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Characteristics of carotenoids and their use in the cosmetics industry

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1. Abstract

Carotenoids are compounds of natural origin and are a product of secondary metabolism of plants and bacteria. These are chemically unsaturated hydrocarbons that act as dyes with a wide range of colors. These compounds are stored in chloroplasts and chromatophores. In living organisms, they are used in the photosynthesis process, have a protective function in the photooxidation process and are designed to neutralize free radicals. Due to the difference in structure, the molecules were divided into 2 groups, i.e. orange - carotenes and yellow - xanthophylls. Due to their unique antioxidant properties, they are widely used in the cosmetics industry. Carotenoids as antioxidants have a beneficial effect on human health and well-being. Currently, the most popular compounds that are used in cosmetology are carotene and lycopene. The development of cosmetology followed the development of biochemistry, chemistry, pharmacy and medicine. Compounds used in care products can be obtained as extracts from plants or obtained by chemical synthesis or biotechnological processes. It can be seen that in recent years the awareness of the use of cosmetic products has increased. This contributed to the increased interest in cosmetics of natural origin. Thanks to the interest in natural / ecological products, we have the opportunity to get to know biologically active substances better and to fully use them in cosmetology, pharmacology and medicine

Key words: carotenoids, cosmetology, pharmacology, medicine, β-carotene, lycopene

1. Introduction

Carotenoids are a group of organic compounds, unsaturated hydrocarbons with numerous double conjugated bonds in trans configuration due to cyclization of the polyisopenthenol chain. They are made of isoprene units with a 40-carbon chain. Characteristic for this group is the presence of two cyclohexyl rings connected by a carbon chain [2]. They are classified into two groups, i.e. carotenes made of hydrocarbons and oxygen derivatives - xanthophylls [9]. Carotenoids are synthesized in plants and some microorganisms. They are produced by secondary metabolism and used in multiple metabolic processes [8].

2. Synthesis of carotenoids

Carotenoid biosynthesis occurs in two ways:

1. Carotenoids are formed by the condensation of 2 digeranyl diphosphate molecules in the presence of phytoene synthase - this reaction produces phytoene. This compound then undergoes oxidase catalyzed reactions to form lycopene. As a result of its cyclization, α-carotene and β-carotene are formed. In the next stages of synthesis, these compounds are converted into zeaxanthin in the process of hydroxylation and lutein in the presence of zeaxanthin epoxidase. A model for this synthesis exists in all higher plants [1].
2. Carotenoids are formed as a result of the synthesis of 2 molecules of farnesyl diphosphate, thus creating a 30-carbon chain. This model is limited to bacteria from the Streptococcus, Staphylococcus and Heliobacterium family [1].

3. Action of carotenoids

Carotenoids, thanks to their unique antioxidant properties, can potentially protect people against an abnormal immune response, premature skin aging and the possible cancerous process [9]. Carotenoids are antioxidants, i.e. they absorb singlet oxygen energy, leading to its loss and changes in the energy state. This is possible thanks to numerous conjugated double bonds that absorb light energy and the presence of cyclohexane rings with hydroxyl groups and ketone groups present in carotenoids. The mechanism of antioxidant properties is related to the ability to photoprotect, i.e. neutralize free oxygen radicals and peroxyl radicals. Radicals increase the ability of the enzymatic antioxidant systems of dismutase and superoxide catalase [4]. Carotenoids and their derivatives are used in cosmetics, dietary supplements and pharmacological agents as antioxidants to prevent excessive cell proliferation. The skin naturally has defense mechanisms the natural aging process or excessive exposure to ultraviolet radiation, the concentration of free radicals increases. Then there is a forced apoptosis and necrosis of skin cells. This leads to photoaging, excessive skin dryness and the formation of wrinkles. Carotenoids have the ability to absorb ultraviolet radiation, thanks to which they act as a filter, counteracting the photoaging effect of the skin, irritation and, consequently, cancer. In addition, they can be used as a means of preventing skin discoloration, improving its color, which is used in the treatment of skin discoloration and self-tanning preparations. Carotenoids also prevent freckles. They have an anti-acne effect, as the normalization of the sebaceous glands, cleans the hair follicles and stimulates the exfoliation process of the epidermis [10].

4. Characteristics of selected carotenoids

Such compounds belonging to carotenoids as β-carotene, vitamin and lycopene are of great importance in cosmetology. They will be presented later in the work.

4.1. β-Carotene

β-Carotene is a chemical compound belonging to the carotenes, which makes up about 70-80% of this group. There are systems at both ends of the molecule β-ionic. This compound has no optical activity. It comes in the form of a trance and contains 11 conjugate bonds (Fig. 4). In the presence of lyase and 2 water molecules, it decomposes into the alcoholic form of vitamin A, which is referred to as provitamin A. It is formed as a result of the decomposition of the molecule's double bond and forms retinal, which is an intermediate product. Retinal is then reduced to vitamin A (Fig. 5) [2].

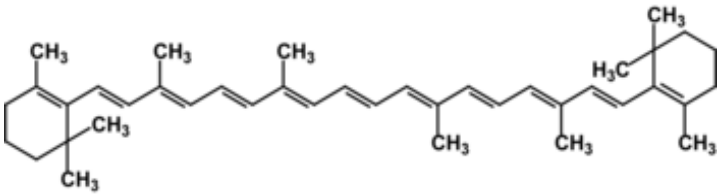


Fig. 1 The structural formula of β-carotene [2].

