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# PHYTOCHEMISTRY ANALYSIS AND MEDICINAL USE OF PLANTS OF THE GENUS *TAGETES*

**Key words:** *Tagetes erecta*, *Tagetes patula*, *Tagetes minuta*, french marigold, african marigold

A B S T R A C T

Given the significant interest in medicinal plants and their use in medicine, the question of finding new promising plants or using long-known plants in a new way is relevant. The growing demand for phytomedicines and the trend for all things natural encourage the search for new plant species that can be a source of biologically active substances. One of the promising genus for detailed pharmacognostic analysis is the genus *Tagetes*, which is widely used in Ukraine, is used as a drug to treat various health problems, including dental, gastric, intestinal, emotional and nervous disorders.

The aim of the work was to analysis and generalization of scientific information on the distribution, chemical composition, pharmacological activity and potential of medical applications of plants of the genus *Tagetes.*

Methodology used in the review is based on the analysis of published original research articles through exhaustive search through scientific databases such as MEDLINE/PubMed and Google Scholar using different key words as «marigolds», «medicinal use», «pharmacological activity», «phytochemistry», «*Tagetes*». The criteria for including publications in the analytical review were: a) language of publication – English, Ukrainian; b) availability of abstract; c) availability of the full publication in free access.

The genus *Marigold* is part of the family Compositae (*Asteraceae*) and includes almost 56 species of plants that are distributed around the world and in Ukraine and are usually cultivated as ornamental plants. The plants of this genus are unofficial; they are used in folk medicine of different countries because they have antibacterial, anti-inflammatory, reparative, hepatoprotective, antioxidant, antitumor, maculoprotective activity. The main biologically active substances of the plant include carotenoids, flavonoids and essential oils and compounds of phenolic nature. In addition, different species of marigolds are studied in agriculture for their fungicidal, bactericidal and insecticidal activity.

Analysis of world experience in the use of plants of the genus *Tagetes* in folk medicine, experimental studies on the phytochemical composition of plants of this genus and a wide range of their pharmacological activity showed that the aboveground organs of different species of plants of the genus *Tagetes (T. patula, T. erecta, T. minuta)* can be considered as promising raw materials for further research.

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**ФІТОХІМІЧНИЙ АНАЛІЗ ТА МЕДИЧНЕ ВИКОРИСТАННЯ РОСЛИН РОДУ *TAGETES* (ЧОРНОБРИВЦІ)**

**Ключові слова:** *Tagetes erecta*, *Tagetes patula*, *Tagetes minuta*, чорнобривці французькі, чорнобривці африканські

АНОТАЦІЯ

Враховуючи значний інтерес до лікарських рослин та їх використання в медицині, актуальним є питання пошуку нових перспективних рослин або використання давно відомих рослин за новим призначенням. Зростаючий попит на фітопрепарати та тенденція до всього природного спонукають до пошуку нових видів рослин, які можуть бути джерелом біологічно активних речовин. Одним із перспективних родів для детального фармакогностичного аналізу є рід *Tagetes*, який широко використовують в Україні як лікарський засіб для лікування різноманітних проблем зі здоров'ям, включаючи стоматологічні, шлункові, кишкові, емоційні та нервові розлади.

Метою роботи був аналіз та узагальнення наукової інформації щодо поширення, хімічного складу, фармакологічної активності та можливостей медичного застосування рослин роду *Tagetes*.

Методологія, використана в огляді, базується на аналізі опублікованих оригінальних дослідницьких статей шляхом вичерпного пошуку в наукових базах даних, таких як MEDLINE/PubMed і GoogleScholar, із використанням різних ключових слів, таких як «чорнобривці», «медичне використання», «фармакологічна активність», «фітохімія», «тагетес». Критеріями включення публікацій до аналітичного огляду були: а) мова видання – англійська, українська; б) наявність реферату; в) наявність повної версії видання у вільному доступі.

Рід чорнобривці належить до родини складноцвітих і налічує майже 56 видів рослин, які поширені по всьому світу та в Україні і зазвичай культивуються як декоративні рослини. Рослини цього роду неофіцинальні. Їх використовують у народній медицині різних країн, оскільки вони мають антибактеріальну, протизапальну, репаративну, гепатопротекторну, антиоксидантну, протипухлинну та макулопротекторну дію. До основних біологічно активних речовин рослини належать каротиноїди, флавоноїди та ефірні олії, сполуки фенольного характеру. Крім того, різні види чорнобривців вивчають у сільському господарстві на їхню фунгіцидну, бактерицидну та інсектицидну дію.

