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COMPARATIVE ANALYSIS OF BIOLOGICALLY ACTIVE COMPOUNDS IN *TAGETES PATULA* L. AND *TAGETES ERECTA* L.

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The aim. *The aim of this study was to conduct a comparative analysis of biologically active compounds accumulated in two species – Tagetes patula L. and Tagetes erecta L. – in order to identify the most promising plant material for pharmaceutical development. The research focused on evaluating the qualitative and quantitative composition of free amino acids, water-soluble vitamins, flavonoids, and polysaccharides, as well as assessing their structural characteristics using titrimetric and phytochemical methods.*

Methods. *Plant raw materials consisting of inflorescences (flowers) of Tagetes patula L. and Tagetes erecta L., collected during the flowering period, were used for analysis. Free amino acids were identified and quantified using chromatographic methods. Water-soluble vitamins were determined spectrophotometrically. The flavonoid profile was established through chromatographic identification of dihydroquercetin, luteolin, rutin, rosavin, quercetin, salidroside, and cynaroside. Polysaccharides, pectic substances, and hemicelluloses were isolated, and their monosaccharide composition was assessed. Titrimetric analysis was used to determine free and methoxylated carboxyl groups and to calculate the degree of esterification of pectic substances. Comparative evaluation between the two species was carried out for all analyzed parameters.*

Results. *A total of 20 free amino acids were identified in both species, including eight essential amino acids. The total amino acid content was significantly higher in T. patula (57.053 mg/g) compared with T. erecta (38.020 mg/g). Both species contained equivalent qualitative sets of water-soluble vitamins-thiamine, riboflavin, pyridoxine, folic, nicotinic, and ascorbic acids–while T. patula demonstrated considerably higher quantitative levels. The flavonoid composition of both species was identical qualitatively; however, the total flavonoid content was markedly higher in T. patula. Polysaccharide analysis showed that pectic substances and hemicelluloses predominated in both species, with lower levels of water-soluble polysaccharides. The degree of esterification indicated highly esterified pectins, with T. patula containing higher levels of both free and methoxylated carboxyl groups.*

Discussion. *The results indicate that Tagetes patula L. contains substantially higher quantities of key biologically active substances – including amino acids, vitamins, flavonoids, and structurally active polysaccharides – compared to Tagetes erecta L. The richer phytochemical profile of T. patula supports its greater pharmacological potential, including anti-inflammatory, antioxidant, antimicrobial, gastroprotective, and anthelmintic properties traditionally attributed to Tagetes species. Structural analysis of polysaccharides further demonstrates their suitability for use as bioactive excipients in dosage forms.*

Conclusions. *Comparative phytochemical evaluation of Tagetes patula L. and Tagetes erecta L. demonstrated that T. patula accumulates significantly higher levels of biologically active compounds. Based on the obtained data, Tagetes patula L. can be considered the optimal species for use as medicinal plant raw material in the development of modern phytopharmaceuticals with pronounced therapeutic activity*

Keywords: *Tagetes patula L., Tagetes erecta L., biologically active compounds, amino acids, flavonoids, water-soluble vitamins, polysaccharides, pectins, phytochemical analysis, medicinal plant raw materials*

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1. Introduction

Medicinal plant raw materials are widely used in modern pharmaceutical production due to their accessibility, low cost, and the absence of significant side effects. They serve as valuable sources for obtaining numerous preparations with a broad spectrum of pharmacological activities. In this regard, the search for new medicinal plants that may serve as raw material sources for the development of safe and effective pharmaceutical products remains highly relevant. One such promising group of plants is *Tagetes* (marigolds), which are characterized by a high content of carotenoids, flavonoids, and other biologically active compounds. Previous phytochemical studies of Tagetes species have been extensively carried out by Ukrainian researchers, particularly Berdei T.S., who investigated the content of flavonoids and hydroxycinnamic acids in Tagetes plants. It is known, for example, that the flavonoid **patuletin**, isolated from the flowers of *Tagetes patula*, reduces capillary permeability, exhibits hypotensive and diuretic effects, and demonstrates vitamin P activity [1, 2].

In traditional medicine, primarily the inflorescences of marigolds are used. These contain essential oils, phenolic compounds, and various biologically active substances. The essential oil of *Tagetes* is recommended for use in conditions such as neuroses and depression. Baths prepared from marigold decoctions have a calming effect on the nervous system, help relieve stress, reduce anxiety, and restore emotional balance. The essential oil also exhibits strong antiseptic and antimicrobial properties. Aqueous infusions of marigold flowers are applied topically for inflammatory skin conditions and are used as diaphoretic, diuretic, and anthelmintic remedies. Traditionally, marigolds have been used as a treatment for fever, night blindness, external and internal bleeding, cystitis, and insect stings. Fresh marigold juice is known to alleviate bee and wasp stings. The plant is also believed to support liver and kidney function and serves as an effective analgesic in inflammatory conditions. Infusions of marigolds are thought to stimulate metabolism and, at early stages of diabetes mellitus, may help reduce blood glucose levels, exerting a positive effect on pancreatic function [3, 4].

Infusions and decoctions prepared from the flowers of *Tagetes* display anti-inflammatory, antibacterial, antioxidant, diaphoretic, diuretic, sedative, ophthalmoprotective, gastroprotective, and anthelmintic properties due to the presence of various biologically active substances such as terpenoids, vitamins, macro- and microelements, carotenoids, alkaloids, flavonoids, phytoncides, and organic acids [5, 6].

To introduce *Tagetes*-based preparations into medical practice, it is necessary to conduct more in-depth studies of the chemical composition of marigold raw materials and to investigate the effects of the major biologically active compounds on biochemical processes.

