

# PLANT RAW MATERIAL AS A SOURCE OF METABOLITES FOR WOUND HEALING AND ANTI-SCARRING PRODUCT

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Cosmeceutical products based on plant raw materials have a complex effect, are available, and low-toxic. The creation of new natural products for wound healing without tissue scarring is topical. For this, the secondary metabolites of the plant must demonstrate antibacterial, anti-inflammatory, and antioxidant effects, and have low cytotoxicity.

*Aim.* To conduct an analysis of literary sources in electronic databases, regarding products on the market with a wound healing effect and plant raw materials that would have a therapeutic effect on wound healing without the formation of scars.

*Results.* The characteristics of four types of scars are described. Plants and secondary metabolites are listed according to their action: antibacterial, antioxidant, anti-inflammatory, collagen-stimulating, and anti-scarring. Lupeol, allicin, and cinnamaldehyde show antibacterial effect; quercetin, resveratrol, luteolin, naringenin, gallic acid, and curcumin show antioxidant effect; asiatic acid, pinocembrin, and myricetin show anti-inflammatory effect. Cryptotanshinone, bexarotene, taspine, sesamol, and astragaloside IV contribute to the deposition of fresh collagen in the wound. On the Ukrainian market, there are natural wound healing products in the form of a balm, cream, and gel. They include vegetable oils, essential oils, extracts of *Thymus L.*, *Arnica montana*, *Inula helenium*, *Aloe vera*, *Matricaria chamomilla*, etc. Wound healing medicinal products of a chemical nature occupy a large part of the Ukrainian market, among them the products with dexapentanol predominate. The use of the cell culture method as an alternative source of plant raw materials for wound and scar treatment is perspective. The biotechnological method helps preserve biodiversity and obtain chemically pure plant raw materials regardless of environmental conditions.

*Conclusions.* The study demonstrates the possibilities of using plant raw materials to create new cosmeceuticals with wound healing and anti-scarring effects for use in combined therapy.

**Key words:** cosmeceuticals, plant biomass, secondary metabolites, wound healing effect, anti-scarring effect.

Since ancient times, people have studied the effects of medicinal plants on the body and used this knowledge in practice. About 21,000 species of plants are used as medicinal, most of them in folk medicine, Arab, Indian, Chinese, and Tibetan traditional medicine [1]. All over the world, there is a growing interest in the study, implementation in practice, and use of medicinal plant raw materials and phytopreparations obtained on their basis with therapeutic and prophylactic purposes for many diseases [2]. New valuable medicinal plants are

being discovered by studying the knowledge of folk medicine; study of medicinal plants forgotten by traditional medicine; analysis of all types of plants that grow in a certain area on the content of the main groups of secondary metabolites; research species phylogenetically close to official medicinal plants [1]. Nowadays significant attention is paid to developing innovative products saturated with natural substances with softening, re-epithelializing, astringent, antimicrobial, antioxidant, and anti-inflammatory effects, which accelerate

and improve wound healing, reducing scars [3]. As a result of military actions on the territory of Ukraine, the military and the civilian population receive wounds that heal with the formation of a scar. It is important to create new products based on medicinal plant raw materials that would accelerate wound healing without forming a scar.

The purpose of the work was to analyze literary sources in electronic databases, including Google Scholar, PubMed, Web of Science, ResearchGate, and Scopus about products for wound healing and smoothing scars. To consider plant raw materials that would have a therapeutic effect on wound healing and smoothing scars.

### Scars and skin scarring

Due to the excessive deposition of connective tissue, a scar is formed at the wound site with the help of collagen. A scar (*Cicatrix*) is a connective tissue formation that occurs as a result of reparative regeneration to replace a defect in body tissues. There are four main stages of scar formation: I stage — epithelization (2–2.5 weeks); II stage — swelling (3–4 weeks); III stage — compaction (2–3 weeks); IV stage — softening (3–4 weeks) [4]. Immune cells, fibroblasts, stem cells, and endothelial cells work together to trigger signaling pathways such as transforming growth factor- $\beta$ 1 (TGF- $\beta$ 1), which regulates proliferation, migration, and collagen synthesis of fibroblasts, which leads to rapid healing and scarring [5]. The variety of scars is caused by different mechanisms of their formation [6]. Skin scars are classified into four types [4]:

- Normotrophic scars (*Sicatrix normotrophica*) are flat, light-colored, and quite elastic (close to normal tissues). They are the result normal reaction of connective tissue to trauma [4].