Аналіз світового досвіду використання рослин роду *Tagetes* (Чорнобривці) у народній медицині, експериментальні дослідження фітохімічного складу рослин цього роду та широкого спектра їхньої фармакологічної активності показали, що надземні органи різних видів рослин роду *Tagetes* (*T. patula*, *T. erecta*, *T. minuta*) характеризуються значним впливом на організм людини та можуть бути розглянуті як перспективна сировина для подальших досліджень.

## Introduction

Every year the number of drugs of synthetic origin increases, which leads to an increase in the frequency and number of adverse reactions resulting from their use. This in turn supports and increases the demand for herbal medicines containing natural compounds [1]. This trend is confirmed by World Health Organisation data, according to which the demand for plant raw materials is constantly growing in both developing and developed countries. The Ukrainian pharmaceutical market doesn't stand aside from global trends, as evidenced by the annual increase in the number of herbal medicines by 5–7% [1, 2].

Given the significant interest in medicinal plants and their use in medicine, the question of finding new promising plants or using long-known plants in a new way is relevant. The growing demand for phytomedicines and the trend for all things natural encourage the search for new plant species that can be a source of biologically active substances. Representatives of the *Asteraceae* family are promising objects for scientific research, due to the variety of natural compounds that are part of them.

One of the promising genus for detailed pharmacognostic analysis is the genus *Tagetes*, which is widely prevalence in Ukraine, is used as a drug to treat various health problems, including dental, gastric, intestinal, emotional and nervous disorders[3].

**The purpose** of the research: analysis and generalization of scientific information on the distribution, chemical composition, pharmacological activity and potential of medical applications of plants of the genus *Tagetes.*

## Materials and methods

Methodology used in the review is based on the analysis of published original research articles through exhaustive search through scientific databases such as MEDLINE/PubMed and Google Scholar using different key words as «marigolds», «medicinal use», «pharmacological activity», «phytochemistry», «*Tagetes*». The criteria for including publications in the analytical review were: a) language of publication – English, Ukrainian; b) availability of abstract; c) availability of the full publication in free access.

## The results and discussion

### *Historical mentions of marigolds*

Homeland of *Tagetes* – Central and South America, where in the XVI century together with other plants (potatoes, corn, dahlias etc.) they were brought by Spanish conquistadors to Europe and North Africa. Marigolds came to the territory of modern Ukraine in about the XVIII century. They were among the first foreign plants and were then called «African flowers» [4].

### *Botanical characteristics of the genus Tagetes*

The genus *Tagetes* belongs to the family Compositae (Asteraceae). It was described as a genus by Linnaeus in 1753. The genus *Tagetes* has almost 60 species of plants that are distributed around the world and are usually cultivated as ornamental plants. However, in recent years, more and more attention is paid to the study of representatives of this genus as a valuable medicinal raw material with subsequent use in medicine and pharmacy [5].

Of the 26 species of marigolds distributed in North and South America from Arizona to Argentina, the most common in Ukraine are such species and their varieties as african marigolds (*Tageteserecta*) (рис. 1) and french marigolds (*Tagetes patula*) (рис. 2), less common are small marigolds (*Tagetesminuta*) [1, 2, 6].

