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PHYTOCHEMICAL ANALYSIS OF EXTRACTIVE SUBSTANCES AND BIOLOGICALLY ACTIVE COMPOUNDS OF *VERBASCUM THAPSUS* L.

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Abstract. Biologically active compounds that have great pharmacological potential are largely obtained through medicinal plants. *Verbascum thapsus* L. has received scientific attention among them because of its varied phytochemical structure and extensive biological activity. The current research was conducted to examine the phytochemical composition of *V. thapsus* roots collected in the Almaty region of Kazakhstan. Spectrophotometric, permanganatometric, and colorimetric determination of biologically active classes of compounds were performed to quantitative determination. The atomic emission spectroscopy, gas chromatography and high-performance liquid chromatography techniques was also applied. Phytochemical analysis revealed that the content of moisture was 6.26%, total ash was 5.31% and extractive substances was 38.83%, which were in confirmation of the quality of the plant material. The quantitative analysis demonstrated the existence of significant content of the secondary metabolites (polysaccharides – 6.35%, tannins – 4.52%, flavonoids – 2.35%, saponins – 2.19%, alkaloids – 1.39%). The mineral analysis showed high level of such essential macroelements as potassium (1189.98 μg/mL), calcium (796.69 μg/mL) and magnesium (220.12 μg/mL) and trace elements, including the following: iron (15.4503 μg/mL), zinc (2.9316 μg/mL), and manganese (2.2882 μg/mL). Fatty acid analysis revealed the existence of saturated (42.288%), monounsaturated (22.190%), and polyunsaturated (34.397%) fatty acids with palmitic, oleic, and linoleic acids being the dominant ones. The HPLC result showed that the vitamin C content was 33.483 mg/100 g, and the

vitamin E was 0.665 mg/100 g. The obtained results indicate that *V. thapsus* growing in the Almaty region contains biologically active compounds, essential mineral elements, fatty acids, and antioxidant vitamins. These findings expand the existing knowledge on the phytochemical composition of this species in Kazakhstan. However, further biological and pharmacological studies are required to confirm its practical application in pharmaceutical and nutraceutical products.

Keywords: phytochemistry, biological active compounds, mineral composition, vitamins, fatty acids, GC, HPLC

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VERBASCUM THAPSUS L. ӨСІМДІГІНІҢ ЭКСТРАКТИВТІ ЗАТТАРЫ МЕН БИОЛОГИЯЛЫҚ БЕЛСЕНДІ ҚОСЫЛЫСТАРЫНЫҢ ФИТОХИМИЯЛЫҚ ТАЛДАУЫ

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Аннотация. Фармакологиялық әлеуеті жоғары биологиялық белсенді қосылыстардың негізгі көзі ретінде дәрілік өсімдіктер қарастырылады. Олардың ішінде *Verbascum thapsus* L. өсімдігі өзінің фитохимиялық құрамымен және кең ауқымды биологиялық белсенділігімен ғылыми қызығушылық тудырады. Бұл зерттеу Қазақстанның Алматы облысында өсетін *V. thapsus* өсімдігінің фитохимиялық құрамын зерттеуге бағытталған. Биологиялық белсенді қосылыстар кластарын сандық анықтау үшін спектрофотометриялық, перманганатометриялық және колориметриялық әдістер қолданылды. Сонымен қатар атомдық-эмиссиялық спектроскопия, газды хроматография және жоғары тиімді сұйықтықтық хроматография әдістері пайдаланылды. Фитохимиялық талдау нәтижелері бойынша ылғал мөлшері 6.26%, жалпы күл мөлшері 5.31%, ал экстрактивті заттардың үлесі 38.83% екені анықталды, бұл өсімдік шикізатының сапасын растайды. Сандық талдау нәтижесінде екінші реттік метаболиттердің айтарлықтай мөлшері анықталды: полисахаридтер – 6.35%, дубильді заттар – 4.52%, флавоноидтар – 2.35%, сапониндер – 2.19%, алкалоидтар – 1.39%. Минералдық

