

WHY NANOPARTICLES ARE THE MOST COMMONLY USED FORM OF SILVER IN COSMETIC AND MEDICINAL PRODUCTS?

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ABSTRACT

Background

Silver is used in cosmetic and medicinal products due to its antibacterial, antifungal, immunostimulating and anti-inflammatory properties.

Aim

The aim of the study was to analyze the composition of cosmetic and medicinal products containing silver available on the Polish market. An attempt was made to find an answer to the question what forms of silver and why are most often used by producers of cosmetics and medicinal products.

Materials and methods

In the period from September 2023 to February 2024, information was collected on available cosmetic and medicinal products containing silver. Drugstores and stationary pharmacies and their websites were visited. When searching for offers on the Internet, the following words were entered: "cosmetics with silver", "silver", "colloidal silver", "nanosilver".

Results

Information was obtained on 42 cosmetic preparations and 32 medicinal preparations containing silver.

The collected cosmetic products containing silver included face masks, body gels, antiperspirant sticks and sprays, shaving gels, aftershave balms, makeup brushes and sponges, combs, toothpastes, nail tincture, tonic, shampoos, gels for washing the face, facial serum, peelings, creams, gels for intimate hygiene, hygienic wipes, soaps, emulsions and body gels, shower gels.

Medicinal products containing silver collected included: throat sprays, lozenges, eye drops, solutions, gels, foot sprays, vaginal capsules, spray powder, creams, ointments, emulsions and wart removal sticks, clothing and tourniquets containing silver ions.

The forms of silver in cosmetic and medicinal products are most often silver nanoparticles.

Conclusion

Medicinal and cosmetic products most often contain silver in the form of nanoparticles for its antimicrobial properties.

Keywords: the role of the sport psychologist, mental toughness, physical culture, relationships.

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INTRODUCTION

Silver (Latin: *argentum*) is an element with the chemical symbol Ag. In the periodic table of chemical elements, it is in the 5th period and the copper group - i.e. group 11. It is a transition metal, the atomic number of which is 47 and the atomic mass is 107.87. The simplified electron configuration of silver is written as follows - [Kr] 4d105s1. It is usually in the 1st oxidation state, less often it is 2nd or 3rd degree. Silver is a noble metal with a white and shiny color. Among all metals, it has the best conductivity of heat and electricity. It is obtained as a result of processing zinc-lead sources. Silver has been used in various industries - from the production of photographic films, in the jewelry industry, in chemical plants to the production of mirrors and protection against corrosion [1].

In the natural environment, silver occurs in free and bound forms, and its prevalence is low. In soils, the concentration of this metal ranges from 0.03 to 0.1 ppm. Its presence in the tissues of terrestrial and marine organisms is also small, as it is estimated at 1.8-80 µg, but despite such a small result, it is present in all tissues. Important properties of silver for medicine and cosmetology are its antibacterial, antifungal and immunostimulating properties. The use of silver also has anti-inflammatory effects. The spectrum of action of silver against bacteria is very broad. Both Gram-positive and Gram-negative bacteria are susceptible to its action. Bacteria sensitive to silver also include aerobic and anaerobic species [2]. The mechanism of silver's action on bacterial cells is based on its electrostatic effect. Ag⁺ cations affect naturally negatively charged bacterial cells. The main structures through which silver affects bacteria are their compounds, which play primary roles in the proper functioning of the microorganism [3].

Namely, these are structural proteins and enzymatic proteins, and their leading representatives may be respiratory enzymes, such as cytochrome oxidase or succinate dehydrogenase (NADH) [4]. It is known that silver combines with amino acids through several groups. These are the following groups: amine (-NH₂), thiol (-SH), carboxyl (-COOH), phosphate (-PO₄) and imidazole (-C₃H₄N₂) [5]. The main silver-binding amino acid is cysteine. The implication of this process is the loss of biological activities of proteins [6]. When silver cations reach the cell interior, they react with nucleic acids [7]. The intercalation of silver with deoxyribonucleic acid (DNA) inhibits the replication process, as a result of which the bacterial cell stops functioning properly and ultimately dies [8]. The antibacterial effect of silver ions is directly proportional to their concentration in the environment surrounding the bacteria [9].

