Review article / Artykuł przeglądowy

OPEN ACCESS

Joanna Kryst 0000-0003-4516-8723

Department of Chemistry and Biochemistry, Institute of Basic Sciences, Department of Physical Rehabilitation
Academy of Physical Education in Kraków, Al. Jana Pawła II 78, 31-571 Kraków
+48 12 683 11 54 *joanna.kryst@awf.krakow.pl*

Sposób cytowania / Cite Kryst J. Cosmetics containing turmeric in the light of the results of scientific research. *Aesth Cosmetol Med*. 2023;12(5):169-174. https://doi.org/10.52336/acm.2023.016

Cosmetics containing turmeric in the light of the results of scientific research

Kosmetyki zawierające kurkumę w świetle wyników badań naukowych

ABSTRACT

In recent years, cosmetics containing substances of natural origin have become increasingly popular. Turmeric and the bioactive substances extracted from it, are the subjects of research not only in medicine but also to demonstrate the positive effects of turmeric on skin conditions.

The study aimed to present the results of scientific research on the potential applications of turmeric and its isolates in dermocosmetics.

Recents studies indicate that curcumin isolated from turmeric has strong antioxidant activity and skin photodamage-minimising properties. Additionally, due to inhibition of enzymes responsible for the degradation of collagen and elastin in the skin, curcumin is expected to be used in formulations that reduce the signs of ageing. On the other hand, the anti-inflammatory and antimicrobial effects of active substances extracted from turmeric can be applied in preparations intended for acne-prone skin. It is also important that the ingredients of the cosmetic preparation provide stability to the active substances extracted from turmeric and increase their penetration into the deeper layers of the skin.

Keywords: skin, turmeric, curcuminoids, dermocosmetics, cosmetics, scientific research

STRESZCZENIE

W ostatnich latach coraz większym zainteresowaniem cieszą się kosmetyki zawierające substancje pochodzenia naturalnego. Kurkuma i pozyskiwane z niej substancje bioaktywne są przedmiotem badań nie tylko w medycynie, ale również mających na celu wykazanie pozytywnego wpływu kurkumy na stan skóry.

Celem pracy było przedstawienie wyników badań naukowych, dotyczących potencjalnych zastosowań kurkumy i pozyskiwanych z niej izolatów w dermokosmetykach.

Badania te wskazują, że izolowana z kurkumy kurkumina ma silne działanie przeciwutleniające oraz właściwości minimalizujące fotouszkodzenia skóry. Dodatkowo, z uwagi na hamowanie aktywności enzymów odpowiedzialnych za degradację kolagenu i elastyny w skórze, kurkumina powinna znaleźć zastosowanie w preparatach redukujących oznaki starzenia. Natomiast działanie przeciwzapalne i przeciwdrobnoustrojowe substancji aktywnych pozyskiwanych z kurkumy może zostać wykorzystane w preparatach przeznaczonych do skóry trądzikowej. Ważne jest również, aby składniki preparatu kosmetycznego zapewniały stabilność substancjom aktywnym pozyskiwanym z kurkumy i zwiększały ich przenikanie w głębsze warstwy skóry.

Słowa kluczowe: skóra, kurkuma, kurkuminoidy, dermokosmetyki, kosmetyki, badania naukowe

INTRODUCTION

The rhizome of the long-stemmed oyster (*Curcuma longa* L.) has been used for more than 6,000 years in traditional medicine and for religious practices in Southeast Asia. It is also called yellow root, golden spice or Indian saffron. It was brought to Europe in the 13th century. The main exporter of this plant is India, where traditional medicine recommends the use of the powdered rhizome of the long spurge, called turmeric, for a number of health problems, mainly inflammation, skin disorders and infections. Turmeric is also one of the oldest cosmetics, as it was traditionally applied to the skin by women to give it a yellowish tone [1].