*Tagetes patula (T. mpatula)* reach a height of 15 to 40 cm, and *Tagetes erecta (T. merecta)* – from 40 to 120 cm. The root system of marigolds is fibrous, branched, at the bottom of the stem there are additional roots. Stem is not pubescent, round, with a ribbed surface. Leaves odd-pinnately dissected, with brown oil glands on each side of the segment of the leaf blade. Leaf placement is the opposite. The flowers are collected in an inflorescence anthodium. The diameter of flower anthodium varies depending on the type and variety of marigolds, reaching from 2 cm to 12–15 cm. Inflorescences of *T. erecta* – spherical, very large, up to 15 cm in diameter. The color of the flowers – from pale yellow, even white-milky, to dark orange. Inflorescences of *T. patula* are hemispherical and flat, 3 to 7 cm in size. The color of the flowers is from bright yellow to reddish-brown or the two-color color is yellow-red, yellow-brown [7–9]. Antodium of french marigolds are cylindrical or cup-shaped, more often single, less often collected in complex inhomogeneous inflorescences. Wrap of one row of five fused leathery leaves covered with elongated and linear flat glands. General perianth flat, glabrous. Disc flowers are tubular bisexual, golden-yellow, orange or orange-red; marginal flowers female lingual single-row (in the forms introduced into the culture, arranged in several rows) golden-yellow, light and dark orange or brown. The blades of the column are blunt, in the middle flowers are longer, twisted, in the marginal – ligulate – divergent. The tufts of different and uneven films, including some fused, obtuse, others – mostly free, pointed in the spine [10]. Fruit – achene; flattened, longitudinally linear, dissected at the apex, gradually tapering downwards. The color of the fruit is black or brownish-black. Seeds are small: the weight of 1000 seeds is 0.6–0.8 g. It blooms from late June to late September. The fruits ripen in August–October [9]. Marigold inflorescences are used for medicinal purposes, the time of collection of which is the period of mass flowering (July). When collecting inflorescences, it should be remembered that the later collection of anthodiums can lead to shedding of seeds. Tagetes flowers are carefully cut. Dried in the shade under a canopy or in a well-ventilated room [9, 11].

***Phytochemistry of plants of the genus Tagetes***

Different species of *Tagetes* consist of a large number of natural compounds according to the literature review.

According to Riaz M. et al. (2020) the prevalent natural compounds of marigolds are flavonoids, carotenoids, terpenoids, thiophenes, terpenes and benzofurans, essential oils [12] saponins, phenols, polysaccharides [13] alkaloids, fatty acids [14].

Studies by various scientists in different years have identified 22 phytocomponents from the ethereal extract of african marigold flowers, including: β-sitosterol, β-daucosterol, 7-hydroxysitosterol, lupeol, erythrodiol, erythrodiol-3-palmitate, 7-kvertite, α-tert-methyl ether, kaempferol, syringic acid, gallic acid, 3-β-galactosyl dicyring acid, palmitin, n-hexadecane [15]. Zang and Zhang (2010) identified in *T. erecta* six more biologically active natural compounds – 4′-methoxy-eupatolithin-3-O-glucoside, kaempferitrin, rutin, beta-sitosterol, daucosterol and gallic acid [16] .

About 19 phytochemicals were identified from the methanolic extract of *T. erecta* leaves, the main ones being tetradecanoic acid, 2,6,10-trimethyl 14-ethylene-14-pemtadecme, N-hexadecanic acid, 15-hydroxy pentadecanoic acid and stigmasterol. While 31 compounds were identified from the methanolic extract of the *T. erecta* flower sample, the main ones are hexadecanoic acid, 7-tetra decenal, vitamin E and norolean-12-ene [17].

Alam U. et al. (2011) investigated samples of *T. erecta* on carotenoid content by thin layer chromatography (TLC) and spectrophotometrically. Xanthophylls (up to 98.7%) predominated in the petals, including lutein (64.1%), anteraxanthin (31.1%), α-cryptoxanthin (3.1%), β-carotene and α-carotene [18]. Similar data were obtained in study made by Shetty L. J. et al. (2015): carotenoids were identified in the flower anthodiums of *T. erecta*, namely: all trans- and cis-isomers of zeaxanthins (5%), all trans- and cis-isomers of lutein and lutein esters (88%) [15, 19].

In general, marigold inflorescences are one of the richest sources of xanthophylls, the main representative of which is lutein. About 95% of the lutein contained in the inflorescences is in the form of complex esters, the main of which is lutein palmitate. Other complex esters of lutein contained in marigolds are dimyristate, myristate, stearate and distearate. The concentration of lutein esters in fresh anthodiums of marigolds varies from 4.0 mg/g in greenish-yellow flowers to 800 mg/g in orange-brown flowers. Plants of the genus *Tagetes* are an industrial source for lutein [20] .

Zhang H. et al. (2020) discovered thatthe content of lutein in different varieties of marigolds can differ more than 100 times, which leads to different colors of petals, which can be white, cream, yellow, orange-red. Formerly Zhang H. et al. developed an inbred marigold line «V-01» with orange petals, in accordance with the increased content of carotenoids in general and lutein in particular, later identified a natural mutant derived from this population «V-01M», which had identical to «V-01» development characteristics and botanical characteristics, with the exception of yellow petals [21].