Despite such an aggressive effect on bacterial cells, silver does not have such an effect on human cells. This property of silver is used in the treatment of skin wounds caused by mechanical injuries, burns, as a result of dermatological diseases and in the treatment of pressure sores and ulcers. Silver patches contain silver nanoparticles or silver ions. Dressings act as a mechanical barrier between the wound and the external environment and provide an appropriate, moist environment for the skin healing process. The silver contained in the patches has a strong anti-inflammatory effect and has a broad antibacterial spectrum. This includes, among others: MRSA (Methicillin-Resistant *Staphylococcus Aureus*), VRE

(Vancomycin-Resistant *Enterococcus*) and *Escherichia coli*.

Additionally, the use of silver dressings is much more comfortable for the patient and medical staff. Their removal is painless and non-traumatic. This type of dressings can be cut and shaped to suit the individual needs of the patient. The use of silver patches allows wounds to heal faster and more effectively. The first commercial dressing containing silver nanoparticles, "Anticoat", shortens wound healing by an average of 3.35 days, compared to standard plasters [10,11]. The development of technology allows us to obtain increasingly more effective silver compounds, but we still do not abandon the use of compounds that have been known for centuries. These include silver nitrate (Latin: *argentum nitricum*), most likely discovered in the 15th century by Basilius Valentinus, a Swiss monk.

Initially, silver nitrate was described as 'lapis infernalis' or 'lapis causticus' and was used to treat wounds, rashes, warts, ulcers and to treat venereal diseases. Silver nitrate then began to be used for people suffering from leprosy. AgNO₃ solution is still used. It is mainly used against bacteria of the genus *Pseudomonas* and *Neisseria*. It is most often used to disinfect the conjunctiva of the eyes of newborns. A procedure called the Credé procedure is intended to reduce the risk of gonococcal infection. The broad spectrum of action of silver nitrate is also used in dermatology, ophthalmology, venereology and dentistry in the form of ointments and eye drops with antibacterial properties [12]. It is claimed that silver stimulates osteoblasts (bone-forming cells) to become more active [13].

However, this statement only applies to small amounts of silver. It has been shown that silver concentrations greater than 10 mg/l in human body fluids may have a toxic effect on some molecules [14]. A healthy human body excretes barely 1 µg of this precious metal daily. In some people, silver secretion of approximately 10 µg per day was observed, but in these cases its level was chronically elevated and it accumulated in the tissues in the form of insoluble silver sulfide. Silver absorption by humans can occur through the lungs, gastrointestinal tract and skin. After reaching the human body and entering the bloodstream, this element combines with albumin in the plasma. Then it is transported to the liver [7,14]. The main amino acid that binds silver is cysteine, therefore the next stage of Ag transformation is combining with metallothioneins (these are low molecular weight proteins that participate in the process of detoxification of the body from metal ions and take part in the defense against oxidative stress [15]), which are rich in residues cysteine. In addition to them, other proteins such as metallothioneins are involved in this process. The liver, which is a key element in the body's detoxification, may eventually undergo necrosis as a result of too high silver levels. Another effect of taking high doses of this metal is argyria. It is a rare disease associated with chronic exposure to products containing silver. It involves the deposition of silver grains in the skin, mucous membranes, eyeballs and internal organs, as well as in the central nervous system. Deposits of this metal cause blue-gray or even black metallic shiny discolorations. The most common compound causing the symptoms of the disease is silver sulfide, formed as a result of the conversion of silver salts in the presence of light and an organic matrix containing sulfur (in the form of amino acids). The silver sulfides created in this way can