Scientific research allows to assess how the compounds contained in turmeric affect processes in the human body, and thus determine for which therapeutic as well as cosmetic purposes they can be used. The turmeric rhizome contains numerous chemical substances with a variety of effects. In addition to carbohydrates, proteins, lipids, minerals and traces of B vitamins and vitamin C, there are curcuminoids which account for 3 to 5% of the chemical composition of turmeric and are its most valuable component. More than 70% of the curcuminoids mentioned are curcumin. The others include demethoxycurcumin (about 16%), bisdemethoxycurcumin (about 8%) and cyclocurcumin. These compounds give turmeric its yellow colour. The essential oils, containing sesquiterpenes (including turmerone) as well as phalladrene, sabinene, cineole, borneol and zingiberene, are mainly responsible for the aroma [2].

Curcumin has been shown in studies to have a variety of biological effects, including anti-inflammatory, antimicrobial, anticancer, antioxidant, hypoglycemic, wound healing acceleration, chemoprevention, and sensitization of cancer cells to chemo- and radiotherapy. This broad variety of biological benefits makes long-stemmed turmeric a useful raw material for the cosmetic sector, which is the third largest consumer of turmeric-containing goods (after the pharmaceutical and food industries) [3]. Due to the very low bioavailability of the chemicals found in turmeric when consumed with food, the use of turmeric in dermocosmetics appears to be a promising technique for leveraging its potential to alter skin problems. Curcuminoids are extremely water-insoluble, unstable in alkaline conditions, and rapidly metabolised in the body. A relatively tiny percentage of the active chemicals included in orally swallowed turmeric enter the bloodstream (up to 80% of ingested curcumin is predicted to not reach the bloodstream) [4].

TURMERIC AND CURCUMIN

The main bioactive ingredients of turmeric are curcumin and its derivatives, generally known as curcuminoids, which exhibit a broad spectrum of biological activities. One of the most important properties of curcuminoids is the prevention of cell and tissue damage caused by reactive oxygen species (ROS) and free radicals. ROS and free radicals are formed both as a result of exposure to external factors (e.g. ultraviolet radiation, cigarette smoke, environmental pollutants) and due to physiological processes in the body (e.g. intracellular respiration). Excessive amounts of ROS in the body are a cause of oxidative stress, leading to cell and tissue damage. Processes initiated by ROS are the reason of changes in skin elasticity, premature ageing and skin cancer. Substances that scavenge ROS, reduce the formation of free radicals or counteract their action are called antioxidants. Curcuminoids' potential in cosmetics is due, among others, to their antioxidant properties [5, 6].

One of the key factors of ROS formation is ultraviolet radiation (UV), defined as electromagnetic radiation with a wavelength between 200 and 400 nm. A distinction is between three ranges of UV radiation: UVA with the longest wavelength (320-400 nm), UVB of intermediate (280-320 nm) and UVC with the shortest wavelength (200-280 nm). UVC radiation is practically entirely absorbed by the Earth's ozone layer, while UVA and UVB reach the lowest layers of the atmosphere. UVB radiation (representing only about 5% of the UV radiation reaching the earth's surface) is retained for the absolute most part in the epidermis and does not reach the deeper layers of the skin. It is responsible for the erythema produced on the skin and the subsequent browning of the skin during sunbathing, the thickening of the epidermis, DNA damage and the initiation of inflammation in the skin and the generation of oxidative stress. UVA radiation (which accounts for about 95% of UV radiation) penetrates into the deeper layers of the skin, where it generates the formation of ROS and causes the reorganisation of the intercellular matrix. Among others, metalloproteinases (MMPs), responsible for the degradation of collagen and elastin, are activated, thus contributing to a decrease in skin elasticity and the formation of wrinkles [7].