The novelty of this study lies in the comprehensive comparative analysis of biologically active compounds in *Tagetes patula* L. and *Tagetes erecta* L. cultivated in Uzbekistan under identical experimental conditions. Unlike previous studies, this work focuses on plants grown in a specific geographical region, allowing evaluation of the influence of regional conditions on the accumulation of biologically active compounds.

The aim of the research. In order to select the most suitable *Tagetes* species for use as medicinal plant raw material, a comparative analysis was conducted of the biologically active compounds present in *Tagetes patula* L. and *Tagetes erecta* L., which are responsible for their pharmacological effects.

2. Materials and methods

Plant raw materials consisting of inflorescences (flowers) of *Tagetes patula* L. and *Tagetes erecta* L., collected during the flowering period, were used for analysis. The studied plants were cultivated in the Tashkent Botanical Garden (Tashkent, Uzbekistan) under standard agronomic conditions.

Identification and quantitative determination of free amino acids, water-soluble vitamins, and flavonoids were performed using high-performance liquid chromatography (HPLC). The analysis was carried out on an Agilent Technologies 1200 chromatograph equipped with a diode-array detector (DAD) and a Discovery HS C18 column (75 × 4.6 mm) [7, 8].

Paper chromatography was applied for the analysis of monosaccharide composition of polysaccharide hydrolysates. Chromatography was performed on Filtrak-FN 13 and FN 18 paper (Germany) using the solvent system n-butanol–pyridine–water (6:4:3). Chromatograms were developed with acidic aniline phthalate (5 min at 100°C) and 5% urea solution [9].

Gas chromatography (GC) was used for the analysis of polysaccharide hydrolysates. The analysis was conducted on a GC Plus 2010 chromatograph under the following conditions: injector temperature 250°C; detector temperature 250°C; column temperature 230°C; total gas flow 60 mL/min; column flow 0.89 mL/min; carrier gas – nitrogen; column – Rxi-624Sil MS, length 3 m, internal diameter 0.25 mm.

Determination of heavy metals was carried out using an ICP-MS NEXION-2000 mass-spectrometric system. Sample preparation was performed by microwave digestion in Teflon digestion vessels. The following reagents were used: multielement standard No. 3 (29 elements), mercury standard (Hg), nitric acid (chemically pure), hydrogen peroxide (chemically pure), bidistilled water, and high-purity argon gas (99.995%) [10].

3. Results

For the comparative evaluation of free amino acids in the plant raw materials of *Tagetes patula* L. and *Tagetes erecta* L., the study was carried out using liquid extracts. Each obtained liquid extract was centrifuged to remove proteins and peptides that could interfere with the free amino acid analysis. To 1 mL of the extract, an equal volume of 20% trichloroacetic acid was added. Phenylthiocarbamyl (PTC) derivatives of amino acids were obtained by reaction with phenylisothiocyanate according to the method of Steven A. and Cohen Daniel.

Identification of the amino acid derivatives was performed by HPLC (Table 1). The mobile phase consisted of:

– **Solution A:** 0.14 M sodium acetate with 0.05% triethylamine, pH 6.4;

– **Solution B:** acetonitrile.

Table 1

Gradient Program for HPLC Analysis

Step	%B (Acetonitrile)	Time interval (min)
I	1 → 6%	0.0–2.5
II	6 → 30%	2.51–40.0
III	30 → 60%	40.1–45.0
IV	60 → 60%	45.1–50.0
V	60 → 0%	50.1–55.0

Note: Flow rate: 1.2 mL/min; detection: UV at 269 nm; column temperature: 25°C.

The obtained comparative data on the free amino acid composition of *Tagetes patula* L. and *Tagetes erecta* L. are presented in Table 2. The chromatogram of the standard amino acid mixture is shown in Fig. 1. Chromatograms of free amino acids in *Tagetes patula* L. and *Tagetes erecta* L. are presented in Fig. 2, 3, respectively.

As seen from the table, both *Tagetes* species contain the same qualitative composition of 20 amino acids, 8 of which are essential. However, the total quantitative content of free amino acids was significantly higher in *Tagetes patula* L. (57.053 mg/g) compared to *Tagetes erecta* L. (38.020 mg/g).

To determine the water-soluble vitamins by high-performance liquid chromatography (HPLC), approximately 5 g of the precisely weighed plant material was placed into a 300 mL flask, followed by the addition of 50 mL of 40% ethyl alcohol. The flask was connected to a reflux condenser and heated for 1 hour with constant stirring. After cooling to room temperature, the mixture was stirred for an additional 2 hours. The extract was then allowed to settle and filtered. The plant residue was extracted twice more with 25 mL portions of 40% ethyl alcohol. All filtrates were combined, transferred into a 100 mL volumetric flask, and brought to volume with 40% ethyl alcohol.

