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Peptides in cosmeceuticals

Skin aging is part of human global aging which becomes evident along the years following different ways in organs, tissues and cells. Aging of the internal organs is masked whilst the skin is the first organ displaying visible signs of passing time. As life expectancy is growing everywhere at a fast pace, many people are on a quest for the fountain of youth, and age usually factors into the perception of beauty.

Peptides feature molecules constituted by chains of two or more amino acids connected by peptide bonds. There are a lot of physiological peptides present in the organism, most of them having a signalling function. Due to the potent activity of these physiological peptides, it was tempting using their model and mimic them in order to get focused therapeutic activities. This trend was initiated in the beginning of twenty-first century, and many peptides were synthesized and are used as active ingredients in cosmeceuticals. Most of these peptides are oriented towards the treatment of skin aging, mainly for the attenuation of fine lines and wrinkles. Others are positioned in the management of hyperpigmentation or may also be antimicrobial peptides. Finally, peptides also exist which can improve hair growth. Formulation of peptides in cosmeceuticals is relatively easy, however attention must be paid to their transcutaneous penetration. For small-sized peptides there is usually no problem, whilst for bigger-sized peptides various artefacts like encapsulation or branching with fatty acids must be used. Another concern about peptides is their eventual toxicity, and there is currently insufficient responses from the industry about this matter.

The majority of research studies are focused on the development of anti-aging actives, and there is still room for research to be carried out to evaluate other functions of these actives and create new actives for other indications. Understanding of cellular mechanisms, gene regulation, receptor activity and metabolic interactions increases constantly and many more peptides will probably appear and have applications in cosmeceuticals.

Key words

Peptides, cosmeceuticals, skin aging, wrinkles, hyperpigmentation, hair, formulation, toxicity.

1. Introduction

Skin aging is part of human global aging which becomes evident along the years following different ways in organs, tissues and cells. Aging of the internal organs is masked whilst the skin is the first organ displaying visible signs of passing time. As life expectancy is growing everywhere at a fast pace, many people are on a quest for the fountain of youth, and age usually factors into the perception of beauty. Recent movements to dispel the myth that only the young can be beautiful may be gaining traction, but this tendency is slow and the myth well installed. This is the reason for the boom of aesthetic medicine occurring for various years, which is bringing a new category of patients to the dermatologist office.

Facing requests and questions from the patient, the dermatologist must be ready to bring convenient responses, especially regarding the use of peptides in cosmeceuticals. The goal of this paper is reviewing in a detailed manner this topic.

2. What are peptides?

Peptides are organic compounds made of chains of amino acids connected by peptide bonds, which differ from proteins in that their molecules are markedly smaller. They consist of two or more amino acids and are classified by the number of amino acids found in the molecule. For example, a monopeptide has one amino acid, a dipeptide has two amino acids, a tripeptide has three amino acids, a tetrapeptide has four amino acids, a pentapeptide has five amino acids, a hexapeptide has six amino acids, and so on.

Oligopeptides are short-chain peptides with a sequence ranging from 10 to 15 amino acids, whilst when the number of amino acids is higher than 100 the resulting compound is usually considered as a protein. Peptides exist naturally in all living beings and usually exert highly specific biological activity, based and dependent on the exact sequence (composition and line-up of the amino acids in the chain). Besides these physiological peptides, biomimetic peptides are compounds which have an identical amino acid sequence to physiological peptides but are synthetized biotechnologically. Bioactive or topical peptides are also synthetic compounds, but they consist of modified amino acid chains, which improve an already existing physiological function.

3. Peptides in the human skin

In the human organism there are multiple peptides involved in the physiological and organic processes. A typical example of a small peptide would be ***Glutathione***, a tripeptide of γ-L-Glutamyl-L-cysteinyl-glycine sequence, well known for its antioxidant and other regulatory activities. Insulin, with 51 amino acids and totally different bioactivities is found at the high molecular weight end of peptides. They can play several biological roles, especially as signalling/regulating molecules in a variety of physiological processes, including defence, immunity, stress, growth, homeostasis, and reproduction.