Another group of natural compounds which was found in large quantities in raw materials of plants of the genus *Tagetes* are flavonoids – a group of phenolic compounds derived from flavones that are involved in redox reactions and have a wide range of pharmacological activity [7].

According to various authors, up to 49 species of flavonoids in the form of aglycones and glycosides have been isolated in different species of marigolds [7, 22, 23].

According to Munhoz V. M. et al. (2012) marigold flowers contain up to 5.5% flavonoids [24]. Xu L. W. et al. (2012) showed that the main flavonoids of *T. erecta* arequercetagetrin, patuletin, patuletrin and the dominant quercetagetin [23]. Marchyshyn S. M. et al. (2021) [25] conducted a qualitative and quantitative analysis of flavonoids in *Tagetes lucida*. According to the research results, it was found that the largest amount of flavonoids is contained in seeds, leaves and flowers – (7.89 ± 0.18)%; (6.58 ± 0.12)%; (4.15 ± 0.18)% respectively. By the method of thin-layer chromatography, quercetin, kaempferol, rutin (except stems), isoquercitrin (except roots), and apigenin (only in flowers) were detected in the studied raw materials.

According to Moliner C. et al. (2018) [26] for the group of flavonoids, laricitrin was the most common aglycone in ethanolic extracts, which corresponds to a previous study performed by Navarro-González et al. (2015) in acidified ethanolic extracts *T. erecta* from Spain [27].

In the composition of plants of the genus *Tagetes* found the presence of hydroxycinnamic acids such as chlorogenic, rosemary, coffee, ferulic [28, 29]. Leaves of *T. erecta* and *T. patula* are able to accumulate free aminoacids, including aspartic, glycine, histidine, valine [30].

Maliuhina O. O. (2017) qualitatively confirmed the presence of vitamin C in the inflorescences of french marigolds, low-growing form, and also quantified its content, which was 0.875 ± 0.77% [31] .

Pakistani scientists found in their chemical composition of all parts of *T. patula* (leaves, stems, roots, flowers) thiophenes and substances of steroidal nature [32]. Similar results on the content of thiophene in plants of the genus *Tagetes* were obtained by Italian scientists, according to which the most promising species in terms of thiophene content are species *T. minutes* and *T. Lucida* [33].

The genus *Tagetes* includes species of plants rich in essential oils, the main components of which are monoterpene hydrocarbons (ocimene, limonene, terpinene, myrcene, etc.) and acyclic monoterpeneketones (tageton, dihydrotagetone and tagetenone) [6]. Similar data were obtained in the study of Maliuhina O. O. et al. (2014), as a result of which the main 18 components of the essential oil of the african marigold inflorescences were identified, 6 of which were for the first time. The main components were piperitenone, piperitone, spatulenol, para-cymenol [34]. The chemical composition of the essential oil of different species and varieties of marigolds varies greatly depending on the geographical conditions of growth [6]. Shetty L. J. et al. (2015) [15] thirty-three components of essential oil derived from herb of *T. erecta* and *T. erecta* flower oil were identified by gas-liquid chromatography. The main phytocomponents characterized were tagetone, tagenone, β-caryophyllene, terpinolene, (E)-ocymenone, (Z)-β-ocimen, piperitenone, (Z)-ocymenone and limonene. Piperitone (50.7%), piperitenone (13.2%) and (E)-β-ocimen (6.7%) were the predominant components in *T. erecta* leaf oil. Flower oil was characterized by the presence of 1,8-cineole, α-pinene, α-terpineol, piperiton and sabinene.

Berdey T. S. (2010) studied the chemical composition of essential oil of different types of marigolds growing on the territory of Ukraine: the main components of essential oil of the herb of african marigold are caryophyllene (22.38%), piperiton (8.18%), caryophyllene oxide (6.33%); essential oil of the herb of french marigold – caryophyllene (25.54%), docosen-1 (8.62%), hermacrene D (5.95%), spatulenol (5.58%) [35]. The largest amount of essential oil accumulates in the phase of flowering and budding. Among the introduced into the culture in Ukraine, the most ethereal representatives of the genus *Tagetes* are the species *Tagetes signata* and *Tagetes minutes* [9].