құрамды зерттеу маңызды макроэлементтердің жоғары мөлшерін көрсетті: калий (1189.98 мкг/мл), кальций (796.69 мкг/мл) және магний (220.12 мкг/мл). Сонымен қатар микроэлементтер де анықталды, олардың ішінде темір (15.4503 мкг/мл), мырыш (2.9316 мкг/мл) және марганец (2.2882 мкг/мл). Май қышқылдарының талдауы нәтижесінде қаныққан (42.288%), моноқанықпаған (22.190%) және полиқанықпаған (34.397%) май қышқылдарының бар екені анықталды, олардың ішінде пальмитин, олеин және линол қышқылдары басым болды. ЖТСХ талдауы бойынша С дәруменінің мөлшері 33.483 мг/100 г, ал Е дәруменінің мөлшері 0.665 мг/100 г екені анықталды. Алынған нәтижелер Алматы өңірінде өсетін *V. thapsus* өсімдігінің биологиялық белсенді қосылыстарға, маңызды минералдарға, май қышқылдарына және антиоксиданттық дәрумендерге бай екенін көрсетеді. Бұл нәтижелер аталған түрдің фитохимиялық құрамы туралы бұрынғы мәліметтерді толықтырып, оны фармацевтикалық және нутрицевтикалық мақсаттарда қолдануға перспективалы өсімдік шикізаты ретінде қарастыруға мүмкіндік береді. Аталған зерттеу нәтижелері *V. thapsus* негізінде өсімдік текті дәрілік препараттар және табиғи антиоксиданттық өнімдер әзірлеуде қолданылуы мүмкін.

Түйін сөздер: Фитохимия, биологиялық белсенді заттар, минералдық құрам, дәрумендер, май қышқылдары, ГХ, ЖТСХ

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ФИТОХИМИЧЕСКИЙ АНАЛИЗ ЭКСТРАКТИВНЫХ ВЕЩЕСТВ И БИОЛОГИЧЕСКИ АКТИВНЫХ СОЕДИНЕНИЙ РАСТЕНИЯ *VERBASCUM THAPSUS* L.

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Аннотация: Биологически активные соединения с высоким фармакологическим потенциалом в значительной степени получают из лекарственных растений. Среди них *Verbascum thapsus* L. привлекает внимание исследователей благодаря богатому фитохимическому составу и широкому спектру биологической активности. Целью настоящего исследования являлось изучение фитохимического состава *Verbascum thapsus* L., произрастающего в Алматинской области Республики Казахстан. Для количественного определения основных классов биологически активных соединений использовали спектрофотометрический, перманганатометрический и колориметрический методы. Дополнительно применяли атомно-эмиссионную

спектроскопию, газовую хроматографию и высокоэффективную жидкостную хроматографию. Установлено, что содержание влаги в исследуемом сырье составляет 6,26 %, общая зольность - 5,31 %, а содержание экстрактивных веществ - 38,83 %, что свидетельствует о высоком качестве растительного материала. Количественный анализ выявил наличие полисахаридов (6,35 %), дубильных веществ (4,52 %), флавоноидов (2,35 %), сапонинов (2,19 %) и алкалоидов (1,39 %). Анализ минерального состава показал высокое содержание калия (1189,98 мкг/мл), кальция (796,69 мкг/мл) и магния (220,12 мкг/мл). Среди микроэлементов выявлены железо (15,4503 мкг/мл), цинк (2,9316 мкг/мл) и марганец (2,2882 мкг/мл). Исследование жирнокислотного состава показало наличие насыщенных (42,288 %), мононенасыщенных (22,190 %) и полиненасыщенных (34,397 %) жирных кислот, среди которых преобладают пальмитиновая, олеиновая и линолевая кислоты. По результатам ВЭЖХ содержание витамина С составило 33,483 мг/100 г, а витамина Е - 0,665 мг/100 г. Полученные результаты подтверждают, что *Verbascum thapsus* L., произрастающий в Алматинской области, является перспективным источником биологически активных соединений, минералов, жирных кислот и антиоксидантных витаминов. Полученные данные расширяют существующие представления о фитохимическом составе данного вида и подтверждают перспективность его использования в качестве растительного сырья для фармацевтической и нутрицевтической промышленности. Результаты исследования могут быть использованы при разработке растительных лекарственных препаратов и натуральных антиоксидантных продуктов на основе *Verbascum thapsus* L.