Some of them are naturally involved in skin biology and homeostasis. ***Substance P*** can be found in the epidermis, a dipeptide with 11 amino acids that acts as a potent vasodilator contributing to the balance between cell differentiation and cell renewal [1]. The ***calcitonin gene related peptide*** (***CGRP***) possesses 37 amino acids and features the most abundant neuropeptide in the skin. CGRP is found in the nerve fibres of the dermis, epidermis and sudoriferous glands, in Meissner corpuscles, perivascular nerves, and Merkel cells. It provokes arteriolar vasodilation but does not stimulate pruritus or pain responses in human skin [1]. As a proinflammatory, it promotes the development of oedema induced by IL-1 and IL-8 and increases the expression and synthesis of IL-8 in endothelial cells [2]. Furthermore, it has already been described that CGRP inhibits the activity of natural-killer cells 70 and the proliferation of T cells and reduces their production of IL-2 and the expression of TNF-alpha, TNF-beta and IFN-gamma [3, 4]. CGRP is also capable of blocking the actions of histamine, leukotriene B4 and serotonin that promote oedema in human skin [5]. Peptides ***somatostatin*** (***SOM***) and ***neuropeptide Y*** found in the skin (NPY — family of endocrine neurotransmitter peptides) play a role on the vascular tonus of the skin by causing vasodilation (by promoting the release of histamine) and vasoconstriction, respectively [1]. The ***vasoactive intestinal peptide*** (***VIP***) is one of the most abundant peptides in the skin. VIP is released in the nerve fibres of the dermis and epidermis, hair follicles, sudoriferous glands, Merkel cells and in perivascular nerves [6]. VIP induces the formation of papules through the releasing of mast cells histamine and vasodilatation by relaxation of the smooth musculature of blood vessels and is also capable of stimulating the migration and proliferation of keratinocytes [7]. ***Pituitary adenylate cyclase-activating polypeptide*** (***PACAP***) is released in the skin by cutaneous C fibres [8]. PACAP generates a similar progressive erythema to that produced by CGRP and provokes the releasing of histamine mast cells, both in laboratory animals and in humans, with an intensity similar to that of VIP [8].

4. Skin aging

Because peptides are mostly used in cosmeceuticals for the purpose of preventing and correcting the symptoms of skin aging, it is compulsory reminding the most relevant characteristics of the latter. With age, the skin undergoes changes that affect the integrity of its support structure and the ability of its cells to communicate, transfer nutrients, regenerate, and repair [9]. These changes include progressive thinning of the epidermis, a more compact stratum corneum, and reduced granular layer thickness [10].

The dermoepidermal junction flattens, due to the retraction of the epidermal papillae as well as microprojections of basal cells into the dermis [11]. The production of collagen gradually diminishes [12]. As a result of these changes, the skin becomes thinner, lax, and less elastic, which leads to the development of bags, lines, wrinkles, and hyperpigmentation. Facial wrinkles are typically the first visible signs of aging, although factors other than senescence contribute to their appearance, including sun damage and muscle movement. It is commonly admitted that 30% of the visible effects of skin aging are due to intrinsic aging (of genetic origin) and 70% are caused by extrinsic aging (related with lifestyle and external factors such as UV-exposure, smoking, or air-pollution). For this reason, and as the aging population is growing and set to rise in the coming decades, the demand for products proven to attenuate and prevent these and other visible manifestations of aging is steadily climbing [9]. Such increased demand and market growth have driven manufacturers in the skin care industry to develop new advanced formulations and ingredients, within a group of topical products collectively known as cosmeceuticals [9]. The term «cosmeceutical», forged by the association of the words cosmetics and pharmaceuticals, defines any bioactive agent that exerts both cosmetic and pharmaceutical therapeutic effects on the skin [13].

5. Peptides in cosmeceuticals

There are many benefits of using peptides in cosmetic formulations. The main reason is probably the high specific activity of each peptide. Some peptides are responsible for increased cell turnover, other peptides are responsible for anti-irritancy, skin repair and hair growth, among other activity. The second reason is the high biological activity that peptides possess. Some peptide can provide very high functionality and activity even when used at very low concentrations. This allows for lower use levels which contributes to reduced product cost coming from the active ingredients used in them. This can keep cosmetic products competitively priced. Further, peptides are easy to formulate. Some of them have water solubility, oil solubility and can be used in water-in-oil or oil-in-water systems. Peptides usually have stability in a wide range of pH as well as some with good light and heat stability. The peptides used in cosmeceuticals are pure, synthetic and analytically defined substances; they might be called «designer peptides» and are a much more recent addition to the plethora of cosmetically active ingredients. There is a great versatility of peptides (for instance, there are $20^5 \geq$ 3 million possible pentapeptide sequences based on the 20 standard amino acids).