Thus, the main natural compounds of plants of the genus *Tagetes* are flavonoids, carotenoids and essential oils.

***Plants of the genus Tagetes in folk medicine of different countries***

Today, all over the world, a variety of raw marigolds are used as medicines to treat different health problems like dental, gastric, intestinal, emotional and nervous disorders [6,12].

For instance, in Bangladesh *T. patula* leaves are used for furunculosis, kidney disease, muscle pain, hemorrhage. Their juice is prescribed for pain in the ears and in ophthalmology [36]. In Pakistan, marigold's leaves and flowers are used as an antipyretic [37]. In Mexico, the Pima tribes prescribe a cup of tea made from the herb *T. tenuifolia* for abdominal pain [38]. In Argentina, this tea is prescribed for infected wounds [39]. In Kenya, the juice of *T. minuta* leaves and flowers is used topically to treat skin diseases. Rahman et al. (2013) indicated the possibility of using *T. minuta* for wound healing in dental diseases [36].

In countries of South America, such as Argentina, Brazil, Bolivia, Peru, Paraguay, infusions and decoctions made from the leaves and flowers of *T. minuta*, used as a choleretic, carminative, antidiarrheal, anthelmintic, antiparasitic agent, as well as to improve digestion. The infusion of the leaves is used to normalize menstruation, as well as in the comprehensive rehabilitation of women after childbirth. In Pakistan, *T. minuta* leaves are used for coughs, stomach upsets and headaches [6]. In Turkey, marigold leaves and stems are used for ear pain [40], and in *Morocco* flower tea from anthodiums of marigolds is used in diseases of the musculoskeletal system [41]. In Bolivia, the infusion of *T. minuta* used as a tonic for the nervous system, and in Brazil, on the contrary, as a sedative before bedtime [42].

*T. erecta*, *T. lucida and T. tenuifolia* in Mexico are considered one of the main phytopreparations for the treatment of diseases such as colds or «friadad», «frío en el estómago» (cold in the stomach), «calor en el estómago» (stomach fever) and «empacho» (stomach upset), as well as constipation, diarrhea in children and eye irritation. Ointments for topical use in skin diseases are prepared from the aboveground part of the tagetes [43, 44].

In herbal medicine in Guatemala also uses medicinal plant raw materials of *T. erecta* for the treatment of diseases of various organs and systems, namely: pneumonia, bronchial asthma, tuberculosis, to combat colic, used as an antibacterial, anti-inflammatory, antiseptic, as well as at the stage of keratinization as a wound-healing agent [45].

Infusion of flowers *T. erecta* shows a wide range of pharmacological activity, as stated in studies of Maity N. et al. (2011). Its positive effects have been noted in influenza, fever, rash, sore throat and muscles, arthritis and heart attacks, hemorrhoids, ear pain. Maity N. et al. (2011) also confirmed the anti-inflammatory, antimicrobial and reparative effects of inflorescences of african marigold in skin diseases such as ulcers, burns, eczema, boils, carbuncles [46]. Two teaspoons of infusion of *T. erecta* flowers twice a day for 8–10 days in combination with minerals help solve kidney problems, including excretion of excess fluid and urine outflow [47,48]. *T. erecta* used in *Spanish* and *French* herbal medicine for external use [49].

The people of Madagascar apply *T. erecta* as an antimalarial agent. Mauritians recommend a glass of decoction of flowers *T. lucida* for abdominal pain caused by diseases of the circulatory system, and jaundice of newborns to nursing mothers [50].

In recent decades, a sufficient number of studies have been conducted, which confirms the different pharmacological activity of extracts from different medicinal raw materials of different species of marigolds.

***Pharmacological activityof plants of the genus Tagetes***

***Antioxidant and anti-inflammatory activity***

In study made by Chkhikvishvili I. et al. (2016) was the first to demonstrate that both flavonoid and carotenoid components of *T. patula* extract can protect Jurkat cells from oxidative stress caused by hydrogen peroxide. These protective mechanisms can be involved both in the direct effects of radical scavenging and by the stimulation of cellular antioxidant enzymes and anti-inflammatory factors such as IL-10 [51].