- Atrophic scars (*Cicatrix atrophica*) are soft. They have a pale or pale pink color [7]. They are almost motionless. Atrophic scars are located below the level of the adjacent skin due to insufficient collagen formation. They are the result of low reactions of connective tissue to damage [4]. In many cases, the scar can expand with age [7].

- Hypertrophic scars (*Cicatrix hypertrophica*) are mobile, protruding above the surface of the skin, with a soft or dense structure and typical hypervascularization [6]. They do not spread beyond the injured skin area. Hypertrophic scars arise as a result of excessive

reaction of connective tissue to injury under unfavorable conditions of healing. Usually, the mechanism of hypertrophic scarring is considered the migration and proliferation of keratinocytes, myofibroblasts, and mast cells [8]. Under these conditions, fibroblasts have a low mortality rate and high proliferation rate [9]. Myofibroblasts synthesize excess collagen with high activity and they slow down cell migration [10]; collagen has a disorganized and convoluted arrangement [6]. In the process of wound healing the combination of fibroblasts and myofibroblasts causes excessive production of an abnormal extracellular matrix protein [11]. With the help of keratinocytes and mast cells, proliferative fibroblasts form massive collagen, which leads to the accumulation of extracellular matrix under the dermis and causes scarring [8]. Hypertrophic scars can partially regress 1–1.5 years after the injury [4].

- Keloid scars (*Cicatrix keloidea*) are formed as a result of the excessively pronounced reaction of tissues to trauma, usually with reduced indicators of general immunity and tissue immunity [4]. With the formation of keloid scars, invasion, and hyperproliferation of dermis fibroblasts, increased biosynthesis and accumulation of extracellular matrix are observed. The bundles of collagen are thick, dense, and poorly structured, which leads to the appearance of knots in the deep layers of the skin. One of the reasons for the formation of keloids is the abnormal regulation of the apoptosis pathway. Apoptosis-resistant fibroblasts are unable to stop proliferation and collagen production, which leads to an imbalance of collagen deposition and degradation [12].

Most often, doctors deal with hypertrophic and keloid scars [6].

### Plant raw materials with wound healing and anti-scarring effects

Medicinal products of plant origin have many advantages over chemical products. First of all, they contain various secondary metabolites, which act in a complex manner and have low allergenicity and toxicity. In terms of potency and pharmacological activity, many herbal medicines cannot always be replaced by synthetic ones. However, they can be used in complex treatment [2].

Wound healing and anti-scarring products must have antibacterial, anti-inflammatory, antioxidant effects, and low cytotoxicity. This

can be achieved by using extracts of plant raw materials in the products.

**Antibacterial effect.** Saponins, acemannan, anthraquinone derivatives, aldehydes, alkaloids, stilbenoids, catechins, polyphenol compounds, tannins, and flavonoids contained in extracts of *Aloe vera*, *Ampelopsis japonica*, *Andrographis paniculata*, *Camellia sinensis*, *Celosia argentea*, *Cinnamomum cassia* (cinnamaldehyde), *Commiphora myrrha*, *Entada phaseoloides*, *Hibiscus rosasinensis*, *Lonicera japonica*, *Rheum officinale*, *Sophora flavescens*, *Stemona tuberosa*, *Calendula officinalis* L. (dichloromethane and hexane fractions) [13] have an antimicrobial effect. Substances with such properties include lupeol [14], arnebin-1 (*Arnebianobilis*) [15], lawson (*Lawsonia Alba Lam.*) [16], allicin [17, 18]. The antibacterial activity of compounds can be explained by the inhibition of the synthesis of vital components of bacteria or suppression of their resistance [19]. Tannins exhibit antibacterial properties by suppressing of protein synthesis, modification of nucleic acid metabolism, prevention of changes in cell wall formation, changes in cell membrane function, and inhibition of bacterial growth [20].

The antibacterial effect of flavonoids is realized through inhibition of the synthesis of bacterial nucleic acids, cell membrane functions, and processes of energy exchange [21]. This activity is mainly determined by the substituents in the benzene ring, the hydroxyl group increases the antibacterial effect, while methylation of the hydroxyl group reduces the effect [22]. Flavonoids also have an antifungal effect, they prevent folic acid metabolism and suppress the formation of biofilm (by blocking the enzyme isocitrate lyase). Flavonoids can cause apoptosis [23].