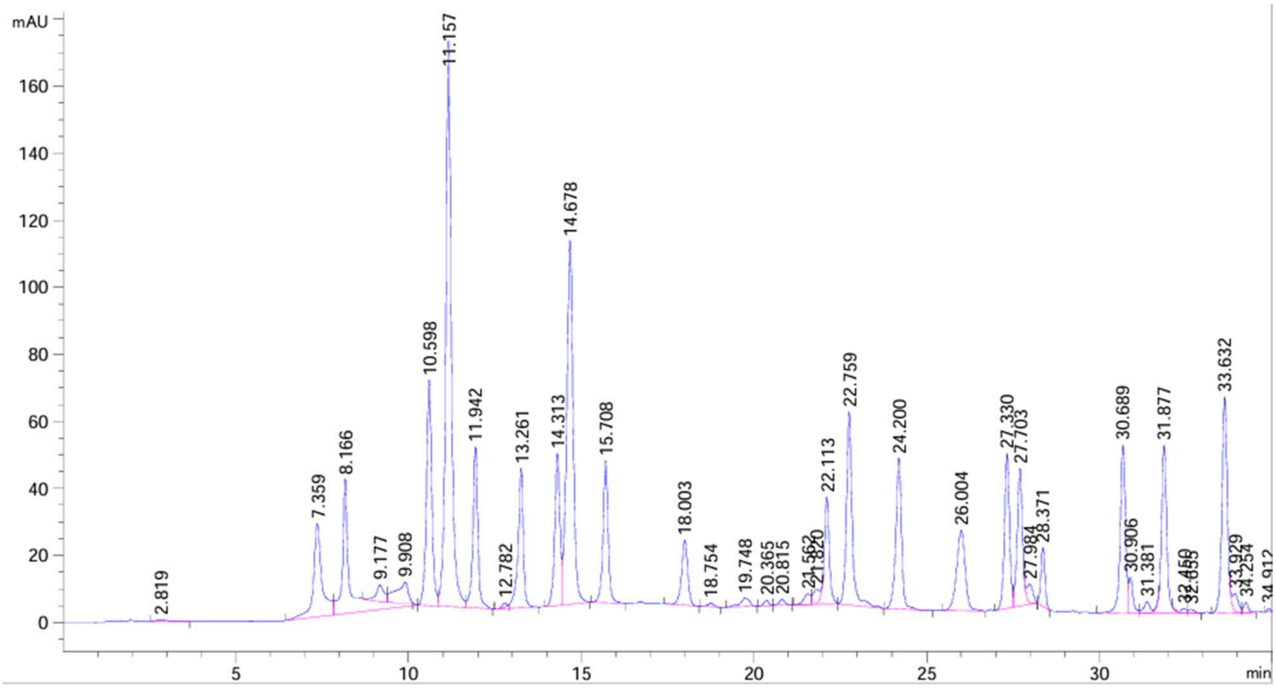


Fig. 1. Chromatogram of the standard amino acid mixture

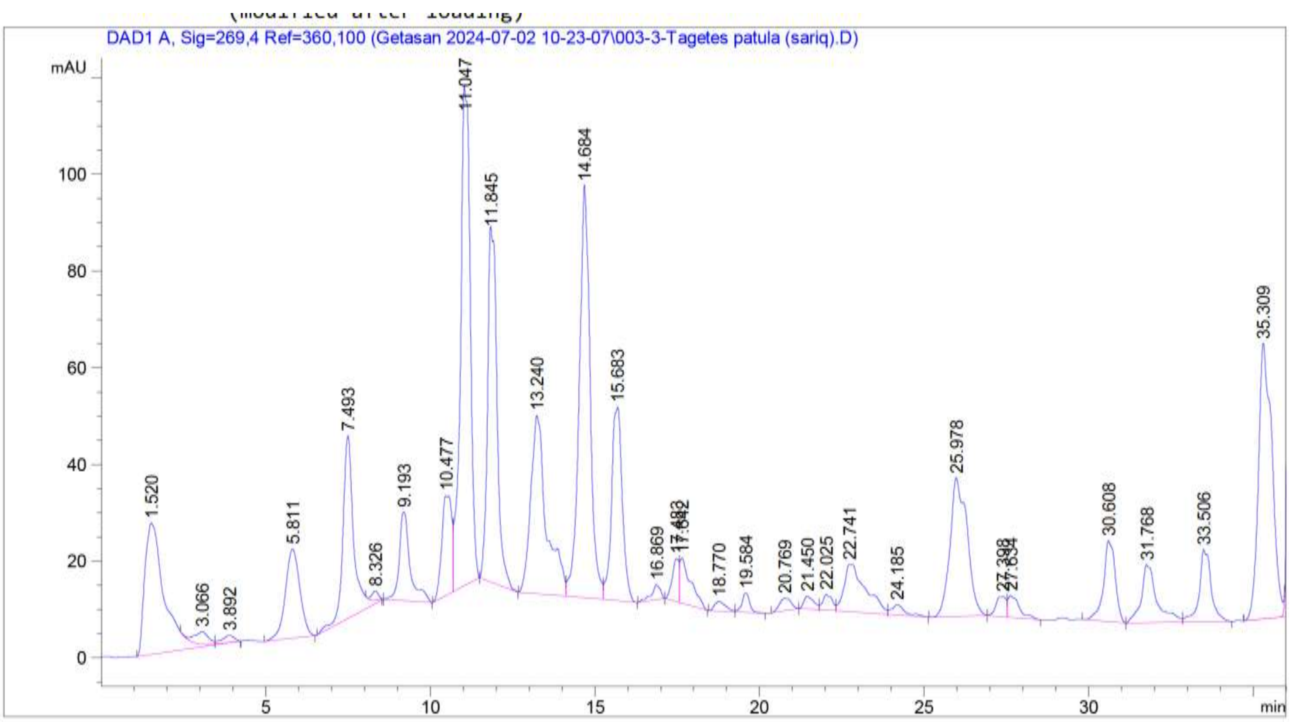


Fig. 2. Chromatogram of free amino acids in the medicinal plant raw material of *Tagetes patula* L.