Ключевые слова: Verbascum thapsus L., фитохимический состав, биологически активные соединения, экстрактивные вещества, минеральный состав, жирные кислоты, витамины, газовая хроматография, высокоэффективная жидкостная хроматография

Introduction. The flora and plant resources of the Kazakhstan are rich in the variety of medicinal plants which can find the usage in medicine. The capacity of medicinal plants to produce a broad range of secondary metabolite under natural conditions has seen medicinal plants being identified as one of the promising sources of new therapeutic agents (Bhat et al., 2022; Gani et al., 2024). These natural products are in several bioactive classes, including phenolic compounds, flavonoids, terpenoids, alkaloids, glycosides and saponins, and many of them are highly biologically active. Considerable pharmacological research studies have proved the existence of a wide spectrum of bioactivities of plant-derived compounds with anti-inflammatory, antioxidant, antibacterial, anticancer and antifungal effects (Li et al., 2022; Mir et al., 2022; Wang et al., 2024). Medicinal plant materials have traditionally played a critical role in discovering and developing new drugs, as either direct source of therapeutic compounds or as structural models of the synthetic modification.

Verbascum thapsus L. (*V. thapsus*) is one of such medicinal species, which is of high scientific interest due to its rich phytochemical profile and long tradition of being used

in traditional medicine. It belongs to the *Scrophulariaceae* family which has over 400 species that are found in Asia, North America and Europe (Dong et al., 2022). *V. thapsus* L. may be defined as a perennial herb with a short life cycle which was able to adapt to a variety of ecological habitats. The phytochemical studies have been able to identify a set of bioactive compounds within this medicinal plant that assists in explaining why it has a wide variety of pharmacological effects that include wound-healing, antioxidant, antibacterial, antifungal, anti-inflammatory, diuretic and detoxifying effects (Keaveney et al., 2020). *V. thapsus* represents a promising source of phytochemicals and therefore deserves further investigation for potential pharmaceutical applications.

Literature review. *Verbascum thapsus* L. is a plant also referred to as mullein. The herb is known as a medicine plant since time immemorial and has a significant medicinal potential in the prevention of some health disorder. The studies on phytochemicals have shown that mullein contains several biologically active compounds such as triterpenes, tetraglycosides, saponins, terpenes, flavonoids, carotenoids, tannins, carbohydrates, phenolic acids, sugars, proteins, and essential minerals. This fact of a wide range of such phytochemicals adds to the pharmacological potential of the plant. Therefore, mullein has been widely used in traditional and folk medicine by the local communities in most parts of the world to treat and prevent numerous diseases (Jan et al., 2022).

The extraordinary biological activity of *V. thapsus* is mostly linked to the existence of vast array of phytochemical constituents. The research into phytochemicals has proved that *V. thapsus* L. contains a high concentration of some groups of secondary metabolites, such as flavonoids, lignans, triterpenoid saponins, iridoid glycosides, steroids, and polysaccharides (Amin et al., 2020). Moreover, the plant also holds a major collection of phenylethanoid glycosides, such as verbascoside, isoverbascoside, leucosceptoside A, martynoside, alyssonoside, and leucosceptoside B. These compounds have been regarded as total key from the chemotaxonomic standpoint in *V. thapsus* L. since it made its chemical characterization and classification (Frezza et al., 2019).

One of the earlier studies outlined chemical composition of aerial parts of two species of *Verbascum*, that is, *V. thapsus* and *V. marschallianum* that was gathered in Altai region of Kazakhstan (Nykmukanova et al., 2017). The quantitative content of certain bioactive classes of alkaloids, saponins, organic acids, tannins, flavonoids and coumarins, as well as the content of macro and microelements, amino and fatty acids of the two species were the targets of the authors.