Moliner C. et al. (2018) [26] demonstrated pronounced antioxidant and neuroprotective properties of extracts of *T. erecta* on various tested models, which confirms the previously obtained results of Bashir S. et al. (2008), which allows in the future to use them to create new drugs of appropriate action [52].

Karimian R. et al. (2014) studied the antioxidant and anti-inflammatory activity of essential oil of *T. minuta* [53]. Essential oil of *T. minuta* exhibited antioxidant properties, removing superoxide radical, $H_2O_2$ and NO radicals, reducing oxidative stress. Reduction of the formation of radicals of reactive oxygen species and NOS in macrophages, was associated with the activity of phenolic groups present in the essential oil, radical scavenging, and/or due to inhibition of iNOS and NOX gene expression. Essential oil *T. minuta* reduced expression genes pro-inflammatory cytokine TNF-α.

In research made by Devika R. et al. (2015) [54] in the experiment was shown anti-inflammatory activity of *T. erecta* due to the presence of flavonoids and salicylic acid.

Monterrosas-Brisson N. et al. (2020) showed the anti-inflammatory activity of hexane and acetone extracts from the aboveground parts of *T. lucida*, which was evaluated oma mouse model of auricle edema caused by 12-O-tetradecanoylforbol-13-acetate. In this study, it was shown that the anti-inflammatory activity of T. lucida extracts is due to the presence of coumarins, and the substituent at position C-7 is a decisive factor in the manifestation of this activity [55].

***Antibacterial activity***

In a study [34] it was shown that the essential oil of inflorescences *T. erecta* has expressive antimicrobial effect against *S. aureus, K. pneumoniae, S. saprophylus,* as well as antifungal action against *C. albicans.*

Behidj-Benyounes N. et al. (2014) [56] noted antimicrobial activity of *T. erecta* against *E. coli*, *B. subtile*, *K. pneumoniae*, *P. aeruginosa*, *S. aureus*, *C. albicans*, *S. cerevisiae,* while [57] noted that the extracts of african marigolds show an even greater range of activity. The antibacterial activity of marigold extracts was studied

by Jain R. et al. (2012) and showed that they are active against both gram-positive and gram-negative aerobic and anaerobic bacteria, including *E. coli, P. vulgaris, P. mirabilis, Salmonella* spp*, etc.* [58].

***Antihelmintic activity***

In studies by Pérez-Ortega G. et al.(2017) showed the antihelmintic activity of aerial parts of *T. erecta* in parasitic infestations. Only the use of flower anthodiums was effective for the treatment of lesions of the nervous system [44]. In study by Piña-Vázquez D. M. et al. (2017) the antihelmintic activity of the aqueous extract of *T. erecta* flowers against wild strains and levamisole-resistant strains of *Caenorhabditis elegans* was studied. The results of the study showed that the aqueous extract of *T. erecta* at a concentration of 25 mg/ml after 8h caused paralysis of 75% of wild-type nematodes, and it also paralyzed levamisole-resistant nematodes. In addition, the aqueous extract of *T. erecta* at a concentration of 25 mg/ml reduced egg laying of the wild strain by 65% compared to the control group [59].

***Antispasmodic activity***

In *in vitro* studies by Ventura-Martínez R. et al. (2018) the antispasmodic activity of *T. erecta* on the ileum of guinea pigs and presented data on the mechanism of their action was demonstrated. The relaxant effect on KCl reduction was more pronounced for aqueous than for ethanolic extracts of *T. erecta* flowers. The flavonoids present in this plant, quercetin and rutin, also showed antispasmodic effects. The results obtained in the experiment confirm the traditional use of *T. erecta* as an antispasmodic in folk medicine and mainly suggest that quercetin is responsible for this effect. The antispasmodic effect affects potentially controlled calcium channels, but not the pathway of nitric oxide or the release of neurotransmitters from intestinal neurons [60].