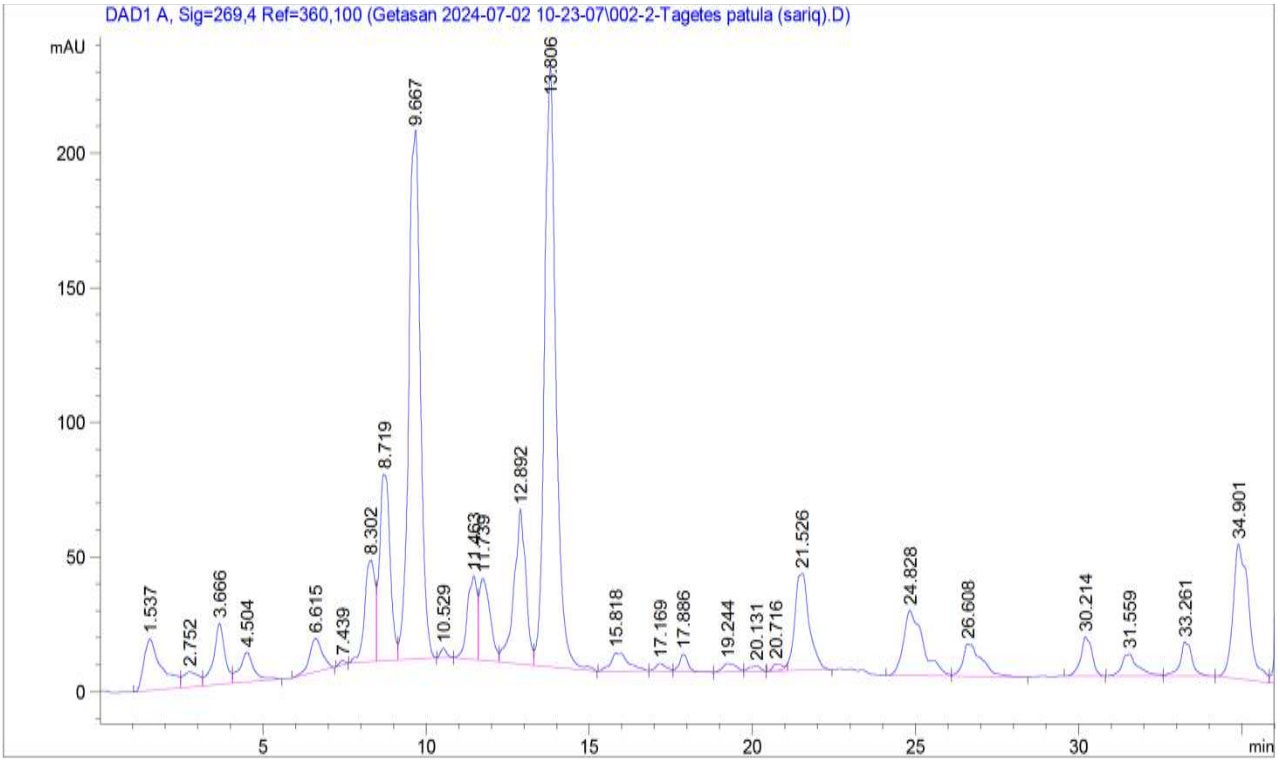


Fig. 3. Chromatogram of free amino acids in the medicinal plant raw material of *Tagetes erecta* L.

Table 2

Comparative quantitative composition of free amino acids in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L.

No.	Amino acid name	*Tagetes patula* L. content, mg/g	*Tagetes erecta* L. content, mg/g
1	Aspartic acid	1.054	1.776
2	Glutamic acid	1.091	2.705
3	Serine	2.640	1.344
4	Glycine	3.942	2.333
5	Asparagine	7.764	3.652
6	Glutamine	5.229	1.399
7	Cysteine	6.985	4.749
8	Threonine*	2.276	4.783
9	Arginine	4.387	3.720
10	Alanine	8.458	3.064
11	Proline	1.103	4.036
12	Tyrosine	0.387	0.269
13	Valine*	3.407	0.190
14	Methionine*	1.491	0.197
15	Histidine	3.069	0.380
16	Isoleucine*	0.633	0.222
17	Leucine*	0.808	0.357
18	Tryptophan*	1.087	1.275
19	Phenylalanine*	0.584	0.807
20	Lysine*	0.659	0.761
Total amino acids		57.053	38.020
Total essential amino acids*		10.945	(not provided)

*Note: * – essential amino acids.*

The resulting solution was centrifuged for 10 minutes at 7000 rpm, and the supernatant was used for analysis.

For each water-soluble vitamin, working standard solutions with a concentration of 1 mg/mL were prepared. For this purpose, an accurately weighed 50.0 mg portion of each vitamin standard was placed into a 50 mL volumetric flask, dissolved in 40% ethyl alcohol, and brought to volume with the same solvent. For chromatographic determination, an eluent system consisting of an acetate buffer and acetonitrile was used.

The chromatogram of the standard vitamin mixture is shown in Fig. 4. The chromatograms of the vitamin composition in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. are presented in Fig. 5, 6, respectively.

As seen from the chromatograms, the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. contain the following identified vitamins: vitamin C, B_3, B_1, B_6, B_9, and B_{12}.

Both *Tagetes* species contain the same qualitative set of water-soluble vitamins, including thiamine, riboflavin, pyridoxine, folic acid, nicotinic acid, and ascorbic acid, without qualitative differences between them. However, as shown in Table 3, the quantitative content of water-soluble vitamins in *Tagetes patula* L. is significantly higher than in *Tagetes erecta* L.

For the comparative evaluation of the quantitative flavonoid content in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L., flavonoids were extracted from accurately weighed portions of finely ground plant material of both samples by triple extraction with 70% ethanol until complete extraction of flavonoids was achieved. The obtained extracts were combined, filtered, placed into a 100 mL volumetric flask, and brought to volume with 70% ethanol. To precipitate ballast substances, the extract was centrifuged for 20–30 minutes at a speed of 6000–8000 rpm. The upper layer of each centrifuged sample was used for identification and quantitative determination of flavonoids.

Comparative evaluation of the flavonoid composition of the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. showed that their qualitative profiles do not differ. The following flavonoids were identified in both species: dihydroquercetin, luteolin, rutin, rosavin, quercetin, salidroside, and cynaroside. However, the quantitative content of flavonoids in *Tagetes patula* L. was found to be significantly higher than in *Tagetes erecta* L.

A phosphate buffer–acetonitrile system was used as the eluent. The quantitative data on the flavonoid content in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. are presented in Table 4.

Table 3

Comparative quantitative composition of water-soluble vitamins in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L.