Peptides commonly used in cosmeceuticals

A. Wound healing signalling peptides for treatment of the aging face

The basement membrane that separates the epidermis and the dermis is rich in extracellular matrix (ECM) proteins including collagens, epilugrin, laminin, fibronectin, elastin, and heparin sulphate proteoglycans [14]. The ECM has a function of mediator of receptor-induced interactions between cells, guiding their growth and differentiation. Protein synthesis and cell differentiation are common mechanisms of repair of damages to ECM. Most of these functions are related to signalling by peptides released from the ECM to cells through cell membrane receptors [15]. Hence, peptides modelled on repair signalling sequences will be capable of enhancing skin rejuvenation.

Palmitoyl pentapeptide-3, derived from procollagen, stimulates production of collagens I and III in addition to fibronectin [16]. It was later renamed palmitoyl pentapeptide-4 to reflect a correction in the data on its molecular structure and is currently the active ingredient in the cosmetic agent Matrixyl. ***Palmitoyl oligopeptide*** is an elastin sequence and stimulates the growth of fibroblasts and accelerates angiogenesis [17]. An anti-ageing bioactive tetrapeptide Gly-Glu-Lys-Gly (***GEKG***) was developed, that has demonstrated in vitro and in vivo capability of inducing collagen production at the transcriptional and translational levels. The topical application of GEKG demonstrated an increase in skin elasticity and a reduction in wrinkle number and depth [18]. The pentapeptide Lys-Thr-Thr-Lys-Ser (***KTTKS***) is a fragment derived from type I procollagen [19] and represents the minimum sequence necessary for potent stimulation of ECM biosynthesis. In an in vitro model using human fibroblasts, KTTKS was found to significantly augment the ECM through increased synthesis of collagen types I and III and fibronectin. Further, Lintner et al. conjugated KTTKS to palmitate, to create palmitoyl pentapeptide (***pal-KTTKS***). This resulted in more effective delivery across skin relative to pentapeptide alone. In a 12-week double-blinded, placebo-controlled clinical study involving 93 women, pal-KTTKS permitted a significant reduction in wrinkles and fine lines as assessed by quantitative image analysis [20]. In this study, pal-KTTKS did not alter the rate of transepidermal water loss, contrarily to retinol. More recently, researchers have demonstrated that pal-KTTKS conjugated with ascorbic acid exhibits increased collagen biosynthesis compared to either compound alone [21]. Another peptide shown to improve skin elasticity through increasing collagen synthesis is the hexapeptide Phe-Val-Ala-Pro-Phe-Pro, also known as ***peptamide-6***. Its mechanism of action involves upregulation of growth factors, matrix and heat shock proteins for an overall firming effect [22]. ***Palmitoyl tripeptide-38*** and ***palmitoyl tripeptide-5*** have been shown to be highly effective at stimulating the production of collagen and hyaluronic acid and promoting dermal thickening [23]. Palmitoyl tripeptide-38 (Matrixyl synthe'6) is a matrikine-mimetic compound with significant ECM building and strengthening properties, that regulates cell activity, wound repair, and collagen tissue remodelling [23]. Palmitoyl tripeptide-5 mimics the action of thrombospondin 1 (TSP-1), a multifunctional adhesive glycoprotein of the ECM [12] that stimulates the production of type I and II collagens, and fibronectin via the activation of tissue growth factor β (TGF-β) [24]. ***Palmitoyl hexapeptide-14***, designed using an innate immunity peptide template has been shown to stimulate cell migration, collagen synthesis, and fibroblast proliferation and scaffolding [15].

B. Other signalling peptides

Oligopeptide-68 (sequence Arg-Asp-Gly-Gln-Ile-Leu-Ser-Thr-Trp-Tyr) is a whitening agent used in cosmetics and on skins affected by melasma. It inhibits the actions of microphthalmia-associated transcription factor (MITF), a regulator of melanocyte differentiation, by reducing its tyrosinase activity and «slowing down» key enzymes of the pigmentation process [25]. In a study on 40 volunteers, three formulations (hydroquinone 2 and 4 %, and oligopeptide-68) were considered, and after 12 weeks the subjects were assessed and the clarifying effects were considered significant, moderate, or slight for 2.6, 76.3 and 21.1 % of the subjects treated with the formulation containing the oligopeptide, respectively, and these values are higher than those observed in subjects treated with creams containing HQ at concentrations of 2 and 4 % [26]. ***Tripeptide-41*** (*Lipoxyn*®) activates NF-kB, a nuclear transcription factor which promotes the synthesis of tumour necrosis factor-α (TNF-α), a cytokine capable of triggering lipolysis. It also reduces the expression of C/EBP, a transcription factor essential for adipocyte differentiation and increases the concentration of cAMP, an important intracellular signalling factor that causes lipolysis by promoting the hydrolysis of lipids into triglycerides [27]. It gives significant results in the treatment of cellulite.