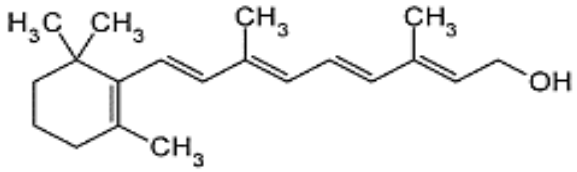
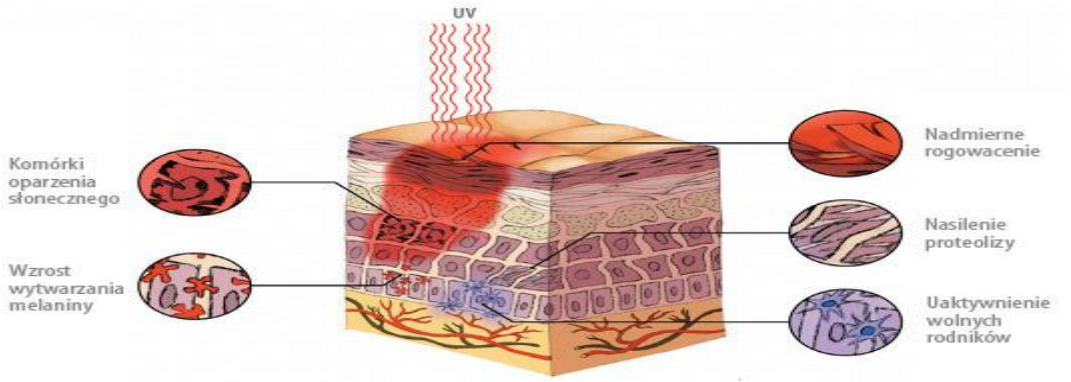


Fig 2 The structural formula of vitamin A [2].

β-Carotene is found in products of plant origin (carrots, pumpkins, peppers) and is extracted from there. It is obtained on a large scale, either synthetically or by fermentation. It is also metabolized by photosynthetic bacteria [2]. The action of carotene is closely correlated with the action of vitamin A. Together they take part in numerous processes in the body. Due to the benefits of their use, they have found great application in the cosmetics industry. Cosmetics containing vitamin A and β-carotene are used due to their antioxidant properties in a hydrophobic environment. They form an antioxidant system which is a protective barrier. This is a favorable phenomenon because the disturbance of the pro-oxidative-oxidative balance causes pathological damage to cells and tissues. The formation of free radicals is caused by UV radiation and ionizing radiation [3].

The negative effect of UV radiation on the skin can be as follows (Fig. 3):

- epidermal damage visible as erythema and pigmentation change;
- formation of reactive oxygen species causing the skin photoaging process;
- damage to collagen and elastic fibers;
- stimulation of metalloproteinases;
- damage to blood vessels;
- epidermal keratosis;
- damage to the DNA of epidermal cells [5]



Rysunek 3 The effect of UV radiation on the skin (http://www.solecrin.pl).

Cosmetics use the properties of vitamin A and β-carotene to reduce the harmful effects of external factors. Preparations with the addition of these compounds are used to increase the elasticity of the skin by reducing its keratosis. They are recommended to delay skin aging processes. The result of their use is the reduction of fine wrinkles and furrows and the lightening of discoloration, lentil spots. These substances work by increasing the number of fibroblasts and regulating collagen synthesis. They cause an increase in the yellow color of the skin, which is now a desirable phenomenon. Cosmetics used before exposure to the sun protect against its harmful effects by increasing the absorption of radiation [11].

4.2. Lycopene

Lycopene is an organic compound belonging to the group of unsaturated hydrocarbons with a linear structure. Having 13 double bonds, including 11 conjugated (Fig. 7). It is produced by plants and autotrophic bacteria. It is found in large amounts in tomatoes, watermelons, and generally red-skinned fruits [6].

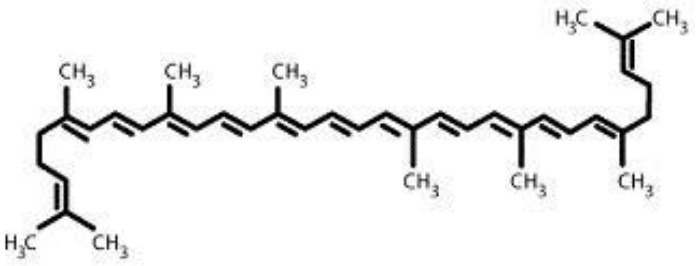


Fig. 4 The structural formula of lycopene [6].

Lycopene is obtained from plant material by extraction with organic solvents at high temperature and increased pressure. It has strong antioxidant properties, neutralizing free radicals by radical addition, hydrogen detachment or electron transfer. It acts as a donor and then becomes a radical itself [6]. Products with lycopene extract are used in cosmetics. The extract is used in the production of protective creams against UV rays, in cosmetics aimed at regenerating and firming the skin and revitalizing. It is especially beneficial for dry, sallow skin. Additionally, it has a toning effect recommended in the care of oily skin. It also has rejuvenating properties, reducing the aging process, gives it elasticity and firmness by regulating the production of procollagen. Procollagen is a collagen precursor protein which additionally protects hyaluronic acid against degradation [7].

Carotenoids are an important group of active compounds widely used in the cosmetic industry due to their unique properties. They protect us against exogenous and endogenous factors. It is expected that cosmetics of natural origin will gain more and more popularity.

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