Unlike the study that was published before, this study will seek to do a systematic phytochemical characterization of *V. thapsus*. In this paper, a particular focus is made on a determination of the phytochemical profile of *V. thapsus* specimens in the Almaty region of Kazakhstan. Besides the biochemical characterization of bioactive components, the amounts of the noteworthy antioxidant vitamins like vitamin C and E, were also revealed. With this, the purpose of the current research is to enlarge the current knowledge on the phytochemical composition of *V. thapsus* with the new data on the plant material grown in another geographical area and the quantitative analysis of the main vitamins that could have biological implications.

Materials and methods.

Materials.

Root samples of *Verbascum thapsus L.* were collected in the Almaty region of Kazakhstan during the vegetation period. The collected plant material was cleaned, air-dried under shade conditions, ground to a fine powder, and stored in airtight containers until analysis. All reagents used in the study were of analytical grade.

Statistical analysis.

All analyses were performed in triplicate (n = 3), and the results are presented as mean ± standard deviation (SD). Statistical calculations were performed using Microsoft Excel 2021.

Methods.

The general procedures for the analysis of medicinal plant raw materials were carried out according to the State Pharmacopoeia of the Republic of Kazakhstan. Atomic emission spectroscopy was used as the total content of macro- and microelements. The amounts of flavonoids, coumarins, saponins, and alkaloids were determined into spectrophotometric analysis. The tannins and organic acid levels were determined through the permanganatometric method, and coumarins were also determined using a colorimetric procedure. The fatty acid samples were identified and measured through the gas chromatography (GC) (Muzychkina et al., 2008). Vitamin C and E content were also determined quantitatively using the high-pressure liquid chromatography (HPLC).

Identification of mineral composition.

About 3 grams of finely ground medicinal plant substance was put into a pre-weighed porcelain crucible and uniformly spread evenly at the bottom. The fire was slowly fried to enable the material to burn or evaporate at the minimum possible temperature. The rest of the carbon particles were also burnt at low temperature, when the majority of the carbon was burnt, the temperature rose. Calcination was done at dull red heat (around 500°C) until a constant mass was reached, without melting the ash or sintering with the walls of the crucible. The ash was dried in a desiccator after which it was heated again at a temperature of approximately 600°C until it had a uniform gray appearance. With heating, 5 mL of HNO_3 (1:1) was used to dissolve the residue. The solution was dried into moist salts and then was dissolved in 10-15 mL of 1 N HNO_3, moved into a 25 mL volumetric flask, and diluted to the mark. An identical solution, of the same acid and concentration, in blank solution was prepared under the same conditions. Atomic absorption spectroscopy IPS-28 (LLC «Mors», Russia) was applied to the prepared samples.

Fatty acid analysis.

A fine and dry powdered plant material was then subsequently placed in a mixture of chloroform and methanol (2:1) and allowed to run for 5 minutes. The extracts obtained were filtered using a paper filter after which the solvent was evaporated to dryness. After this, 10 mL of methanol and 2-3 drops of acetyl chloride was added to the extracts obtained and the process of methylation done at 60-70°C in a special system and lasted 30 minutes. Methanol was eliminated with the help of a rotary evaporator after the reaction, and the samples were dissolved with hexane (5 mL). The fatty acid composition was analyzed using a Carlo Erba-420 gas chromatograph (Italy) equipped

with a flame ionization detector (FID). Fatty acid methyl esters were separated on a capillary column using nitrogen as carrier gas. Injector and detector temperatures were maintained at 250°C and 280°C, respectively. Identification of fatty acids was performed by comparison with standard fatty acid methyl ester mixtures.

Quantitative determination of vitamin content.

Vitamin C and vitamin E were determined using high-performance liquid chromatography (HPLC). Prior to analysis, samples were filtered through a 0.45 μm membrane filter. Chromatographic separation was performed on a C18 reversed-phase column (250 × 4.6 mm, 5 μm). The mobile phase consisted of methanol and water. The flow rate was maintained at 1.0 mL/min, the column temperature was 25°C, and detection was carried out using a UV detector at 254 nm. Identification of vitamins was performed by comparing the retention times of sample peaks with those of authentic vitamin C and vitamin E standards. Quantification was based on calibration curves prepared from standard solutions.

