Setaria viridis* (L.) Beauv., and *Echinacea purpurea* display relatively weak O-H stretching vibrations in the span of $3600\text{--}3000\text{ cm}^{-1}$. This suggests the possible presence of fewer substances such as sugars, phenols, alcohols, and carboxylic acids. In summary, the extracts from the flowers of 20 herbaceous plants species display C=C stretching vibrations in the range of $1700\text{--}1610\text{ cm}^{-1}$. This indicates the potential presence of compounds such as flavonoids, amino acids, and alkaloids.^[31] The existence of active functional groups in most plant flower extracts implies that these extracts are probably endowed with medicinal value. This discovery furnishes a scientific foundation for the comprehensive utilization and further investigation of plant flower extracts as prospective therapeutic agents.

As illustrated in Fig. 1e, the ethanol extract of *Echinacea purpurea*, exhibits the highest proportion of hydrocarbon substances. Among the ethanol extracts of various plant flowers, the highest proportion of phenolic alcohol substances

was identified in the ethanol extract of *Hemerocallis hybrida* Bergmans. The highest proportion of aldehyde ketone substances is found in the ethanol extract of *Paeonia lactiflora* Pall.. The highest proportion of acid substances is found in the ethanol extract of *Leucanthemum maximum* (Ramood) DC.. The ethanol extract of *Cirsium arvense* var. *integrifolium* Wimm. & Grab., has the highest proportion of ester substances.

3.2 The ethanol extracts of herbaceous plant flowers contain active substances that possess insect - resistant, antibacterial, antioxidant, or cytotoxic functions.

By combining the attached materials and searching for the paper, it can be concluded that 34 active substances with insect resistance, antibacterial, antioxidant, or cytotoxic functions were found in the ethanol extracts of flowers from 20 herbaceous plant species, (Fig. S1-S20; Table S1-S20), including n-Hexadecanoic acid, Dodecane, 1-fluoro-, Melezitose, 7-Ethyl-4-decen-6-one, 2-Cyclohexylpiperidine, Hexadecanoic acid, methyl ester, Methyl 12,13-tetradecadienoate, 9,12-Octadecadienoic acid (Z,Z)-, Methyl 4,7,10,13-hexadecatetraenoate, Caryophyllene, etc. Among them, 22 substances with cytotoxicity were found, including n-Hexadecanoic acid, Melezitose, 2-Cyclohexylpiperidine, Hexadecanoic acid, methyl ester, 9,12-Octadecadienoic acid (Z,Z)-, Caryophyllene, cis- α -Bergamotene, Benzoyl isothiocyanate, Methyl 3,5-tetradecadiynoate, etc.

Application of material in Table 1 of the paper query: n-Hexadecanoic acid has been shown to induce nuclear condensation and fragmentation in T24 cells, thereby inhibiting cell proliferation. Additionally, n-Hexadecanoic acid exhibits antioxidant properties.^[34] Dodecane, 1-fluoro- exhibits potential anti-inflammatory properties.^[36] Melezitose induces apoptosis of A549 cells by causing cell cycle arrest at the G1 phase.^[37] 7-Ethyl-4-decen-6-one has been identified as a compound with potential for the synthesis of antibacterial agents.^[38] 2-Cyclohexylpiperidine exhibits potent anti-inflammatory and apoptotic activities.^[39] Hexadecanoic acid, methyl ester demonstrates significant anti-cancer activities, particularly against breast cancer and skin cancer.^[40] 15-Tetradecanoic acid, methyl ester, (Z)- exhibits remarkable medicinal value in facilitating the regeneration of nerve cells and repairing damaged nerve fibers.^[41] Methyl 12,13-tetradecadienoate has been shown to decrease the affinity between α -glucosidase and isomaltose. As a result, It has the potential to serve as a therapeutic option for diabetes treatment.^[42] 9,12-Octadecadienoic acid (Z,Z)- exhibits substantial antioxidant activity.^[43] Methyl 4,7,10,13-hexadecatetraenoate demonstrates anti-inflammatory and antibacterial activities.^[44] Butyl propionate can be utilized in the preparation of banana essence and ether-like flavors. Moreover, it can serve as a flavoring agent in food production.^[45] Caryophyllene exhibits anti-cancer and anti-inflammatory activities. Additionally, it has the potential to relieve itching.^[46] cis- α -Bergamotene has anticancer activity.^[49] β -biphenyl has antioxidant and anticancer activities.^[50] Benzoyl

Table 1: Active substances with insect resistance, antibacterial, antioxidant or cytotoxic functions in GC-MS analysis.