No.	Vitamin	*Tagetes patula* L. concentration, mg/g	*Tagetes erecta* L. concentration, mg/g
1	B_1 (Thiamine)	1.37	0.89
2	B_2 (Riboflavin)	15.36	7.77
3	B_6 (Pyridoxine)	23.72	5.95
4	B_9 (Folic acid)	9.15	2.85
5	PP (Vitamin B_3 / Niacin)	1.08	0.19
6	C (Ascorbic acid)	11.60	1.21

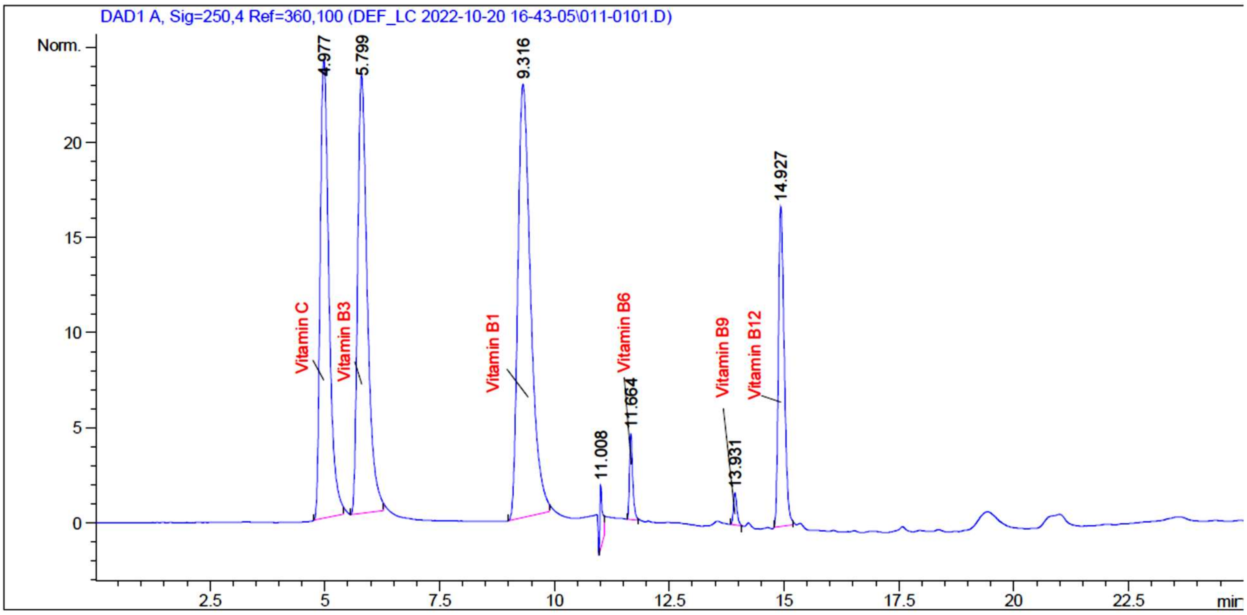


Fig. 4. Chromatogram of the standard vitamin mixture

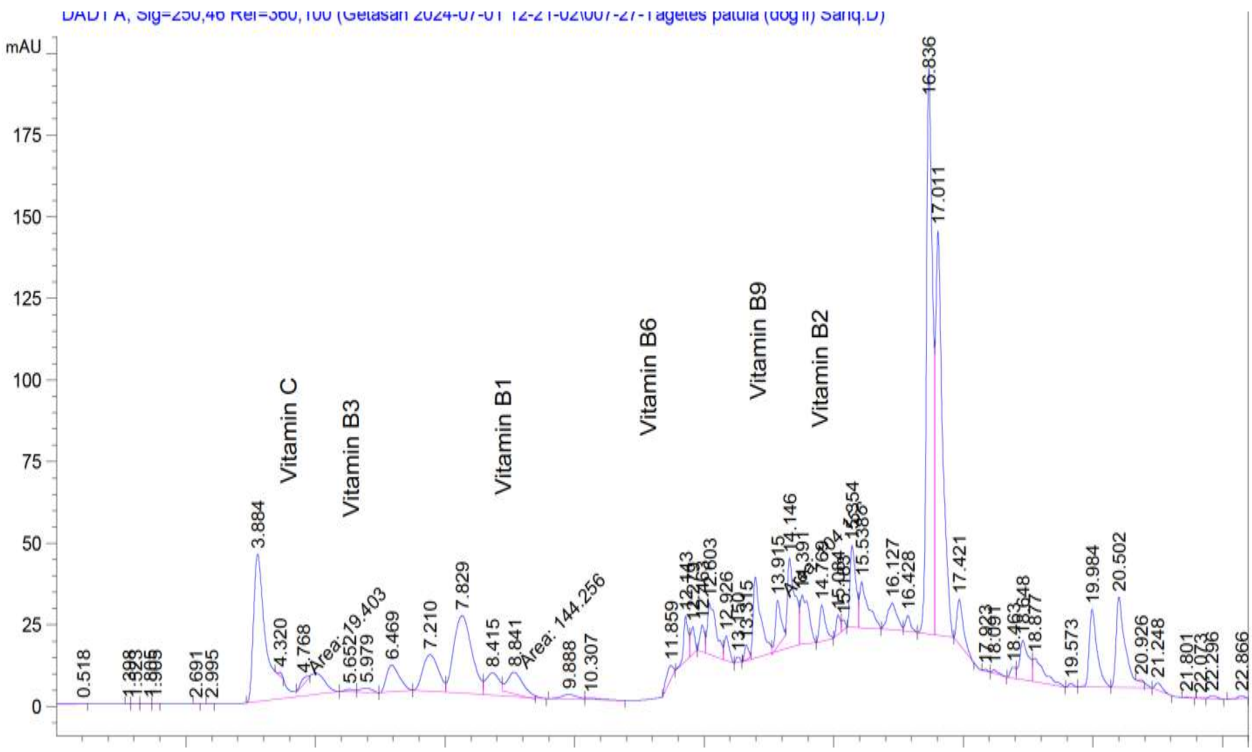
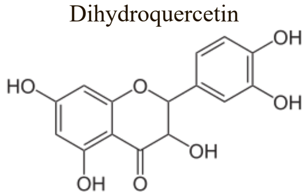
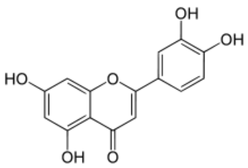
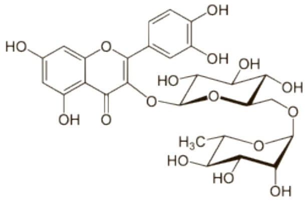
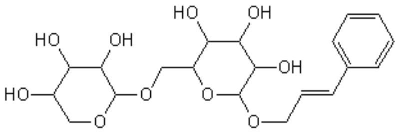
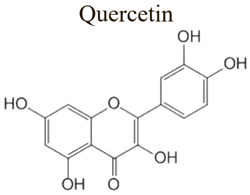
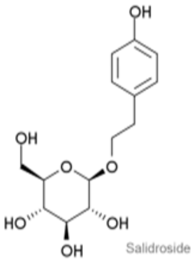
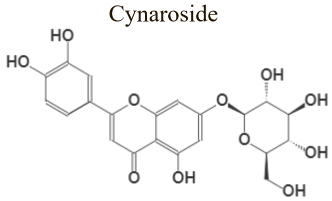