Results. Based on the described methodology, the authenticity and the content of classes of biologically active compounds of *V. thapsus* were identified and presented in tables 1 and 2.

Table 1 – The authenticity of *V. thapsus* plant material

Authenticity parameters / Plant material	Moisture	Ash content	Extractive substances
Content (%) in *V. thapsus*	6.26 ± 0.07	5.31 ± 0.05	38.83 ± 0.41

Data are presented as mean ± SD (n = 3).

Quantitative analysis demonstrated the presence of several groups of biologically active compounds in the roots of *V. thapsus L.* The obtained results are presented in Table 2.

Table 2 – The biological active constituents of *V. thapsus* L.

Biological active classes	Quantitative determination (%)
Tannins	4.52 ± 0.06
Organic acids	0.39 ± 0.01
Saponins	2.19 ± 0.04
Flavonoids	2.35 ± 0.05
Coumarins	0.42 ± 0.01
Alkaloids	1.39 ± 0.03
Polysaccharides	6.35 ± 0.09

Data are presented as mean ± SD (n = 3).

The received results proved that polysaccharides were the most common class (Figure 1) which amounted to 6.35% of the dry plant material. The predominance of polysaccharides suggests that *V. thapsus* roots contain compounds of potential biological significance, as polysaccharides are frequently associated with immunomodulatory

and protective properties. Tannins were also found in large quantities of 4.52%. The flavonoids content was established at 2.35% that also may be a large concentration of the biologically active compounds.

The content of saponins was determined as 2.19% which showed a moderate level of saponins in *V. thapsus* roots. The alkaloid concentration was 1.39% which proved the appearance of nitrogen-containing secondary metabolites. In addition, the coumarins and organic acids were also found in lower concentrations of 0.42 and 0.39% respectively. Although these classes are relatively low, they are very crucial in the biological activity of plants. Coumarins are known to possess anticoagulant, antioxidant, anti-inflammatory, and antimicrobial properties, whereas organic acids contribute to metabolic regulation and may enhance the antioxidant potential of extracts. Therefore, even minor concentrations of these bioactive groups can influence the overall biological activity and therapeutic potential of the investigated plant material.

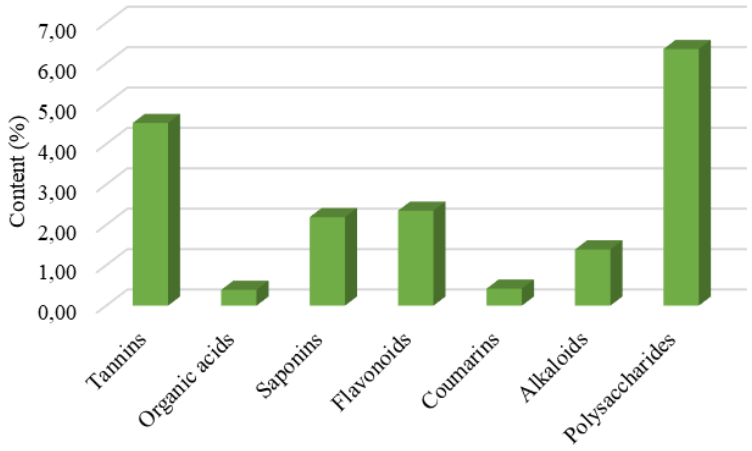

Figure 1 – The content of biologically active constituents of *V. thapsus* L.

Error bars represent SD (n = 3).

The mineral composition of the root was detected to quantify the concentrations of essential macro and microelements. The results are shown in Table 3. As a major component of plant metabolism, minerals have the potential to play a major role in the pharmacological and nutritional quality of medicinal plant raw materials hence the checking out (Wang et al., 2023).

Table 3 – Mineral composition of *Verbascum thapsus L.* roots

Content of microelements (μg/mL)	
Cadmium (Cd)	0.0207 ± 0.0004
Lead (Pb)	0.0735 ± 0.0015
Copper (Cu)	0.0997 ± 0.0020
Nickel (Ni)	0.1504 ± 0.0030
Manganese (Mn)	2.2882 ± 0.04
Zinc (Zn)	2.9316 ± 0.05

Iron (Fe)	15.4503 ± 0.21
Content of macroelements (µg/mL)	
Sodium (Na)	21.090 ± 0.32
Magnesium (Mg)	220.12 ± 3.15
Calcium (Ca)	796.69 ± 11.24
Potassium (K)	1189.98 ± 16.42

Data are presented as mean ± SD (n = 3).