**Antioxidant effect.** A high concentration of oxidants in the wound causes damage to tissues and prevents enzymatic reactions during healing [24]. Because of this, the presence of antioxidants is very important in wound healing agents. Antioxidant substances include quercetin (*Oxytropis falcate Bunge*), resveratrol, catechin, luteolin, syringic acid, metformin, naringenin, gallic acid, ferulic acid, curcumin [13], etc. Extracts of *Astragalus propinquus* and *Rehmannia glutinosa* [25], *Andrographis paniculata* [26], *Angelica sinensis* [27], *Camellia sinensis* [28], *Calendula officinalis* [13], *Carthamus tinctorius* [29,30], *Celosia argentea* [31], *Commiphora myrrha* [32], *Lonicera japonica* [13], *Paeonia suffruticosa* [33], *Panax notoginseng* [34], *Rheum officinale* [35], *Rhodiola imbricata*

[36], *Salvia miltiorrhiza* [37], *Sophora flavescens* [38], *Wedelia trilobata* (luteolin) [39], *Zanthoxylum bungeanum* (alkaloids, terpenoids, flavonoids and free fatty acids) [40] show antioxidant effect. Flavonoids have an antioxidant effect due to the hydrogen atoms of phenolic hydroxyl groups [41].

**Anti-inflammatory effect.** Natural compounds of plant origin with anti-inflammatory properties are asiatic acid (*Centella asiatica*), pinocembrin, ursolic acid (*Hedyotis herbacea*), myricetin (*Tecomaria capensis v. aurea*), apigenin, lupeol (*Bowdichia virgilioides Kunth*), steroid glycosides, verbascoside (*Plantago subulata*), hesperetin, carophylloid (*Calophyllum inophyllum Linn*), artocarpine (*Artocarpus communis*), etc.[13].

Myricetin, carophylloid, verbascoside, and lupeol affect inflammation cytokines (TNF- $\alpha$ , CD68, IL-1 $\beta$ , and others) [42]. Steroid glycosides increase the regulation of genes of early inflammation (IL2, IL4, IL10, CD40LG, IFNG, and CXCL11) and remodeling genes (CTSG, F13A1, FGA, MMP and PLG) [43]. Flavonoids inhibit phosphodiesterase and delay the expression of cAMP (the main pro-inflammatory messenger)[44]. Flavonoids have a long-term effect on the activation and maturation of immune cells [45]. Macrophages are key target cells for the anti-inflammatory effects of flavonoids [46].

**Collagen-stimulating effect.** The function of collagen during wound healing is to attract fibroblasts and promote the deposition of fresh collagen in the wound. Compounds capable of promoting collagen synthesis in the healing process play an important role.

Saponins (*Panax notoginseng*), cryptotanshinone (*Salvia miltiorrhiza* Bge.), bexarotene, taspine, 2-hydroxy-1-naphthaldehyde-isonicotinoylhydrazone (*Daemonorops draco*), sesamol, astragaloside IV (*Astragali Radix*), polysaccharide APS2-1 (*Astragalus membranaceus*), asiaticoside (*Centella asiatica*), gallic acid and quartzetin (*Glycyrrhiza glabra* L.), asiatic acid, alkaloids (*Evolvulus alsinoides*), madecassoside (*Centella asiatica*), triterpenes (*Buddleia scordioides*), deoxyelephantopine (*Elephantopus scaber*), *Calendula officinalis* extract, *Aloe vera* gel stimulates collagen formation [13].

Plant extracts have a complex wound-healing effect due to increased proliferation and mobility of fibroblasts, deposition of collagen and hexosamine in the wound, improvement of re-epithelialization, formation of organized granulation tissue, and influence on signaling pathways of wound