Number	RT	substance
1	35.447	n-Hexadecanoic acid
2	14.654	Dodecane, 1-fluoro-
3	20.334	Melezitose
4	23.18	7-Ethyl-4-decen-6-one
5	28.547	2-Cyclohexylpiperidine
6	34.502	Hexadecanoic acid, methyl ester
7	25.132	15-Tetracosenoic acid, methyl ester, (Z)-
8	22.292	Methyl 12,13-tetradecadienoate
9	27.872	9,12-Octadecadienoic acid (Z,Z)-
10	25.82	Methyl 4,7,10,13-hexadecatetraenoate
11	10.325	Butyl propionate
12	25.545	Caryophyllene
13	25.157	cis-.alpha.-Bergamotene
14	27.108	β -biphenyl
15	8.223	Benzoyl isothiocyanate
16	26.539	Methyl 3,5-tetradecadiynoate
17	36.754	Arachidonic Acid, TBDMS derivative
18	32.995	1-heptatriol
19	34.446	Tert-Hexadecanethiol
20	35.597	Hexadecanoic acid, ethyl ester
21	6.553	3-Hexen-1-ol benzoate
22	13.065	3-Furanmethanol
23	28.553	trans-13-Octadecenoic acid
24	29.848	Octadecanoic acid, ethyl ester
25	6.072	Trifluoroethanol, TBDMS derivative
26	17.338	Alpha-l-rhamnopyranose
27	18.251	5-Thio-D-glucose
28	25.476	Thymidine
29	18.976	Thymine
30	27.434	Phenol, 3,5-bis(1,1-dimethylethyl)-
31	24.444	Copaene
32	25.832	cis-5,8,11,14,17-Eicosapentaenoic acid
33	12.446	Nonanoic acid
34	15.899	Eucalyptol

isothiocyanate has anti-cancer and antibacterial activity.^[51] Methyl 3,5-tetradecadiynoate has antibacterial and anticancer activities.^[52] Arachidonic Acid, TBDMS derivative have anticancer activity. 1-heptatriol has antifungal and anticancer activities. Tert-Hexadecanethiol has antibacterial and cytotoxic properties.^[53] Hexadecanoic acid, ethyl ester constitutes the substance responsible for the odor of the extract of red clover flowers.^[53] Compounds mainly composed of 3-Hexen-1-ol benzoate exhibit antibacterial activity.^[54] 3-

Furanmethanol has anti hepatitis B virus activity.^[55] The extract mainly composed of trans-13-Octadecenoic acid has insecticidal and anti-tumor activities.^[56] Octadecanoic acid, ethyl ester has cytotoxicity.^[58] Trifluoroethanol, TBDMS derivative can be used to make antibacterial films.^[59] Alpha-l-rhamnopyranose has cytotoxicity.^[60] 5-Thio-D-glucose has anti-tumor activity and can be used for radiation therapy.^[61] Extracts containing Thymine exhibit cytotoxicity.^[62] Hexadecanoic acid, ethyl ester can kill insects through contact

killing.^[62] Thymidine is cytotoxic and can be used as an anti AIDS drug.^[63] Phenol, 3,5-bis(1,1-dimethylethyl)- has antibacterial and anticancer activities.^[64] Trifluoroethanol, TBDMS derivative can be used to make antibacterial films.^[58] Copaene has antibacterial and bactericidal effects.^[65] cis-5,8,11,14,17-Eicosapentaenoic acid exhibits insect resistance activity.^[66] Nonanoic acid has anti-inflammatory, cardioprotective, and analgesic activities. Eucalyptol contains cytotoxic, antibacterial, antioxidant, and enzyme inhibitory activities.^[67]

4. Summary and Prospect

In summary, the flower extracts of 20 herbaceous plant species contain diverse chemical substances. The majority of flower extracts from these plants contain substances with insect-resistant, antibacterial, antioxidant, and anticancer activities. These extracts render the plants suitable for use as medicinal plants in understory intercropping systems. Moreover, they hold great potential for applications in various fields such as food, pharmaceuticals, agriculture, and cosmetics. This study therefore lays a theoretical groundwork for the comprehensive utilization of the flowers of these 20 herbaceous plant species. Especially in the flowers of these 20 herbaceous plant species, there are n-Hexadecanoic acid, Melezitose, 2-Cyclohexylpiperidine, Hexadecanoic acid, methyl ester, 9,12-Octadecadienoic acid (Z,Z)-, Caryophyllene, cis-.alpha.-Bergamotene, Benzoyl isothiocyanate, Methyl 3,5-tetradecadiynoate, and other anticancer active substances indicate that flower extracts from 20 herbaceous plant species can be used for cytotoxicity testing.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflict of Interest

The authors declare that they have no conflict of interest.

Supporting Information

Applicable.

CRedit Statement

Limin Wang: Writing – original draft, Visualization, Methodology, Conceptualization. **Wan Adibah Wan Mahari:** Writing – original draft, Visualization, Methodology, Conceptualization. **Rock Keey Liew:** Writing – review & editing, Visualization. **Guanyan Li:** Visualization. **Xiaochen Yue:** Writing – review & editing. **Haiping Gu:** Writing – review & editing, Supervision, Conceptualization. **Wanxi Peng and Xiangmeng Chen:** Methodology, Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

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