Fig. 5. Chromatogram of the vitamin composition of *Tagetes patula* L. raw material

Table 4

Comparative quantitative composition of flavonoids in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L.

No.	Flavonoids	*Tagetes patula* L. concentration, mg/g	*Tagetes erecta* L. concentration, mg/g
1	Dihydroquercetin 	1.78	0.96
2	Luteolin 	0.28	0.24
3	Rutin 	0.56	0.52
4	Rosavin 	1.84	1.24
5	Quercetin 	11.3	6.3
6	Salidroside 	1.62	0.67
7	Cynaroside 	5.1	2.1

To identify and compare the quantitative content of water-soluble polysaccharides (WSP), pectic substances (PS), and hemicelluloses, the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. were subjected to inactivation as follows: 100 g of finely ground raw material from each sample was extracted twice with 200 mL of boiling 82% ethanol for 1.5 hours. The alcoholic extracts were separated by filtration, combined, evaporated, and analyzed by paper chromatography using the solvent system *n-butanol–pyridine–water* (6:4:3). Glucose was identified using acidic aniline phthalate as the developer (5 min, 100°C), while fructose and sucrose were visualized using a 5% urea solution.

The content of uronic anhydride in pectic substances was determined using the carbazole method.

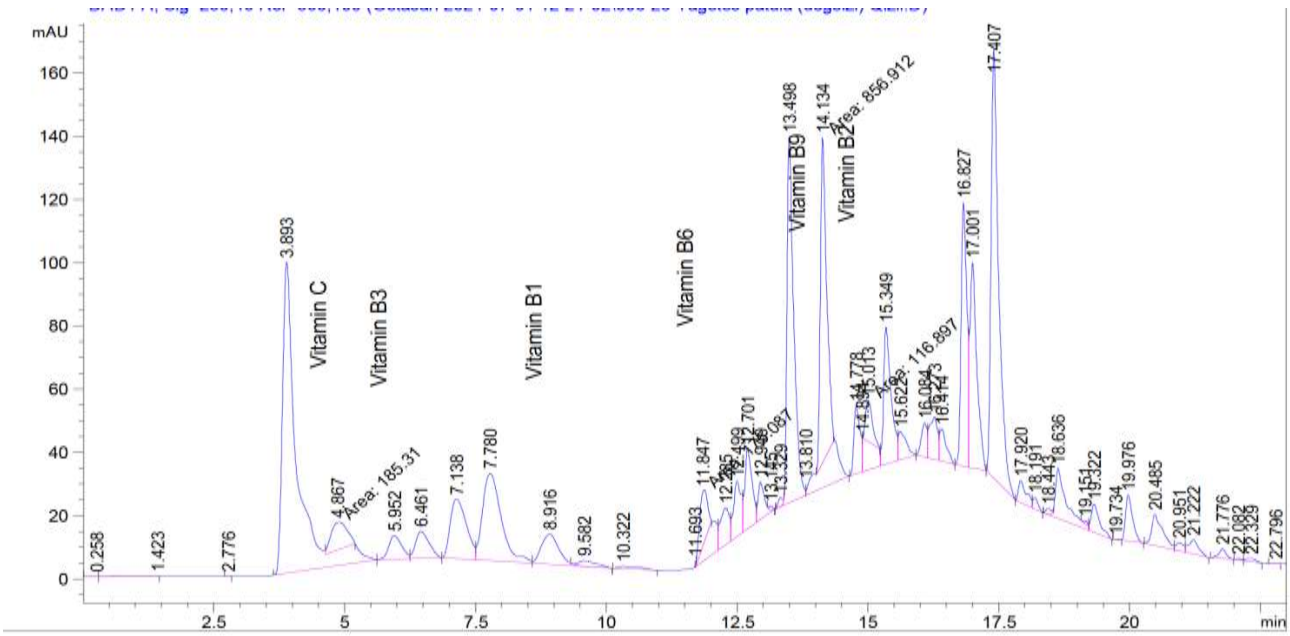


Fig. 6. Chromatogram of the vitamin composition of *Tagetes erecta* L. raw material

To isolate water-soluble polysaccharides, the remaining plant residue was treated with water for 3 hours under continuous stirring at hydromodules 1:8 and 1:5. The extracts were separated, evaporated, and precipitated with alcohol. The resulting precipitate was filtered, washed, and dried with ethanol. A comparative analysis of WSP yields is presented in Table 5.