healing. Extracts of *Astragalus propinquus* and *Rehmannia glutinosa* [47], *Ampelopsis japonica* [48], *Arctium lappa* [49], *Angelica sinensis* [50], *Blumea balsamifera* [51], *Caesalpinia sappan* [52], *Calendula officinalis* [53], *Carthamus tinctorius* (hydroxysaflor yellow A (HSYA)) [54], *Celosia argentea* [55], *Centella asiatica* (asiaticoside, triterpenes, madecassoside) [56–58], *Cinnamomum cassia* (cinnamaldehyde [59]), *Curcuma longa* [13], *Daphne genkwa* (biflavonoids, coumarin, diterpenes, and triterpenes) [60], *Hibiscus rosasinensis* [61], *Ganoderma lucidum* [62], *Panax ginseng* (ginsenoside Rb2 [63]), *Panax notoginseng* (triterpenoid saponins) [64,65], *Polygonum cuspidatum* [66], *Lithospermum erythrorhizon* (shikonin, arnebin-1) [67], *Rhodiola imbricata* [68], *Salvia miltiorrhiza* (danshensu (DSU) and salvianolic acid B (SAB)) [69], *Sanguisorba officinalis* [70], *Stemona tuberosa* (stilbenoids, tocopherols) [71] have the indicated complex effect.

Prenylated flavonoids have a well-defined wound-healing effect, they are found in the families *Moraceae*, *Fabaceae*, *Cannabaceae*, *Guttiferae*, *Rutaceae*, *Paulowniaceae*, *Umbelliferae* [72], *Euphorbiaceae* [73], *Celastraceae* [74], *Asteraceae* [75] and *Thymelaeaceae* [76]. Alpinumisoflavone, artocarpine, bavachin, diplacone, glabrene, isobachalcone, sophoraisoflavone A, kazinol B, gancaonin Q, kuanone A, C, E, G, licochalcone A, B, C, E, licoflavone C, lycoflavanone, lonhocarpol A, lupalbigenin, mimulon, morusin, morusinol, papyriflavonol A, warangalone, sophoraflavanone G, tomentodiplacon B, xanthoangelol, xanthohumol, 3-O-methyldiplacol, 3'-O-methyldiplacon, 3'-O-methyl-5'-hydroxydiplacon, 3'-O-methyl-5'-O-methyldiplacon, 4-hydroxy lonhocarpine [77] have numerous benefits actions and participate in wound healing.

**Anti-scarring effect.** Studies show that secondary metabolites affect scarring in different ways. Losartan, chitosan, and asiaticoside are aimed at inhibiting angiotensin-converting enzyme (ACE) and blocking angiotensin receptors (AR) in the TGF- $\beta$ /Smad pathway, which is a classical signaling pathway that contributes to the formation of scars [78]. An important driver of the scarring process is TGF- $\beta$ 1, therefore, decorin, (-)-epigallocatechin-3-gallate (EGCG) and other substances are used to inhibit the activity of this factor [79, 80]. Decreased TGF- $\beta$  production suppresses collagen type 1 accumulation, reduces fibroblast proliferation, and induces apoptotic cell

death. A number of compounds target the genes involved in the formation of scars, thus inhibiting the scarring process: the FGF2 gene is affected by NPC-18 (trafermin); the PI3KCA gene is affected by BEBT-908, Bimiralisib, SF-1126, Copanlisib. For such substances, the development of targeted products is promising [81].

Extracts of *Arctium lappa* [13], *Astragalus propinquus*, *Rehmannia glutinosa* [47], ANBP (a combination of *Agrimonia eupatoria* (A), *Nelumbo nucifera* (N), *Boswellia sacra* (B) and pollen of *Typha angustifoliae* (P) [13]), *Camellia sinensis* (EGCG) [80], *Ligusticum striatum* [13] have anti-scarring activity.

For the treatment of hypertrophic scars, five preparations based on medicinal plant raw materials are described: 10-HCPT (*Camptotheca acuminata*) encapsulated in liposomes [82,83], oxymatrine-phospholipid complex (OMT- PLC) (*Sophora flavescens*, *Sophora alopecuroides*, *Sophora subprostrata*) [84], solid hydrogel with lipid nanoparticles (SLN-gel) (*Astragalus membranaceus*) [85], ginsenoside Rg3/poly(l-lactide) (G-Rg3/PLLA) (*Red Panax ginseng*) [86], encapsulated extract of *Centella asiatica* [87]. Some plant extracts are prepared in the form of injections for deep anti-scarring treatment (*Carthamus tinctorius* extract) [88].

### Treatment of scars

In 2002, at the consensus of the International Advisory Group on Scar Management, approaches to the treatment of scars were systematized [89]. The traditional methods of treating scars are mostly based on surgical excision, pressotherapy, radiation therapy, injections into the thickness of the scar, and laser therapy. These methods are aimed at stimulating angiogenesis, reducing the inflammatory response, and controlling cell proliferation and extracellular matrix deposition. One of the important problems of skin regeneration remains the restoration of tissues of the microcirculatory vascular bed, hair follicles, and sweat glands [90, 91].