RESULTS OF THE REVIEW

Action to minimise photodamage to the skin

The results of the study by Djawad et al. suggest that curcumin may act as a counteracting agent against the negative effects of skin exposure to UVB radiation. In the experiment, a short-term (up to 7 days) topical application of curcumin solution at concentrations ranging from 0.1 µM to 100 µM was used on the skin of mice prior to UVB exposure. The application of curcumin was observed to lead to a reduction in the number of cells that underwent programmed cell death (apoptosis) as a result of UV radiation. The most beneficial effects were observed with the highest concentration of curcumin analysed

(100 µM). Inactivation of ROS, formed by UVB radiation and causing damage to nucleic acids, proteins and lipids, is the postulated mechanism responsible for the observed effects of curcumin in this study [8]. The outcomes of another study indicate that topical application of curcumin in mice in the concentration range of 100 nM to 100 µM prior to UVB exposure (3 times a week for 3 weeks) also led to a reduction in the effect of thickening of the stratum corneum, typical of photo-ageing lesions. In this aspect, the most beneficial effects were obtained using the highest concentrations of curcumin tested - 10 µM and 100 µM [9].

In a study by Zheng et al., it was observed that also an essential oil extracted by hydro-distillation from turmeric could counteract UV-induced skin damage. The use of turmeric essential oil inhibited photo-ageing changes induced by prolonged (8 weeks) exposure to UVB radiation. In the skin of nude mice exposed to UV radiation, a thickening of the stratum corneum was observed, and the effect was significantly reduced in mice that received regular topical application of turmeric essential oil at a concentration of 5% or 10%. As repeated UVB exposure can lead to inflammation, the study also analysed levels of the pro-inflammatory cytokines such as interleukin-1β and tumour necrosis factor -α (TNF-α) in a biopsy from mouse skin. Pro-inflammatory cytokine levels in skin biopsy were significantly lower in mice treated with essential oil derived from turmeric, compared to control mice (which were not treated with oil during the 8-week UVB exposure). These results suggest a reduction in inflammation in the skin, induced by UV exposure, as a result of topical application of essential oil extracted from turmeric [10]. Similar anti-inflammatory effects of compounds contained in turmeric were demonstrated in cell cultures of human keratinocytes (cells that form the epidermis). After UVB radiation exposure, the expression of interleukin-1β and TNF-α were significantly lower in cells incubated with *C. longa* root extract (at a concentration of 600 µg/ml), compared to control keratinocytes (incubated without added extract) [11]. Another study in cultured human keratinocytes showed that short-term exposure to UVB radiation causes damage to cell membrane integrity and a dramatic increase in cellular levels of ROS. Both of these effects of UVB exposure were significantly reduced by prior incubation of the cells with curcumin applied at a concentration of 10 mM. In addition, a comet assay which demonstrate DNA damage in cells showed that incubation of keratinocytes with curcumin reduced UVB-induced DNA damage [12]. The authors of this study also analysed the effect of topical application of curcumin (2 mg/ml) to the skin of nude BALB/c mice, prior to short-term (3 days) exposure to high doses of UVB radiation. Curcumin application led to a reduction in the infiltration of inflammation-specific cells in the skin, a significant influx of which was observed in control mice (exposed to UVB radiation but without curcumin application). Moreover, damage caused by ROS generated by UVB exposure and causing lipid peroxidation was significantly lowered in the curcumin-treated group of mice [12].

Heng et al. presented case reports of patients with pronounced photodamaged skin treated with curcumin gel. Regular and long-term (at least 6 months) application significantly improved the appearance of the skin reducing keratosis. One proposed explanation for the observed results is that curcumin promotes apoptosis in cells that have been exposed to UV light [13].

In contrast, a randomised, double-masked clinical trial analysed the effect of a gel containing plant extracts (with 0.1% tetrahydrocurcumin) on symptoms of photo-ageing. According to the participants' opinion, the use of the gel for 4 weeks was significantly more effective than the placebo, which was confirmed by objective measurement using a device that allows the assessment of skin elasticity. The interpretation of this study is problematic, however, as the product used was a combination of plant components (in addition to tetrahydrocurcumin, it also contained extracts of rosemary and Centella Asiatica) and dimethylaminoethanol, so it is difficult to attribute the observed effects to only one ingredient [14].