Table 5

Comparative quantitative composition of water-soluble polysaccharides in the raw materials of T*agetes patula* L. and *Tagetes erecta* L.

No.	Type of carbohydrate	Yield, %	Monosaccharide composition	UAc, %	Viscosity (ηrel), s (0.5% H_2O)
			Gal	Glc	Ara
Tagetes patula L.					
1	WSP (Water-soluble polysaccharides)	3.5	2.0	1.8	3.0
2	PS (Pectic substances)	5.5	2.5	1.0	3.0
3	HC (Hemicelluloses)	8.3	2.0	1.5	3.0
Tagetes erecta L.					
4	WSP (Water-soluble polysaccharides)	3.6	3.0	2.0	4.0
5	PS (Pectic substances)	8.2	3.3	2.2	4.5
6	HC (Hemicelluloses)	14.7	2.0	1.0	3.0

The data presented in the Table 5 show that the predominant polysaccharides in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. are pectic substances (PS) and hemicelluloses (HC). Water-soluble polysaccharides (WSP) are present in smaller amounts. The isolated WSP are amorphous brown powders that dissolve well in water. Aqueous solutions of WSP from *Tagetes patula* L. and *Tagetes erecta* L. give a positive reaction for starch.

After the isolation of water-soluble polysaccharides, the remaining plant residue was extracted with a mixture of 0.5% oxalic acid and ammonium oxalate solutions (1:1) at 75°C, twice, for 1.5 hours, at hydromodules 1:4 and 1:2. The extracts were combined, evaporated, dialyzed, and precipitated with a twofold volume of ethanol. The precipitate was separated and dried as described for the WSP. The yield of PS is presented in Table 4.

To isolate hemicelluloses, the remaining plant residue was extracted with a 5% alkali solution (250 mL) at room temperature for 2 hours under continuous stirring. The alkaline extract was separated, neutralized with CH_3COOH, dialyzed, evaporated, and precipitated with ethanol. The precipitate was filtered, washed, and dried with ethanol. The yields of hemicelluloses are shown in Table 4.

Water-soluble polysaccharides, pectic substances, and hemicelluloses were extracted and characterized from the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. Their monosaccharide composition was established.

Complete acid hydrolysis of the polysaccharides was carried out at 100°C:

– WSP were hydrolyzed with 1 N H_2SO_4 for 8 hours;

– PS and HC were hydrolyzed with 2 N H_2SO_4 for 24 hours.

The hydrolysates were neutralized with $BaCO_3$, deionized using KU-2 (H^+) cation-exchange resin, evaporated, and analyzed chromatographically.

The isolated WSP were amorphous brown powders readily soluble in water. Aqueous solutions of WSP from *Tagetes patula* L. and *Tagetes erecta* L. gave a positive starch reaction.

The results of complete acid hydrolysis followed by paper chromatography revealed that the WSP of *Tagetes patula* L. and *Tagetes erecta* L. contain galactose, glucose, arabinose, xylose, and uronic acids. According to their monosaccharide profiles, the polysaccharides are heterogeneous and consist of both acidic and neutral monosaccharides.

The content of uronic acids was determined by the carbazole method.

The pectic substances contained in the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. are amorphous cream-colored powders, well soluble in water, forming viscous solutions that give a blue coloration with iodine solution, indicating the presence of starch-type polysaccharides. Aqueous solutions of PS from the aerial part show a high relative viscosity.

The pectic substances are characterized by the same monosaccharide composition: galactose, glucose, arabinose, xylose, rhamnose, and uronic acids.

By titrimetric analysis, the contents of free carboxyl groups (Cs) and methoxylated carboxyl groups (Cm) were determined, which allowed calculating the degree of esterification (DE). The obtained values classify the studied pectic substances as highly esterified (Table 6).

Table 6

Comparative evaluation of the physicochemical parameters of pectic substances from the raw materials of *Tagetes patula* L. and *Tagetes erecta* L.

Pectic substances	Titrimetric parameters, %			
	Cs (free carboxyl groups)	Cm (methoxylated carboxyl groups)	Ct (total carboxyl groups)	DE (degree of esterification)
Tagetes patula L.	25.2	16.2	41.4	39.0
Tagetes erecta L.	2.60	14.2	40.8	31.0

Hemicelluloses (HC) are brown powders that dissolve well in dilute alkaline solutions. Their monosaccharide composition consists of both acidic and neutral monosaccharides: galactose, glucose, arabinose, xylose, and uronic acids, while rhamnose is present in trace amounts.

4. Discussion

The comparative phytochemical analysis demonstrated clear quantitative differences between *Tagetes patula L.* and *Tagetes erecta L.*, despite their similar qualitative profiles. While previous studies mainly focused on individual phytochemical groups or a single *Tagetes* species, the present work provides a comprehensive comparative evaluation of two widely used species under identical analytical conditions, which represents a key distinction from earlier investigations.

Earlier reports on *Tagetes patula L.* primarily emphasized its flavonoid and carotenoid composition or isolated biological activities without parallel comparison to *T. erecta* [11–13]. In contrast, the present study simultaneously analyzed free amino acids, water-soluble vitamins, flavonoids, and polysaccharide fractions, allowing a more integrated assessment of the biochemical potential of both species.

Amino acid profiling revealed that both species contain 20 amino acids, including eight essential ones, which is in general agreement with previously published data on *Tagetes* species. However, quantitative data on the total free amino acid content of *T. erecta L.* are scarce in the literature, and the demonstrated 1.5-fold higher accumulation in *T. patula L.* provides new comparative insight into nitrogen metabolism differences between these species [14–16].

Previous studies have reported the presence of antioxidant vitamins and phenolic compounds in *Tagetes* species but often lacked quantitative comparison of water-soluble vitamins between *T. patula* and *T. erecta*. The significantly higher levels of riboflavin, pyridoxine, folic acid, and ascorbic acid identified in *T. patula* in the present work highlight its enhanced antioxidant potential, extending earlier qualitative observations [17–19].

