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ScienceDirect
European Journal of Pharmaceutics and Biopharmaceutics 69 (2008) 943–947
European Journal of Pharmaceutics and Biopharmaceutics
www.elsevier.com/locate/ejpb

Research paper

Cutaneous concentration of lycopene correlates significantly with the roughness of the skin

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Received 25 September 2007; accepted in revised form 31 January 2008
Available online 13 February 2008

Abstract

Antioxidant substances in the skin are expected to slow down photo ageing. We therefore developed the hypothesis that high levels of antioxidant substances may be correlated to lower levels of skin roughness.

By utilizing modern optical non-invasive in vivo methods, the structures of the furrows and wrinkles as well as the concentration of lycopene were analyzed quantitatively on the forehead skin of 20 volunteers aged between 40 and 50 years.

In a first step, the age of the volunteers was correlated to their skin roughness. Here, no significant correlation was found. In a second step, a significant correlation was obtained between the skin roughness and the lycopene concentration ($R = 0.843$).

These findings indicate that higher levels of antioxidants in the skin effectively lead to lower levels of skin roughness, and therefore support our hypothesis.

Keywords: Roughness; Furrows; Wrinkles; Lycopene; Free radicals; Skin ageing

1. Introduction

Recently, different authors have demonstrated that high doses of UV-radiation produce free radicals in the human skin, such as singlet oxygen (O_2), hydroxyl radicals (OH^-), super-oxide-ions (O_2^-) or peroxide radicals [1]. The processes of free radical and reactive oxygen species (ROS) formation are more efficient in the UVA spectral range than in the UVB part of the spectra [2,3]. The radicals and ROS not only damage the DNA, but also negatively influence the generation of connective tissue [3,4]. As a result, the renewal of elastin and collagen fibres is disturbed, and furrows and wrinkles appear on the skin [5,6]. Visual skin ageing is therefore in part the result of the accumulation of irreversible conformational changes and defects in the skin tissue, caused by the action of free radicals and ROS [7,8].

The human body has developed a natural protection mechanism against these reactive molecules. Antioxidant substances such as carotenoids, vitamins and others are stored in the skin, and are able to provide protection against free radicals and ROS before they interact with the living cells [9–11].

Carotenoids are one of the main antioxidant substances in the skin [12,13], which, however, cannot be synthesized by the human organism. Therefore, carotenoids must be taken up with the diet. The most important carotenoid antioxidants of the skin are β-carotene and lycopene. These substances effectively neutralize the oxidative activity of free radicals and other reactive species. The efficacy in neutralizing radicals is much higher for lycopene than for other carotenoids presented in the skin [14]. Several studies have

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doi:10.1016/j.ejpb.2008.01.034

indicated that antioxidant substances can reduce skin damage by neutralizing the destructive action of free radicals and ROS [2,7,8,13]. Based on this assumption, different cosmetic products and nutritional foods are on the market, which promise an anti-ageing effect for the skin.

Taking the protective behaviour of antioxidant substances, in particular for the skin, into consideration, the hypothesis arises that a correlation exists between the cutaneous concentration of antioxidants and the visual appearance of the skin.

Therefore, the present study was developed to verify whether there is a correlation between the lycopene level in the skin and the skin surface structure (roughness), using modern non-invasive techniques. The development of non-invasive techniques for the measuring of the skin surface structures [15–17] and for the detection of carotenoid antioxidant substances in the skin by Raman spectroscopy [18–21] has substantially facilitated this effort.

2. Materials and methods

2.1. Volunteers

The experiments were performed on 15 female and 5 male volunteers, aged between 40 and 50 years (mean 44.85 ± 2.37 years). This age group was selected because the furrows and wrinkles of the skin are usually more pronounced in this age group compared with younger subjects. In addition, the narrow age range makes it possible to minimize the influence of age on the skin surface structure. Seventeen volunteers were of photo type II and 3 volunteers were of photo type III.

The volunteers were carefully interviewed about their lifestyle habits during the last 20 years with the help of a questionnaire, such as:

– private and occupational stress factors
– health conditions
– nutritional habits
– tobacco and alcohol abuse
– mean sun exposure.

This questioning was performed in order to exclude that lifestyle habits had changed significantly during the last 20 years. Substantial lifestyle changes as well as the regular application of skin care products or food supplements containing antioxidants led to an exclusion of the volunteers from the study.

Approval of the experiments had been obtained from the Ethics Committee of the Charité Hospital. The study was conducted according to the ethical rules stated in the Declaration of Helsinki Principles. The volunteers participating in the study had given their informed written consent.

Two measurements were carried out on the light-exposed skin area on the center of the forehead without any pre-treatment of the skin:

1. the determination of the skin surface structure
2. the determination of the relative concentration of lycopene in the skin, in order to evaluate whether both values show a significant correlation.

2.1.1. The determination of the skin surface structure (roughness)

The skin surface structure was analyzed in the non-contact mode using the 3D optical system Primos 4.0 (GFMesstechnik GmbH, Teltow, Germany) as described in detail by Jacobi et al. [16]. This system is based on the digital stripe projection technique, which is used as an optical measurement process. A parallel stripe pattern is projected onto the skin surface and depicted on the CCD chip of a camera through an optical system. The measurement system consists of a freely movable optical measurement head (with an integrated micro-mirror projector, a projection lens system, and a CCD recording camera), together with an evaluation computer. The 3D effect is achieved by the minute elevation differences on the skin surface, which deflect the parallel projection stripes. The measurements of these deflections represent qualitative and quantitative measurements of the skin profile [15–17]. The roughness, which is based on the depth and the density of the furrows and wrinkles of the skin, was determined using the software Primos system. The average roughness (R_a) was determined as a mean value of the roughness parameters measured along 24 selected lines. R_a is the mathematical average value of profile amounts within the total measuring length, and represents the roughness of the skin surface structure [22].

The same skin area was measured three times and the mean values and standard deviations were subsequently determined. High roughness values corresponded to deep furrows and wrinkles with a high density.

2.1.2. Determination of the relative concentration of lycopene in the skin

A non-invasive fast optical measuring method based on resonance Raman spectroscopy was used in this study. The experimental prototype of the Raman setup was specially developed and optimized for measurements of the carotenoid lycopene in the skin, as described in detail by Darvin et al. [20].

The radiation of an Ar^+ laser at 514.5 nm is focused into an optical fibre which is connected to an optical imaging system, where the light is filtered and focused onto the skin. The Raman signal from the skin is collected by a lens system and transferred into a fibre bundle, connected to a spectrograph. The spectrum is recorded by a CCD camera and transferred to a personal computer.

The same skin area of each volunteer was measured three times, after which the average values and standard deviations were determined.

The relative concentration of lycopene was determined non-invasively by Raman spectroscopic measurements on