Reduction of hyperpigmentation

Exposure to UV radiation is one of the main causes of skin hyperpigmentation. UV leads to the formation of ROS, which in turn activate melanogenesis - the biochemical pathway in which the amino acid L-tyrosine is converted into the skin pigment melanin. Many substances exhibit the ability to inhibit the melanin biosynthesis pathway. However, their use is often associated with adverse effects. For this reason, naturally occurring substances with antioxidant effects are expected to inhibit melanogenesis. In guinea pig skin biopsy exposed to UVB radiation for 2 weeks, a significant reduction in hyperpigmentation was observed in objects that received topical application of a preparation containing extracts of turmeric (500-1000 µg/ml) and cucumber quail (*Momordica charantia* L.) - commonly referred to as bitter melon - throughout the study period. The observed effects were equivalent to or even superior to the use of a commercially available product comprising, among other things, hydroquinone - a tyrosinase inhibitor with known melanogenesis inhibiting efficacy [15]. In the aforementioned case reports of patients with photodamaged skin, regular use of curcumin gel led to a significant lightening of skin discolouration resulting from exposure to UV [13].

Anti-ageing and anti-inflammatory action

Skin ageing is mostly caused by changes that occur in the extracellular matrix, which fills the spaces between cells in tissues, including the skin. The extracellular matrix contains a network of collagen and elastin fibres that give the skin its strength and elasticity. The activation of proteolytic enzymes, such as collagenase and elastase, degrades collagen and elastin fibres, contributing to its ageing with visible symptoms such as wrinkles, loss of elasticity and tension. Therefore, compounds are being sought in natural ingredients to reduce the expression or activity of the enzymes responsible for the degradation of the above fibres, thus delaying skin ageing. In a study by Liu et al. human fibroblasts (cells that produce collagen and elastin proteins in the skin) were incubated with curcumin and then exposed to UVA. It was shown that curcumin applied at a concentration of 5 µM significantly reduced the UV-enhanced expression of enzymes responsible for collagen degradation (metalloproteinases: MMP-1 and MMP-3). These results further suggest that curcumin may protect the skin against photodamage caused not only by UVB radiation, as described previously, but also by UVA radiation, which accounts for 95% of the radiation reaching the earth's surface. Curcumin also reduced ROS accumulation in UVA-exposed human fibroblasts and partially restored the cells' natural protective mechanisms against oxidative stress. Indeed, an increase in the activity of antioxidant enzymes (superoxide dismutase and catalase) and glutathione, which participate in antioxidant reactions, was observed in curcumin-treated fibroblasts [16]. These results suggest that curcumin may reduce the expression of collagen-degrading enzymes and minimise UVA-induced damage in human fibroblasts.

The inhibition of gelatinase activity, which is involved in collagen degradation, by an extract obtained from the root of *C. longa,* was demonstrated in a study by Muta et al. By purifying the extract, the authors showed that curcuminoids, among which curcumin was the main component, were the most effective in inhibiting gelatinase activity. The authors also showed that monthly application of a cream with *C. longa* extract resulted in a significant increase in the elasticity of the subjects' facial skin, as measured using a cutometer [17].

In relation to the anti-ageing effect, the results of the study by Jugreet et al. showed that out of the 10 essential oils tested, isolated from aromatic medicinal plants, the oil extracted from *C. longa* showed the greatest efficacy in inhibiting the activity of elastase and collagenase - enzymes involved in the degradation of fibres responsible for skin elasticity and strength. It is likely that the turmerone present in *C. longa oil* is mainly in charge of inhibiting the activity of these enzymes. According to research, the essential oil extracted from turmeric may have an anti-aging effect on the skin, as well as antifungal and antibacterial activity against *Mycobacterium* bacteria, which cause infections in humans [18].

In contrast, in the cell culture of human fibroblasts, 24-hour incubation with curcumin at a concentration of 2 µM increased the expression of proteins (tropoelastin and fibrillin-1), key to the formation of elastin fibres in the intercellular space. The results of this study suggest that curcumin may be used in dermocosmetics as an active substance to stimulate elastin fibre formation [19].