C. Carrier peptides

Carrier peptides play a key role in delivering essential metals to the skin, particularly copper, an important cofactor in the biosynthesis of collagen and elastin via activation of lysyl oxidase, downregulation of matrix metalloproteinases (MMPs) and anti-collagenase activity [28]. The tripeptide glycyl-L-histidyl-L-lysine (***Copper peptide GHK-Cu***) spontaneously binds copper to form a copper-tripeptide complex, which facilitates the uptake of the metal at the cellular level. This, in turn, has been shown to stimulate collagen synthesis, resulting in reduced wrinkles, increased skin firmness, and improved texture [28]. It also increases levels of MMP-2 and MMP-2 messenger RNA, as well as the secretion of the metalloproteinase inhibitors TIMP-1 and TIMP-2, which suggests a role in collagen remodelling. Another carrier peptide with MMP synthesis suppressing activity used in skin care formulations is ***dipalmitoyl hydroxyproline*** [29].

D. Peptides as an alternative to Botulinum neurotoxin

Botulinum neurotoxins cause muscle paralysis by blocking acetylcholine release at nerve–muscle junctions through a very specific and exclusive endopeptidase activity in the presynaptic exocytosis machinery [15]. Synthetic peptides that emulate the amino acid sequence of the synaptic protein SNAP-25 were shown to be specific inhibitors of neurosecretion at micromolar concentrations. ***Acetyl hexapeptide-3***, a six-amino-acid peptide derived from SNAP-25 has been shown to produce the desired interference with the neurosecretion [30]. A clinical study reported that acetyl hexapeptide-3 at a 10 % concentration reduces the depth of wrinkles up to 30 % after 30 days of use [31]. Many venomous organisms produce toxins that disrupt neuromuscular communication in order to paralyze their prey. Based upon the observation that Wagler's pit viper, Tropidolaemus wagleri, possess a venom, Walerin-1, featuring a 22-amino-acid peptide that causes paralysis by competitively antagonizing muscle acetylcholine receptors [32], a tripeptide that mimics the effect of Waglerin-1, ***Dipeptide Diaminobutyroyl Benzylamide Diacetate***, was synthesized for reducing wrinkles by inhibiting muscle contractions. ***Pentapeptide-3***, an oligopeptide marketed as *Vialox*®, has been developed to reduce wrinkles and lines. It exhibits curare-like activity, as it is a competitive antagonist at the acetylcholine postsynaptic membrane receptor. Consequently, this prevents sodium ion channels from opening, thereby inhibiting depolarization and muscle contraction [33]. In vivo studies have showed it leads to a 49 % decrease in wrinkle size and 47 % decrease in skin roughness after 28 days of application [34]. ***Pentapeptide-18*** is a modified enkaphalin that couples to the enkaphalin receptor outside of nerve cells. Enkephalins are endogenous opioids that inhibit neuronal activity by binding G-protein coupled inhibitory receptors [33]. This initiates a cascade inside the neuron, resulting in decreased excitability and reduced acetylcholine release, thereby diminishing muscle contraction. In vitro studies showed reduced neurotoransmitter release [35]. In vivo studies revealed decreased wrinkle depth [35].

E. Peptides of the innate immune system for treatment of acne and dermatoses

Peptides can also play a significant role in protection against pathogens and toxins by modulation of inflammation, binding of toxins, and neutralization of bacteria and fungi. Immunity peptides such as defensins and LL-37 are well known for binding and neutralizing bacterial debris, resulting in down-regulation of pro-inflammatory cytokines [36]. A synthetic peptide, ***oligopeptide-10***, has been developed for inclusion in topical anti-acne treatments. Oligopeptide-10 has also shown potential in mitigating symptoms associated with yeast and fungi colonization, including dandruff and seborrheic dermatitis and tinea pedis [37].