***Hepatoprotective, choleretic activity***

Numerous studies on various models of hepatitis have shown the hepatoprotective activity of extracts of various types of marigolds [61–64]. Karwani G., Sisodia S. S. (2015) studied the hepatoprotective activity of the aqueous-alcoholic extract of *T. erecta* in the $CCl_4$-induced hepatitis model in Albino Wistar rats. The drug silymarin was used as a positive control. Subcutaneous injection of $CCl_4$ caused a marked increase in the level of biochemical markers. Whereas oral administration of *T. erecta* extract at doses of 200 mg/kg, 400 mg/kg and 600 mg/kg to rats with $CCl_4$-induced hepatitis contributed to a significant decrease in the level of biochemical markers, which is comparable to the results after the use of silymarin [62]. In the next study [63], the authors studied the hepatoprotective and antioxidant activity of *T. erecta* root extract in a model of ethanol-induced hepatitis. The use of *T. erecta* extract contributed to the improvement of biochemical indicators of blood and the structure of the liver at the histological level, damaged as a result of experimental hepatitis.

Hydroxycinnamic acids contained in flower inflorescences and herbs of different types of marigolds have antioxidant, antimicrobial, anti-inflammatory, analgesic, hepatoprotective and wound-healing activity [28].

***Antitumor activity***

Alvarado-Sansininea J. J. et al (2020) aimed at studying the antitumor activity of flavonoids isolated from flower inflorescences of african and french marigolds. Quercetin, quercetagetin and patuletin have been shown to have antiproliferative activity. In addition, replacement at the C6 position of the flavonoid skeleton of quercetin and patuletin potentiates the antiproliferative activity, which is manifested by activation of apoptosis, its internal pathway. In addition, quercetin and quercetagetin showed selective proapoptotic activity against the lung cancer cell line SK-Lu-1 [24].

***Antiprostatic activity***

The efficacy of the aqueous decoction of *T. patula* was studied in relation to chronic non-bacterial prostatitis in a rat model induced subcutaneously with estradiol in castrated male rats. Decoction of *T. patula* in small doses significantly facilitated the course of prostatitis. Low doses of polysaccharide and supernatant in *T. patula* reduced IL-1β, TNF-α, PSA and EGF levels and improved testosterone and dihydrotestosterone levels *in vivo*. Flavonoids and polysaccharides have been effective components against prostatitis, and this effect may be mediated by maintaining hormone balance and reducing the level of mediator inflammation of the prostate [66].

***Application in ophthalmology***

It is impossible not to mention the use of plants of the genus *Tagetes* to improve the condition of the retina due to the action of lutein and zeaxanthin, which are the main representatives of xanthophylls in their composition. Lutein and zeaxanthin (a carotenoid formed directly in the retina from lutein) and present in the macula of the human eye (zeaxanthin mainly in the macular area and lutein throughout the retina) can penetrate the eye tissue; regulate visual acuity, prevent retinal aging. These carotenoids have a positive effect on blood microcirculation and strengthening of retinal blood vessels, reduce the development of cataracts and age-related macular degeneration [66]. Lutein reduces eye fatigue after prolonged work at the computer, reading, under artificial light, protects the retina from bright light, prevents cataracts, absorbs ultraviolet light, improves visual acuity. Like some other carotenoids, including lycopene and beta-carotene, lutein has pronounced antioxidant properties, it protects cellular structures from destruction by free radicals, has an immunomodulatory effect, reduces the risk of cardiovascular, cancer and infectious diseases, mitigates harmful factors, environment, increases the body's adaptive capacity, resistance to stress [9, 67].

***Application in agriculture***

In addition, different species of marigolds are studied in agriculture for their fungicidal, bactericidal and insecticidal activity. Thus, acetone extract of *T. patula*

has a pronounced larvicidal effect against *Aedes aegypti* [68]. Indian folk veterinary medicine uses drops of extract from anthodiums of *T. erecta* in cows and buffaloes for otitis [69], and uses the leaves to stop bleeding and repair broken horns, external injuries and eye diseases [70]. In southern Ethiopia, leaves and stems of *T. minuta* are ground, mixed with water and given orally to cattle and sheep affected by anthrax and amebiasis [71]. Marotti I. et al. (2010) propose the use of marigold plants as biocidal crops for pest control [33].

## Conclusions

Analysis of world experience in the use of plants of the genus *Tagetes* in folk medicine, experimental studies on the phytochemical composition of plants of this genus and a wide range of their pharmacological activity showed that the aboveground organs of different species of plants of the genus *Tagetes (T. patula, T. erecta, T. minuta)* can be considered as promising raw materials for further research and development of new phytomedicines with a wide range of pharmacological activity.

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