On the other hand, Di Lorenzo et al. evaluated the effects of a cream containing curcumin (the percentage in the cream was 0.02%) in women aged 40 to 65 years. In addition, some of the participants took orally a nutricosmetic containing curcuminoids (70 mg once a day). The use of the curcumin cream for 4 weeks led to an improvement in the skin's elasticity. An ultrasound examination showed a thickening of the skin, probably resulting from an increase in collagen as a result of the curcumin preparation. The effect of the study used was a shallowing of wrinkles [20]. The increase in collagen synthesis as a result of topical application of curcumin gel was also confirmed in an animal model, in which the effect of curcumin on wound healing was analysed [21].

One aspect associated with the use of curcumin/curcuminoids is their effective delivery to the deeper layers of the epidermis and skin. In studies using skin fragments taken from donors, high penetration of curcumin into both the dead stratum corneum and its living layer and dermis was demonstrated. Curcumin's good lipid solubility is probably responsible for the observed effects, making it easier for curcumin to overcome the stratum corneum, which is the most difficult skin barrier to cross. After crossing this barrier, curcumin can further penetrate into the deeper layers of the skin [22].

The use of preparations that increase the penetration of curcuminoids may have greater benefits. One study compared a preparation in which curcumin was encapsulated in microbubbles with free curcumin and a commercially available preparation containing curcumin. All 3 formulations were in the form of an ointment and applied topically on the skin of mice. During the study, the skin of the mice was deprived of hair and exposed for 6 weeks (5 times per week) to broad-spectrum UV radiation, including both UVA and UVB. All formulations were applied immediately after UV exposure. Curcumin applied as microcapsules at the highest concentration tested (10 µmol/100 mg) was most effective in minimising the effects of photo-ageing (wrinkle formation and skin damage assessed both macroscopically and histopathologically) and in preventing loss of skin elasticity. Biochemical studies have also shown the high efficacy of curcumin used in the form of microcapsules at concentrations 10 µmol/100 mg in neutralising ROS that cause lipid peroxidation, and the observed effects were more favourable than with a commercially available curcumin-containing preparation. Curcumin encapsulated in microcapsules at lower concentrations (1-3 µmol/100 mg), as well as free curcumin, showed very weak or even no effect in individual tests [23].

SUMMARY

The above-mentioned scientific findings help to clarify the indications for which the use of dermocosmetics containing turmeric or its extracts may be beneficial. Notably, the main active ingredient in turmeric is curcumin, which is responsible for a broad spectrum of biological effects. For this reason, the vast majority of the studies cited evaluated the effects of curcumin. A well-documented effect of curcumin and its isolates is antioxidant action, which enables to neutralise the harmful effects of UV on the skin, resulting from the generation of ROS. Although formulations containing turmeric in their composition do not protect against UV radiation, they are able to reduce the damage that occurs as a result of this exposure, protecting against excessive thickening of the stratum corneum, initiation of inflammation and damage caused by ROS. An important aspect of the action of turmeric and the isolates extracted from it is also the inhibition of the activity of enzymes responsible for the degradation of collagen and elastin, which are stimulated by UV exposure. Since damage to collagen and elastin fibres in the skin is responsible for the symptoms of photo-ageing, dermocosmetics containing turmeric extracts in their composition should be designed to minimise photodamage to the skin. An additional advantage of these cosmetics is the reduction of skin hyperpigmentation resulting from exposure to UV. An important aspect of turmeric and its ingredients is also its antimicrobial and anti-inflammatory effects. These properties can be successfully used in formulations designed for acne-prone skin, in order to minimise the inflammatory process. A major advantage of products containing turmeric or its extracts is the favourable safety profile; however, as with other preparations containing plant extracts, skin allergic reactions may occur in rare cases.