stimulate the synthesis of melanin. In the skin, silver is deposited mainly around appendages in the dermis. The effect is most visible on sun-exposed areas such as the face, neck, arms and back of the hands, but can also be seen on the nails, conjunctiva and oral mucosa. Ocular argyriosis is the most common type of local Ag accumulation. It manifests itself as a permanent, dirty gray to brownish discoloration limited to the eye and adjacent parts. Silver salts may come from external sources, such as silver-containing eye drops, makeup products, or from systemic silver deposition. This affects most structures of the eye except the optic nerve, retina, lens and vitreous body. There are few reports of ocular argyriosis developing as a result of occupational exposure to silver nitrate in an industrial plant and corneal argyriosis resulting from trauma caused by a volcanic eruption [17,18]. It is a rare disease and ignorance of this disorder causes the clinical presentation to be misdiagnosed as cyanosis, leading to invasive, expensive and unnecessary diagnostic procedures. Silver deposition and skin discoloration in argyriasis are permanent and are primarily of cosmetic importance, and there is no effective treatment [19]. The minimum concentration of this element causing discoloration must reach 25 to 30 g and be administered for six months [14].

OBJECTIVE

The aim of the study was to analyze the composition of cosmetic and medicinal products containing silver available on the Polish market. Additionally, an attempt was made to find an answer to the question what forms of silver are most often used by producers of cosmetics and medicinal products.

MATERIALS AND METHODS

In the period from September 2023 to February 2024, information was collected on cosmetic and medicinal products containing silver available on the Polish market. Six drugstores were visited and the online offer of drugstores operating in Poland was searched. Three stationary pharmacies and websites of pharmacies operating in Poland were also visited. When searching for offers available on the Internet, the following words were entered: 'cosmetics with silver', 'silver', 'colloidal silver', 'nanosilver'.

RESULTS

Information was obtained on 42 cosmetic preparations and 32 medicinal preparations containing silver.

According to applicable regulations, ingredients in cosmetic products are listed in order from the ingredient used in the largest amount to the ingredient used in the smallest amount.

Among the collected cosmetic products containing silver, 7.1% are face masks, 4.8% 2in1/3in1 body gels, 7.1% antiperspirant sticks, 2.4% shaving gels, 4.8% aftershave balms, 2.4% antiperspirant spray, 2.4% makeup brushes, 2.4% makeup sponges, 2.4% combs, 2.4% toothpaste, 2.4% nail tincture, 4.8% tonics, 2.4% shampoos, 4.8% facial cleansing gels, 4.8% facial serum, 4.8% peelings, 19.5% creams, 2.4% intimate hygiene gels,

2.4% tissues, 4.8% soaps, 2.4% body spray emulsions, 4.8% gels, 1.5% shower gels.

The forms of silver in the products presented in the collection are: Nanosilver 38%, Silver citrate 29%, silver ions 7%, Silver 22%, Silver aXonnite 2%, Silver Carboxymethylalaninate 2%.

Among the collected medicinal products containing silver, throat sprays account for 19% of the collection, lozenges 6.25%, eye drops 6.25%, solutions 9.3%, gels 6.25%, foot sprays, vaginal capsules, spray powder, creams, ointments, emulsions and sticks for removing warts each constitute 3.1%, and clothing and tourniquets containing ions silver constitutes a total of 31.25%.

The forms of silver in the products presented in the collection are: Nanosilver 38%, aXannite silver 9%, Argentum Nitricum 6%, TIAB (nanocrystalline titanium dioxide with covalently bonded monovalent silver ions) 6%, ionic silver 3%, micronized silver 6%, Silver 32%.

DISCUSSION

Although each form of silver has some antiviral, antibacterial and antifungal potential, most studies conducted to determine these activities have shown that silver nanoparticles are the most effective of all metals in this regard [20]. By interacting with the surface components and receptors of microbial cell membranes, silver nanoparticles disrupt them, causing protein degranulation, production of reactive oxygen species (ROS), which disrupts and inhibits DNA replication and disrupts the expression of proteins and enzymes that are part of the microorganism's respiratory chain [21]. Silver nanoparticles show antiviral effectiveness against several viruses. These include hepatitis B virus [22], human immunodeficiency virus (HIV-1) [23], herpes simplex virus type 1 [24] and influenza virus [25].