F. Peptides for the hair

Peptides such as ***Myristoyl Tetrapeptide-12***, ***Myristoyl Hexapeptide-16*** and ***Myristoyl Pentapeptide-17*** are capable of stimulating hair growth, especially at the level of eyelashes. The latter two are stimulating in a significant manner the keratin gens. It was demonstrated on human keratinocytes that Myristoyl tetrapeptide-12 directly activates SMAD 2 and induces the linking of SMAD3 with DNA [38]. SMAD2 and SMAD3 act as activators of stem cells of the hair follicle in order they turn from the telogen to anagen phase [39].

6. Limits of the activity of peptides in cosmeceuticals

As far as the peptides under consideration are small molecule-sized, their penetration through the stratum corneum makes no problem. In table, we are reporting the molecular size of some peptides mentioned in this paper, and we can observe that they have molecular weights similar to molecules classically used in dermatology such as neomycin, tacrolimus or pimecrolinus, and nobody doubts about the capacity of these molecules to penetrate through the stratum corneum.

When the molecular size of the peptides used is higher, their transdermal delivery may be a concern. Topical and transdermal routes of delivery present an overlying challenge with designing any therapeutic peptide as it is difficult to counter the diffusional resistance of the stratum corneum. For this reason peptides are often covalently linked to lipophilic molecules such as N-isobutyloxycarbonyl and N-octyloxycarbonyl, or branched with fatty acids such as palmitoleic or myristoleic acids to prevent enzymatic degradation and increase concentration at active sites [40].

Other modifications that improve transdermal delivery include formulations with chemical solvents, such as alcohols, pyrrolidones, DMSO and 1-dodecylazacycloheptan-2-one (Azone), urea, sugar esters and surfactants [33]. Alternatively, liposomal systems may potentially be a solution to the challenge of peptide delivery as they not only protect encapsulated molecules from degradation, but also facilitate transport of various types of biological materials to many different cell types [33]. In addition to structural and chemical modifications that enhance permeability, technological interventions utilizing active transport mechanisms, such as iontophoresis, electroporation, sonophoresis, microdermabrasion and fractional photothermolysis have also demonstrated success in transdermal peptide delivery [40]. However, a number of key factors need to be considered to ensure maximum efficacy and safety. Using the correct amounts of peptide is one such factor. Usually their concentration in cosmeceuticals is ranging between 1.000 and 3.000 ppm.

Table. **Study of the molecular size of peptides, g/mol**

Peptides	Molecular size	Comparison with other drugs
Palmitoyl Tripeptide-5	611.9	Neomycine: 614
Dipeptide Diaminobutyroyl Benzylamide Diacetate	1119.3	Cyclosporine: 1202
Palmitoyl Dipeptide-5 Diaminobutyroyl Hydroxythreonine	780.2	Tacrolimus: 804
Palmitoyl Dipeptide-5 Diaminohydroxybutyrate	679.3	Pimecrolimus: 810

Practicing dermatologists should proactively seek this information from manufacturers or refer to the product monograph of the specific peptide they are interested in using [23].

7. Toxicology of peptides

Toxicity of peptides used in cosmeceuticals is a major concern. These products are highly active, even at very low concentration, and there is an infinity of peptides which makes impossible to perform a complete toxicological evaluation on each one as this would be the case for pharmaceutical active ingredients. Of course, each manufacturer is performing skin irritation test, ocular irritation test and patch test as a minimum.

As regards systemic toxicity of peptides there is a paucity of data. An interesting initiative is the In Silico approach for predicting the toxicity of peptides [41]. Toxic and non-toxic peptides having 35 or fewer residues were observed from various databases. It was observed that certain residues like Cys, His, Asn, and Pro were abundant as well as preferred at various positions in toxic peptides. Models based on machine learning technique and quantitative matrix using various properties of peptides were developed for predicting toxicity of peptides. The performance of dipeptide-based model in terms of accuracy was 94.50 %. In addition, various motifs were extracted from the toxic peptides and this information was combined with dipeptide-based model for developing a hybrid model. In order to evaluate the over-optimization of the best model based on dipeptide composition, its performance was evaluated on independent datasets and achieved accuracy around 90 %. Based on this study, a webserver, ToxinPred has been developed, which would be helpful in predicting (i) toxicity or non-toxicity of peptides, (ii) minimum mutations in peptides for increasing or decreasing their toxicity, and (iii) toxic regions in proteins.

8. Conclusions

Cosmeceutical bioactive peptides have become increasingly popular in dermatology in recent years and probably constitute a major event in the evolution of skin-care occurred in the beginning of this century. As we could observe, the majority of research studies are focused on the development of anti-aging actives, and there is still room for research to be carried out to evaluate other functions of these actives and create new actives for other indications. Understanding of cellular mechanisms, gene regulation, receptor activity and metabolic interactions increases constantly and many more peptides will probably appear and have applications in cosmeceuticals.