It is important to remember that the effectiveness of a given preparation depends on its effective delivery to the site of action. Although curcumin shows high penetration into the epidermis and deeper layers of the skin, methods are being sought to further enhance its absorption. One promising option for transdermal delivery of the substance, also in cosmetic preparations, are microemulsions and nanoemulsions. These are dispersion systems consisting of water, oil and surfactants, in which the particles are measured in nanometres. Their use can significantly increase the bioavailability of difficult-to-solubilise substances and improve their stability, which is an advantage over classical gels, emulsions and solutions. It has been shown that, in cultures of skin sections taken from donors, the application of a microemulsion containing curcumin (at a concentration of 27.1 mM) increased its penetration into the dermis and reduced apoptosis in epidermal cells induced by UVB exposure [24].

REFERENCES / LITERATURA

1. Gopinath H, Karthikeyan K. Turmeric: A condiment, cosmetic and cure. *Indian J Dermatol Venereol Leprol*. 2018;84:16-21. https://doi.org/10.4103/ijdvl.IJDVL_1143_16
2. Kotha RR, Luthria DL. Curcumin: Biological, Pharmaceutical, Nutraceutical, and Analytical Aspects. *Molecules*. 2019;24(16):2930. https://doi.org/10.3390/molecules24162930
3. Sharifi-Rad J, Rayess YE, Rizk AA, et al. Turmeric and Its Major Compound Curcumin on Health: Bioactive Effects and Safety Profiles for Food, Pharmaceutical, Biotechnological and Medicinal Applications. *Front Pharmacol*. 2020;11:01021. https://doi.org/10.3389/fphar.2020.01021
4. Thomas SL, Zhao J, Li ZJ, et al. Activation of the p38 Pathway by a Novel Monoketone Curcumin Analog, EF24, Suggests a Potential Combination Strategy. *Biochem Pharmacol*. 2010;80:1309-1316. https://doi.org/10.1016/j.bcp.2010.06.048
5. Basnet P, Skalko-Basnet N. Curcumin: An Anti-Inflammatory Molecule from a Curry Spice on the Path to Cancer Treatment. *Molecules*. 2011;16(6):4567-4598. https://doi.org/10.3390/molecules16064567
6. Hsu KY, Ho CT, Pan MH. The therapeutic potential of curcumin and its related substances in turmeric: From raw material selection to application strategies. *J Food Drug Anal*. 2023;31(2):194-211. https://doi.org/10.38212/2224-6614.3454
7. D'Orazio J, Jarrett S, Amaro-Ortiz A, et al. UV radiation and the skin. *Int J Mol Sci*. 2013;14(6):12222-12248. https://doi.org/10.3390/ijms140612222
8. Djawad K, Patellongi IJ, Miskad UA, et al. Single or Daily Application of Topical Curcumin Prevents Ultraviolet B-Induced Apoptosis in Mice. *Molecules*. 2023;28(1):371. https://doi.org/10.3390/molecules28010371
9. Djawad K, Yusuf I, Miskad UA, et al. Topical Curcumin as Chemoprotector Against Photoproducts Production: The Role of Cyclobutyl Pyrimidine Dimers, 8-Hydroxy2'Deoxyguanosine Expression and Epidermal Hyperplasia in Acute and Chronic UVB-Induced Mice. *Clin Cosmet Investig Dermatol*. 2022;15:1787-1795. https://doi.org/10.2147/CCID.S377055
10. Zheng Y, Pan C, Zhang Z, et al. Antiaging effect of Curcuma longa L. essential oil on ultraviolet-irradiated skin. *Microchem J*. 2020;154:104608. https://doi.org/10.1016/j.microc.2020.104608
11. Asada K, Ohara T, Muroyama K, et al. Effects of hot water extract of Curcuma longa on human epidermal keratinocytes in vitro and skin conditions in healthy participants: A randomized, double-blind, placebo-controlled trial. *J Cosmet Dermatol*. 2019;18(6):1866-1874. https://doi.org/10.1111/jocd.12890
12. Li H, Gao A, Jiang N, et al. Protective Effect of Curcumin Against Acute Ultraviolet B Irradiation-induced Photo-damage. *Photochem Photobiol*. 2016;92(6):808-815. https://doi.org/10.1111/php.12628
13. Heng MC. Curcumin targeted signaling pathways: basis for anti-photoaging and anti-carcinogenic therapy. *Int J Dermatol*. 2010;49(6):608-622. https://doi.org/10.1111/j.1365-4632.2010.04468.x
14. Sommerfeld B. Randomised, placebo-controlled, double-blind, split-face study on the clinical efficacy of Tricutan on skin firmness. *Phytomedicine*. 2007;14(11):711-715. https://doi.org/10.1016/j.phymed.2007.09.015
15. Fithria RF, Anas Y, Safitri EI. Antihyperpigmentation Effect of The Combination of Turmeric (Curcuma domestica Val.) and Bitter Melon Leaves (Momordica Charantia L.) Ethanol Extracts on Guinea Pig Skin. *Jurnal Kefarmasian Indonesia* (*The Indonesian pharmaceuticla journal*). 2018;8(1):10-16.
16. Liu X, Zhang R, Shi H, et al. Protective effect of curcumin against ultraviolet A irradiationinduced photoaging in human dermal fibroblasts. *Mol Med Rep*. 2018;17(5):7227-7237. https://doi.org/10.3892/mmr.2018.8791