The largest micro-element that was found is iron (Fe), with a maximum concentration of 15.4503 µg/mL (Figure 2A). The second one was zinc (Zn) and manganese (Mn) with 2.9316 and 2.2882 µg/mL respectively. Nickel (Ni) (0.1504 µg/mL) and copper (Cu) (0.0997 µg/mL) were moderate. The amount of lead (Pb) and cadmium (Cd) was relatively low, 0.0735 µg/mL and 0.0207 µg/mL, respectively. Lastly, the high concentration among macro-elements was potassium (K) (1189.98 µg/mL) as shown in Figure 2B, then calcium (Ca) (796.69 µg/mL), magnesium (Mg) (220.12 µg/mL), then sodium (Na) (21.090 µg/mL). Each element plays own role in plant nutritional and pharmacological importance. The macroelements may support physiological processes, including electrolyte balance, bone metabolism, enzymatic activity, oxygen transport, and antioxidant defense mechanisms. The identified microelements contribute to immune regulation, antioxidant enzyme activity, and metabolic functions. Furthermore, the concentrations of lead and cadmium were found to be low, suggesting a low level of heavy-metal contamination in the investigated plant material.

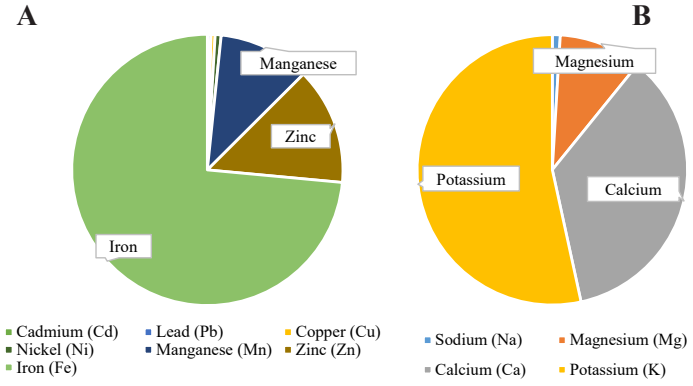

Figure 2 – The content of (**A**) micro- and (**B**) macroelements of *V. thapsus* L.

Error bars represent SD (n = 3).

The fatty acid content of the roots of *Verbascum thapsus* was analyzed to determine the distribution of saturated and unsaturated fatty acids and to further get their possible biological implications (Table 4). Analytical findings demonstrated a variety of fatty acids, both in terms of chain lengths and levels of unsaturation.

Table 4 – The fatty acids content of *V. thapsus* L.

Fatty Acid (Notation)	Fatty Acid Name	Group	Content (%)
$C_{16:0}$	Palmitic acid	saturated	21.127 ± 0.32
$C_{18:0}$	Stearic acid	saturated	6.093 ± 0.09
$C_{18:1n9c}$	Oleic acid	monounsaturated	12.031 ± 0.18
$C_{18:2n6c}$	Linoleic acid	polyunsaturated	15.313 ± 0.23
$C_{18:3n3}$	Linolenic acid	polyunsaturated	0.978 ± 0.02
$C_{20:0}$	Arachidic acid	saturated	14.035 ± 0.21
$C_{20:1\ (cis\text{-}11)}$	Eicosenoic acid	monounsaturated	10.159 ± 0.15
$C_{20:3n3\ (cis\text{-}11,14,17)}$	Eicosatrienoic acid	polyunsaturated	18.106 ± 0.27
$C_{22:2}$	Docosadienoic acid	polyunsaturated	1.125 ± 0.02
$C_{23:0}$	Tricosanoic acid	saturated	0.651 ± 0.01
$C_{24:0}$	Lignoceric acid	saturated	0.382 ± 0.01

Data are presented as mean ± SD (n = 3).