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Пептиди в космецевтиці

Старіння шкіри є частиною глобального старіння людини, яке виявляється поступово протягом кількох років, з різними змінами в органах, тканинах і клітинах. Старіння внутрішніх органів практично не помітно, водночас як шкіра є першим органом, на якому позначається час. Зі збільшенням тривалості життя люди шукають джерело молодості, оскільки вік, як правило, впливає на сприйняття краси.

Пептиди містять молекули, що складаються з ланцюгів із двох або більше амінокислот, пов'язаних пептидними зв'язками. В організмі є багато фізіологічних пептидів, більшість з яких мають сигнальну функцію. Через сильну активність цих фізіологічних пептидів було заманливо використовувати їхню модель та імітувати їх, щоб отримати цілеспрямовану терапевтичну активність. Цю тенденцію започатковано в XXI столітті, коли багато пептидів було синтезовано і їх використовували в космецевтиці як активні інгредієнти. Більшість із цих пептидів орієнтовані на боротьбу зі старінням шкіри, в основному для зменшення зморщок. Інші використовують для боротьби з гіперпігментацією або як антимікробні пептиди. Нарешті, існують також пептиди, котрі можуть поліпшити ріст волосся. Виробити пептиди в космецевтиці відносно легко, проте слід звернути увагу на їхнє проникнення крізь шкіру. Для пептидів малих розмірів зазвичай немає проблем, водночас як для пептидів більшого розміру потрібно використовувати різні артефакти, такі як інкапсуляцію або розгалуження з жирними кислотами. Інша проблема пов'язана з їхньою можливою токсичністю, і на сьогодні в промисловості недостатньо відповідей на це запитання.

Більшість досліджень присвячено розробці активних речовин, що запобігають старінню, і все ще є місце для оцінки інших функцій цих активних речовин і створення нових активних речовин для інших показань. Розуміння клітинних механізмів, регуляції генів, рецепторної активності і метаболічних взаємодій постійно зростає і, ймовірно, з'явиться багато інших пептидів, які можуть знайти застосування в космецевтиці.

Ключові слова: пептиди, космецевтика, старіння шкіри, зморшки, гіперпігментація, волосся, рецептура, токсичність.

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Пептиды в космецевтике

Старение кожи является частью глобального старения человека, которое проявляется постепенно на протяжении нескольких лет, с различными изменениями в органах, тканях и клетках. Старение внутренних органов практически не заметно, в то время как кожа является первым органом, на котором проявляется отпечаток времени. С ростом продолжительности жизни люди ищут источник молодости, поскольку возраст, как правило, влияет на восприятие красоты.

Пептиды содержат молекулы, состоящие из цепей из двух или более аминокислот, связанных пептидными связями. В организме присутствует много физиологических пептидов, большинство из которых имеют сигнальную функцию. Из-за сильной активности этих физиологических пептидов было заманчиво использовать их модель и имитировать их, чтобы получить целенаправленную терапевтическую активность. Эта тенденция появилась в начале XXI века, когда многие пептиды были синтезированы и используются в космецевтике в качестве активных ингредиентов. Большинство из этих пептидов ориентированы на борьбу со старением кожи, в основном для уменьшения морщин. Другие используются для борьбы с гиперпигментацией или как антимикробные пептиды. Наконец, существуют также пептиды, которые могут улучшить рост волос. Производить пептиды в космецевтике относительно легко, однако следует обратить внимание на их чрескожное проникновение. Для пептидов малого размера обычно нет

проблем, в то время как для пептидов большего размера должны использоваться различные артефакты, такие как инкапсуляция или разветвление с жирными кислотами. Другая проблема связана с их возможной токсичностью, и в настоящее время в промышленности недостаточно ответов на этот вопрос.

Большинство исследований посвящено разработке активных веществ, предотвращающих старение, и все еще есть место для оценки других функций этих активных веществ и создания новых активных веществ для других показаний. Понимание клеточных механизмов, регуляции генов, рецепторной активности и метаболических взаимодействий постоянно возрастает и, вероятно, появится много других пептидов, которые могут найти применение в космецевтике.

Ключевые слова: пептиды, космецевтика, старение кожи, морщины, гиперпигментация, волосы, рецептура, токсичность.

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