The flavonoid composition identified in this study is consistent with earlier phytochemical investigations of *T. patula*; however, most published works reported flavonoid profiles without direct quantitative comparison between species. The substantially higher flavonoid concentrations observed in *T. patula* strengthen the rationale for its preferential pharmaceutical use and represent an important quantitative advancement over previous reports [20].

Regarding polysaccharides, available literature on *Tagetes* species mainly describes the presence of polysaccharide fractions without detailed structural characterization. The present study differs by providing a comparative analysis of water-soluble polysaccharides, pectic substances, and hemicelluloses, including monosaccharide composition and degree of esterification. The higher uronic acid content and degree of esterification of pectins in *T. patula* indicate improved functional properties, which have not been sufficiently addressed in earlier studies.

Overall, the novelty of this study lies in the systematic and parallel comparison of two *Tagetes* species using identical experimental approaches. This integrated evaluation demonstrates that *Tagetes patula L.* possesses a distinctly superior biochemical profile compared with *Tagetes erecta L.*, providing new evidence for its selection as medicinal plant raw material in phytopharmaceutical development.

Practical relevance. The obtained results can be used to select *Tagetes patula* L. as a promising medicinal plant raw material for the development of phytopharmaceutical products. The data may be applied in the standardization, quality control, and formulation of herbal preparations with antioxidant and anti-inflammatory activity.

Research limitations. The study was limited to plant material collected from one geographical region and one vegetation period and focused on phytochemical analysis only, without pharmacological or clinical evaluation.

Prospects for further research. Further studies should investigate seasonal and geographical variability, conduct pharmacological and toxicological evaluations, and develop standardized extracts and dosage forms based on *Tagetes patula* L.

The obtained results indicate that the accumulation of biologically active compounds in Tagetes species is significantly influenced by geographical and environmental conditions. The present study provides new data on *Tagetes patula* L. and *Tagetes erecta* L. cultivated in Uzbekistan, which has not been sufficiently reported in previous studies. The higher content of biologically active substances in *Tagetes patula* L. highlights its potential as a promising source of medicinal plant raw materials for the development of phytopharmaceutical products.

5. Conclusion

A comparative assessment of the free amino acid composition of the raw materials of *Tagetes patula* L. and *Tagetes erecta* L. was carried out. A total of 20 amino acids were identified and quantified, 8 of which–threonine, valine, methionine, isoleucine, leucine, tryptophan, phenylalanine, and lysine–are essential. However, the total quantitative content of free amino acids was significantly higher in *Tagetes patula* L. (57.053 mg/g) compared to *Tagetes erecta* L. (38.020 mg/g).

Both *Tagetes* species share the same qualitative set of water-soluble vitamins, including thiamine, riboflavin, pyridoxine, folic acid, nicotinic acid, and ascorbic acid. However, the quantitative content of these vitamins in *Tagetes patula* L. was considerably higher, as shown in Table 2.

Comparative evaluation of the flavonoid composition revealed that both species contain the same flavonoids–dihydroquercetin, luteolin, rutin, rosavin, quercetin, salidroside, and cynaroside. Nevertheless, the total flavonoid content was much higher in *Tagetes patula* L. than in *Tagetes erecta* L.

Water-soluble polysaccharides (WSP), pectic substances (PS), and hemicelluloses (HC) were isolated and characterized from the raw materials of both species. Their monosaccharide composition was determined, showing that the predominant polysaccharides in *Tagetes patula* L. and *Tagetes erecta* L. are PS and HC, whereas WSP are present in smaller quantities.

The isolated WSP were amorphous brown powders, readily soluble in water. Aqueous WSP solutions from both species produced a positive starch reaction. Results of complete acid hydrolysis followed by paper chromatography confirmed the presence of galactose, glucose, arabinose, xylose, and uronic acids in the WSP of both *Tagetes* species. These polysaccharides are heterogeneous and consist of acidic and neutral monosaccharides.

The pectic substances isolated from *Tagetes patula* L. and *Tagetes erecta* L. were amorphous cream-colored powders, well soluble in water, forming viscous solutions that produced a blue coloration with iodine, indicating the presence of starch-type polysaccharides. Aqueous PS solutions of the aerial part showed a high relative viscosity.

The pectic substances of both species had identical monosaccharide compositions: galactose, glucose, arabinose, xylose, rhamnose, and uronic acids.

Titrimetric analysis determined the content of free carboxyl groups (Cs) and methoxylated carboxyl groups (Cm), enabling the calculation of the degree of esterification (DE), which classified the pectic substances as highly esterified. However, the quantitative content of both free and methoxylated carboxyl groups was much higher in *Tagetes patula* L. than in *Tagetes erecta* L.

Thus, the analysis and comparative evaluation of the accumulation of biologically active substances in local *Tagetes patula* L. and *Tagetes erecta* L. demonstrated that *Tagetes patula* L. is the most optimal species for use as medicinal plant raw material in the development of pharmaceutical preparations.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this article.

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Data availability

Data will be made available on reasonable request from the corresponding author.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the submitted work.

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Authors' contributions

Toshtemirova Charos: Conceptualization, Methodology, Investigation, Writing – original draft; **Zuparova Zulfiya:** Conceptualization, Supervision, Methodology, Writing – review & editing; **Ismoilova Guzaloy:** Formal analysis, Validation, Data curation; **Pulatova Dildora Kahramonovna:** Investigation, Resources, Methodology; **Akhmadova Gulrano:** Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing, Project administration; **Jalilov Utkirbek Mamaraimovich:** Methodology, Formal analysis, Validation; **Madatova Nazira Abdugaffarovna:** Supervision, Writing – review & editing.

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