Palmitic acid became the major saturated fatty acid and its proportion in the total fatty acid pool was 21.127% as can be seen in Figure 3. Other saturated fatty acids were arachidic acid (14.035%), and stearic acid (6.093%). Ligoceric acid and tricosanoic acid were also identified as minor long-chain saturates. The saturated fatty acids were found to make up 42.288 % of the total composition of fatty acids. Oleic acid and eicisenoic acid were the main monounsaturated fatty acids, and their concentrations were 12.031% and 10.159%, respectively. The total percentage of monounsaturated material was 22.190%, which is a moderate percentage of the investigated plant material.

There were also large quantities of polyunsaturated fatty acids. Eicosatrienoic acid and the linoleic acid were the main compounds. Reduced levels of linolenic acid and docosadienoic acid were detected. Polyunsaturated fatty acids are associated with anti-inflammatory mechanisms, cell signalling and membrane activities. Their total percentage composition was 34.397% of the total fatty acids.

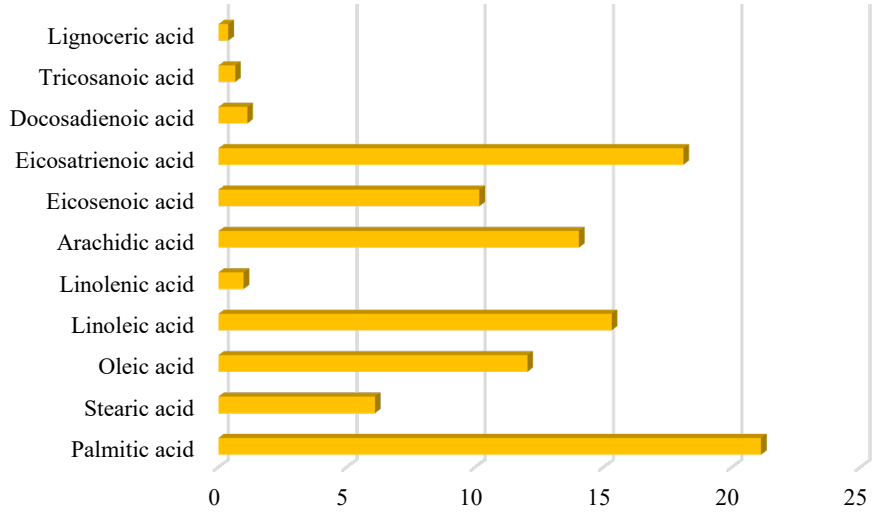

Figure 3 – The fatty acids content of *V. thapsus* L.

Error bars represent SD (n = 3).

High-Performance Liquid Chromatography (HPLC) was adopted to establish the concentrations of vitamins in the sample under analysis. The outcome revealed that vitamin C content was 33.483 mg/100 g and vitamin E concentration was 0.665 mg/100 g. These discoveries show that the plant material under study contains antioxidant vitamins that can be attributed to its possible pharmaceutical applications. The level of vitamin C is relatively high, suggesting the plant has potential as a natural source of water-soluble antioxidants. The role of ascorbic acid in reducing the level of ROS, preventing the damage of cellular components and supporting the physiological functions such as collagen synthesis and immune function are of paramount importance (Boo, 2022). Therefore, the detected level of vitamin C suggests a significant antioxidant potential of the sample studied. Vitamin E had lower concentration as compared to vitamin C but has a pharmacologic significance. Vitamin E is an antioxidant which is lipid soluble and protects the biological membrane from lipid peroxidation and contributes to the stabilization of cell structure (Abdelqader et al., 2023). Tocopherols can be synergistic with vitamin C and may have an even more protective effect when they are present in plants at relatively low levels.

Discussion. The authenticity parameters confirmed the good quality of the investigated plant material. The moisture content (6.26%) was within acceptable limits for medicinal plant raw materials, indicating adequate drying and suitability for storage and further phytochemical analysis. The ash content (5.31%) reflected the presence of inorganic constituents, whereas the relatively high extractive value (38.83%) suggested a considerable amount of soluble phytochemicals in the plant material.