As an antibacterial agent, nanosilver affects Gram-positive and Gram-negative bacteria, but it does not have the same effect on both types of bacteria. The structure of the bacterial wall plays an important role in the antibacterial effect of silver nanoparticles. Gram-positive bacteria are characterized by a thicker layer of peptidoglycan, which makes them slightly less sensitive (but still significantly sensitive) to nanosilver than Gram-negative bacteria. Acne vulgaris is a chronic inflammatory disease of the pilosebaceous units, in the pathophysiology of which an important role is played by a Gram-positive bacterium - *Propionibacterium acnes*. Due to the antibacterial and anti-inflammatory properties of silver, preparations containing it are recommended for people struggling with acne vulgaris. The few studies conducted on the impact of the use of silver in the care of acne-prone skin show a reduction in the number of inflammations on the skin of affected people. They also showed no irritation or damage to the hydro-lipid barrier of the epidermis.

For this reason, silver compounds are recommended for the care and treatment of acne. The use of silver is also indicated in the treatment of atopic dermatitis. This disease is characterized by chronic inflammation and dry skin, with persistent itching. There is no medicine that will completely cure the disease, and the only treatment options offer a chance to put the symptoms into remission, but many people with many diseases often experience relapses. It has been shown that over 90% of people with atopic dermatitis have excessive

colonization of *Staphylococcus aureus* bacteria. A study was conducted to observe the effect of clothing with the addition of silver compounds on the number of *S. aureus* bacteria on the skin of patients with atopic dermatitis. The results showed that in most subjects, 7 days of using such clothing textiles significantly reduced the density of *S. aureus* colonies and alleviated disease symptoms compared to cotton clothing. Despite the positive results of the study, this method also has its disadvantages. Washing clothes four times reduces the silver content to 1%. Additionally, during washing silver enters the water, where it reduces the number of bacteria used for water treatment [26]. A contemporary problem in medicine is the very common use of antibiotic therapy, which results in the emergence of bacterial strains with developed resistance to antibiotics. Nanotechnology comes with an alternative. It seems that silver nanoparticles do not have the disadvantage of traditional antibiotic substances. Although nanosilver can be an alternative to antibiotics, their simultaneous use also has its advantages. Scientific research conducted under Shahverdi's supervision has proven that the use of preparations containing silver nanomaterials in combination with antibacterial drugs such as erythromycin, clindamycin, amoxycycline, vancomycin or penicillin G enhances their effect [27].

However, considering the ability of microorganisms to become resistant to stressful conditions, there is a concern that the widespread use of silver may contribute to the emergence of bacteria with developed resistance to this metal. To prevent this process from occurring, an important factor is the

prudence of producers in encouraging consumers to unjustifiably use products with silver nanoparticles [28]. Another aspect that justifies the widespread use of silver particles is its greater resistance to temperature changes than traditional antimicrobials. A comparison of the forms of silver found in the compositions of the products presented in the tables shows that manufacturers of cosmetic and medicinal products mainly decide to use silver in the form of nanoparticles. Percentage calculations show that nanosilver is a component of 38% of both cosmetic and medicinal products. Silver in other cosmetic products occurs in the form of: nanosilver, silver citrate, silver ions, silver, silver aXonnite, silver Carboxymethylalaninate

Other medicinal preparations containing silver contain it in the form of: silver nanocolloid, aXannite silver, silver ions, Argentum Nitricum, micronized silver.

Based on the analysis of the forms of silver used in cosmetics and medicinal products, it can be concluded that the form of nanoparticles is most often used by manufacturers.

CONCLUSION

Medicinal and cosmetic products containing silver most often contain it in the form of nanoparticles due to its favorable profile of action on pathogens and the human body.

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