17. Muta K, Inomata S, Fukuhara T, et al. Inhibitory effect of the extract of rhizome of Curcuma longa L in gelatinase activity and its effect on human skin. *J Biosci Bioeng*. 2018;125:353-358. https://doi.org/10.1016/j.jbiosc.2017.10.001
18. Jugreet BS, Lall N, Anina Lambrechts I, et al. In Vitro and In Silico Pharmacological and Cosmeceutical Potential of Ten Essential Oils from Aromatic Medicinal Plants from the Mascarene Islands. *Molecules*. 2022;27(24):8705. https://doi.org/10.3390/molecules27248705
19. Lee SM, Chiang SH, Wang HY, et al. Curcumin enhances the production of major structural components of elastic fibers, elastin, and fibrillin-1, in normal human fibroblast cells. *Biosci Biotechnol Biochem*. 2015;79(2):247-252. https://doi.org/10.1080/09168451.2014.972324
20. Di Lorenzo R, Grumetto L, Sacchi A. Dermocosmetic evaluation of a nutricosmetic formulation based on Curcuma. *Phytother Res*. 2023;37(5):1900-1910. https://doi.org/10.1002/ptr.7705
21. Yen YH, Pu CM, Liu CW, et al. Curcumin accelerates cutaneous wound healing via multiple biological actions: The involvement of TNF-α, MMP-9, α-SMA, and collagen. *Int Wound J*. 2018;15(4):605-617. https://doi.org/10.1111/iwj.12904
22. Friedrich RB, Kann B, Coradini K, et al. Skin penetration behavior of lipid-core nanocapsules for simultaneous delivery of resveratrol and curcumin. *Eur J Pharm Sci*. 2015;78:204-213. https://doi.org/10.1016/j.ejps.2015.07.018
23. Agrawal R, Kaur IP. Inhibitory effect of encapsulated curcumin on ultraviolet-induced photoaging in mice. *Rejuvenation Res*. 2010;13(4):397-410. https://doi.org/10.1089/rej.2009.0906
24. Greenwald MBY, Frušić-Zlotkin M, Soroka Y, et al. Curcumin Protects Skin against UVB-Induced Cytotoxicity via the Keap1-Nrf2 Pathway: The Use of a Microemulsion Delivery System. *Oxid Med Cell Longev*. 2017;2017:5205471. https://doi.org/10.1155/2017/5205471

otrzymano / received: 06.05.2023 | poprawiono / corrected: 13.05.2023 | zaakceptowano / accepted: 24.05.2023