Quantitative phytochemical analysis revealed that polysaccharides (6.35%) and tannins (4.52%) were the predominant groups of biologically active compounds in V. thapsus roots. The high content of polysaccharides may contribute to the biological significance of the species, as these compounds are frequently associated with immunomodulatory and protective effects (Mizuno and Minato, 2024). Tannins and flavonoids were also detected in appreciable amounts (4.52% and 2.35%, respectively), indicating that the investigated plant material contains measurable amounts of phenolic constituents. Compared with previous studies on *Verbascum* species from Kazakhstan (Nykmukanova et al., 2017), the present results demonstrate a generally comparable phytochemical profile. Nevertheless, variations in the concentrations of individual compounds may reflect differences in geographical and environmental conditions. Furthermore, this study provides a more comprehensive characterization of *V. thapsus* roots by combining the quantitative determination of major groups of secondary metabolites, mineral elements, fatty acids, and antioxidant vitamins C and E, thereby expanding the currently available data on this species in Kazakhstan.

Mineral analysis demonstrated that potassium, calcium, and magnesium were the predominant macroelements, whereas iron was the major microelement. The relatively high concentrations of these essential elements may contribute to the nutritional value of the plant material. At the same time, the concentrations of lead and cadmium were low, suggesting minimal heavy-metal contamination of the investigated samples. The

detected concentrations of lead and cadmium were within the limits recommended by the WHO guidelines for medicinal plant materials, indicating the absence of significant heavy-metal contamination. These findings indicate favorable environmental conditions in the collection area and support the suitability of the plant material for further phytochemical investigation (World Health Organization, 2011).

Fatty acid profiling revealed a balanced composition of saturated (42.288%), monounsaturated (22.190%), and polyunsaturated fatty acids (34.397%). Palmitic acid, linoleic acid, and eicosatrienoic acid were identified as the dominant constituents. The presence of substantial amounts of unsaturated fatty acids may enhance the biological relevance of the plant material because these compounds are known to participate in membrane structure and various physiological processes (Henschel et al., 2024).

The determination of vitamins C (33.483 mg/100 g) and E (0.665 mg/100 g) represents an additional contribution of the present study. These antioxidant vitamins may contribute to the overall biological activity of the plant material. However, it should be emphasized that the current investigation was limited to phytochemical characterization and did not include biological assays. Therefore, the obtained results indicate the presence of potentially bioactive constituents but do not directly confirm pharmacological efficacy. Further biological and pharmacological studies are required to evaluate the therapeutic significance of the identified compounds.

Conclusion. The current research offered detailed phytochemical and physicochemical description of *Verbascum thapsus* that grows in Almaty region, Kazakhstan. The received results proved the idea that the investigated plant material is of good quality as indicated by the acceptable values of moisture, total ash, and extractive substances. Quantitative analysis indicated the presence of diverse groups of biologically active compounds, including polysaccharides, tannins, flavonoids, saponins and alkaloids with potential biological significance.

The mineral composition of *V. thapsus* revealed that the plant is a significant source of such macroelements as potassium, calcium, and magnesium, and such microelements as iron, zinc, and manganese. Moreover, fatty acid profiling indicated that saturated fatty acids, monounsaturated and polyunsaturated fatty acids were present with palmitic, oleic and linoleic acids being dominant. Existence of antioxidant vitamins especially vitamin C and vitamin E further points out the nutritional and therapeutic potential of this species.

On the whole, the data show that *Verbascum thapsus* growing in Almaty area is a source of biologically active substances and important nutrients. The results expand the current understanding of the phytochemical composition of this species and highlight its potential as a promising source of plant raw material for future pharmaceutical, nutraceutical, and functional food applications. Future research can concentrate on the isolation of individual bioactive compounds and analyzing their pharmacological activities in more detail. The novelty of the present study lies in the comprehensive phytochemical characterization of *V. thapsus* collected in the Almaty region, including quantitative determination of antioxidant vitamins C and E together with mineral and fatty acid profiling. Nevertheless, further biological and pharmacological investigations are necessary to confirm the biological activity and therapeutic relevance of the identified compounds.

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