In 2012, approaches to treatment were updated and products containing silicone were put in the first place [89]. Analyzing the market of drugs with anti-scar effects, there are silicone-based gels “Nascar” (Great Britain), “Ketolan” (Cyprus), “Dermatics Ultra” (USA), “Strataderm” (Switzerland), “Biotrade Scarex” (Bulgaria), cream “Dermofibreze” (Ukraine). “Dermofibreze” also contains plant extracts of *Spongilla*,

*Allium porrum*, *Allium cepa*. These drugs are therapeutic and prophylactic agents against wounds and scars. Products with panthenol (“Depanzan”, “Panthenol-spray”, “Pantestin-Darnytsia”, etc.) are also used to treat burns [92]. Some products with anti-scarring and wound healing effects based on plant raw materials are presented in Table 1.

Plant essential oils consist of monoterpenes, sesquiterpenes, oxygenated monoterpenes, oxygenated sesquiterpenes, and phenolic compounds. They are one of the important therapeutic ingredients that are used in the development of new therapeutic agents, due to their antitumor, antiviral, antidiabetic, antibacterial, antioxidant, and aromatherapeutic effects.

*Hippophae rhamnoides* oil has antioxidant, anti-inflammatory, antimicrobial, and analgesic effects, stimulates epithelization processes and granulation [93]. *Rosa* L. oil has anti-inflammatory, antimicrobial, and

analgesic effects. *Lavandula* L. and *Geranium* L. oils have an antiseptic effect [94]. Extracts of Pine resin, *Thymus* L., *Arnica montana* have antiseptic activity. *Arnica montana* extract also has hemostatic and wound-healing effects. *Eucalyptus* oil promotes wound healing and has bactericidal, pain-relieving, anti-inflammatory activity. *Matricaria chamomilla* exhibits analgesic, antimicrobial, anti-inflammatory, and antipruritic effects. *Citrus limon* oil has a reparative effect [94]. *Inula helenium* extract has an antiseptic and anti-inflammatory action, used to treat wounds that do not heal for a long time. *Melissa officinalis* extract has anti-inflammatory and antiseptic activity. *Aloe vera* extract has wound-healing and anti-inflammatory properties, used to increase the resistance to infectious diseases. *Kalanchoe daigremontiana* extract has a similar effect. *Allium cepa* when applied externally has antiseptic, pain-relieving, anti-itching, wound healing, and depigmenting

Table 1

**Products with anti-scarring and wound healing effect based on plant raw materials [92]**

Release form	Active substances	Name	Producer
Liquid (Balm)	Hippophae rhamnoides oil, clarified butter, turpentine oil, vitamin E, beeswax, naphthalene oil, Rosa L., Lavandula L., Melaleuca L. essential oils.	Spasatel Forte	Poland
	Pine resin extract, Thymus L. extract, Arnica montana extract, wheat germ oil, Eucalyptus L. oil, Lavandula L. oil, Citrus bergamia oil, Melaleuca L. oil, polyethylene glycol ester of alpha-tocopherol.	Zhyvytsya	Ukraine
	Ghee, propolis, mumiyo, Hippophae rhamnoides oil, wheat germ oil, natural honey, Geranium L. oil, terpene oil, vaseline oil, lecithin, pine resin, birch bark tar, camphor, vitamin E.	Mintalon	Ukraine
	Hippophae rhamnoides, Matricaria chamomilla, Olea europaea natural oils, Citrus limon, Lavandula L. essential oils, beeswax, oil extract of Rumex confertus, vitamins A, B, C, E, lanolin.	Phytobalm Adverso “For wound healing”	Ukraine
Liquid (Cream-balm)	Pinus L. extract, Arnica montana extract, Inula helenium extract, Melissa officinalis extract, Aloe vera extract, Matricaria chamomilla extract, Lavandula L. essential oil, Eucalyptus L. essential oil, menthol.	Tsilytel	Ukraine
Soft (Cream)	Matricaria chamomilla extract, Aloe vera extract, shea butter, Melaleuca L. oil, colloidal silver, D-panthenol.	EXpress Opik	Ukraine
	Hippophae rhamnoides, Aloe vera, Kalanchoe daigremontiana, Populus tremula bark, wheat germ oil, Amaranthus.	Cream Dr. Trav Ranozhiv for wound healing	Ukraine
Soft (Gel)	Bischofite, Allium cepa extract, D-panthenol, Laminaria L. extract, Mentha piperita essential oil, olive oil ether.	Anty-rubets Mg ++	Ukraine

Table 2

## Wound healing drugs on the Ukrainian market [92]

Release form	Active substances	Name	Producer
Chemical origin			
Soft (Gel)	Dexpanthenol, miramistin	Pantestyn-Darnytsia	Ukraine
	Thyrothricin	Tyrosur	Germany
Soft (Cream)	Dexpanthenol, chlorhexidine dihydrochloride	Bepanten plus	Germany
		Panthenol plus	Ukraine
	Dexpanthenol	Pantecrem	
	Dexpanthenol, chlorhexidine, benzalkonium chloride	Panthenol- Zdorovya	
Soft (Ointment)	Mefenamine sodium salt, vinilinum	Mefenat	Ukraine
	Thiotriazoline	Dalmaxin	Germany
	Malic acid, benzoic acid, salicylic acid	Acerbin	
	Methyluracil, miramistin	Methyluracil with miramistin	
	Methyluracil, chloramphenicol	Levomekol	Germany
	Dexpanthenol	Panthenol-Teva	
Aerosol (Skin foam)	Dexpanthenol	Panthenol aerosol	Ukraine
		Panthenol	
		Hepiderm- Zdorovya	
	Dexpanthenol, allantoin	Hepiderm forte	
Aerosol (Spray)	Dexpanthenol, chlorhexidine digluconate	Bepanten plus	Germany
		Panthenol-plus	Ukraine
	Dexpanthenol	Panthenol Spray	Germany
Liquid (Solution)	Retinol acetate, alpha-tocopherol acetate, menadione, beta-carotene	Aecol	Ukraine
	Polyvinylbutyl ether	Vynilin (Shostakovsky's balm)	
	Brilliant green	Brilliant green	
Soft (Laniment)	Chloramphenicol (synthomycin)	Sintomycin liniment	
Natural origin			
Soft (Gel)	Deproteinized hemoderivative from the blood of calves	Solcoseryl	Switzerland
Soft (Ointment)	Calendula officinalis extract	Kalenduly maz	Ukraine
	Propolis extract, carophyllene, Styphnolobium japonicum extract, Potentilla erecta extract, Achillea millefolium extract.	Wundehill	
	Symphytum officinale extract, vitamin E oil solution 98%	Zhyvokostu maz	
Liquid (Extract)	Extract of Salvia officinalis leaves	Shavliyi nastoyka	Ukraine
Liquid (Oil)	Rosa canina oil	Shypshyny oliya	Ukraine
Soft (Suppositories)	Phenolic hydrophobic propolis preparation	Propolis	Ukraine
Solid (Lyophilisate for solution for injection)	Chymotrypsin	Chymotrypsin krystalichnyy	Ukraine
Combined origin			
Aerosol	Hippophae rhamnoides oil, chloramphenicol, benzocaine, boric acid	Olazol aerosol	Ukraine

effects. *Mentha piperita* accelerates wound healing and has antifungal and analgesic effects [94].

Wound healing medicinal products of a chemical nature contain antibiotics, nonsteroidal anti-inflammatory substances, antiseptics and disinfectants, fat-soluble vitamins, and organic acids as an active ingredient. Natural therapeutic products with a wound healing effect include tinctures and oils of medicinal plants, enzymes, and blood components. Combined products contain medicinal plants oils and antibiotics. Wound healing drugs are produced in various forms: ointment, gel, cream, foam, spray, and solution (Table 2).

Due to the content of metabolites in plants, their extracts show different biological actions. For example, *Calendula officinalis* has anti-inflammatory and antiseptic properties, promotes wound healing, it is used for depigmentation of freckles. Extracts of the fruits of *Sophora japonicum* are used to heal purulent wounds, burns, and ulcers. *Potentilla erecta* has a pain-relieving, hemostatic effect, and helps wound healing. *Achillea millefolium* shows hemostatic, antiseptic, and anti-inflammatory properties. *Symphytum officinale* is used externally to accelerate wound healing. *Salvia officinalis* galenic products have anti-inflammatory, astringent, and disinfectant effects. *Rosa canina* oil is used for healing wounds, and for the treatment of stomatitis and dermatoses [94].

For products based on plant raw materials, a large amount of biomass is needed throughout the year. Plant raw materials are obtained by an alternative biotechnological method of tissue culture for the preservation of plant biodiversity, used throughout the year, regardless of the quality of the soil, weather, and seasons, to reduce the price. It can be used for the production of pharmacocosmeceuticals, namely to obtain plant biomass *in vitro* using a nutrient medium in sterile conditions. The advantages of the method are simple modeling of the process, which allows obtaining clean

biomass with a large number of secondary metabolites, and the process can be scaled up to industrial volumes. Biomass obtained *in vitro* is environmentally friendly, its production does not depend on environmental conditions and does not require the use of large land areas [95–99]. The use of the method of tissue culture is not indicated in all products on the Ukrainian market.

Taking into account the fact that due to the war, many territories of Ukraine became unsuitable for the collection of medicinal plant raw materials, the *in vitro* tissue culture method will provide an opportunity to obtain plant biomass with the necessary secondary metabolites in laboratory conditions.

## Conclusions

Antibacterial, anti-inflammatory, antioxidant, collagen-stimulating effects are typical for wound healing and anti-scarring therapeutic and cosmeceutical products. An analysis of plant raw materials that would possess these properties was conducted. On the Ukrainian market, the majority of therapeutic and preventive products with a natural composition have a wound healing effect but do not guarantee the smoothing of scars. Combined therapy has a promising effect in the treatment of scars, capable of suppressing the spread of scars. Plant raw materials obtained *in vitro* can be an alternative source in the development of pharmaceuticals, cosmetics, and hygiene products. The article systematizes data that will help researchers and manufacturers of cosmeceutical products to create a new effective natural product with a wound-healing effect that prevents scarring.

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### Authors' contribution

KIH — data collection and analysis; ROP — manuscript review and editing.

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## РОСЛИННА СИРОВИНА ЯК ДЖЕРЕЛО МЕТАБОЛІТІВ ДЛЯ РАНОЗАГОЮВАЛЬНОГО ТА ПРОТИРУБЦЕВОГО ЗАСОБУ

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Космецевтичні препарати на основі рослинної сировини проявляють комплексну дію, є доступними та малотоксичними. Актуальним є створення нових натуральних засобів для загоєння ран без рубцювання тканини. Для цього вторинні метаболіти рослини повинні проявляти антибактеріальну, протизапальну, антиоксидантну дію, мати низьку цитотоксичність.

*Мета.* Провести аналіз джерел літератури в електронних базах даних щодо засобів на ринку з ранозагоювальною дією та щодо рослинної сировини, яка б мала терапевтичну дію для загоєння ран без утворення рубців.

*Результати.* Описано характеристики чотирьох типів рубців. Рослинні та вторинні метаболіти наведено згідно їхньої дії: антибактеріальна, антиоксидантна, протизапальна, колагенестимулювальна, протирубцева. Антибактеріальну дію проявляють лупеол, аліцин, коричневий альдегід; антиоксидантну дію — керцетин, ресвератрол, лутеолін, нарінгенін, галову кислоту, куркумін; протизапальну дію — азійська кислота, піноцембрин, мірицетин. Сприяють відкладенню свіжого колагену в рані криптаншинон, бексаротин, таспін, сезамол, астрагалозид IV. На ринку України присутні ранозагоювальні натуральні засоби з формою випуску бальзаму, крему, гелю. До їхнього складу входять рослинні олії, ефірні олії, екстракти *Thymus L.*, *Arnica montana*, *Inula helenium*, *Aloe vera*, *Matricaria chamomilla* та інші. Ранозагоювальні лікарські препарати хімічної природи займають більшу частину ринку України, серед них переважають засоби з дексапентанолом. Перспективним є використання методу культури клітин як альтернативного одержання сировини для засобів лікування ран та рубців. Біотехнологічний метод допомагає зберегти біорізноманіття та отримати хімічно чисту сировину незалежно від умов середовища.

*Висновки.* Дослідження демонструє можливість використання рослинної сировини для створення нових космецевтичних засобів із ранозагоювальною та протирубцевою дією для використання у комбінованій терапії.

**Ключові слова:** космецевтичні засоби, рослинна біомаса, вторинні метаболіти, ранозагоювальна дія, протирубцева дія.