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ORIGINAL RESEARCH

The Use of Hemispheric Directional Reflectance Method to Verify the Usefulness of Filters Protecting the Skin Against Infrared Radiation

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Introduction: Infrared radiation (IR) has a wide spectrum of both positive and harmful effects on the human body. Negative properties, manifested by increasing the level of reactive oxygen species (ROS), affect the skin ageing acceleration. Other adverse effect of infrared exposure is related to its ability to significantly penetrate deep into the skin, between its layers, up to blood vessels and other tissues and warm them up. Due to its harmful effects, protecting the skin against infrared radiation becomes an important issue.

Aim: The aim of the research was verifying the usefulness of filters available on the market with protection against infrared radiation declared by the manufacturers, by examining their impact on the directional reflectance of the human skin.

Methods: A group of 27 people was gathered, to obtain the results. Four products were applied on the participant's forearm skin, and then measurements of the directional reflectance of the skin were made at successive time points, using the 410-Solar reflectometer. The collected data was analyzed, and showed changes in reflectance under the influence of the applied protective products.

Results: The products used in the study showed a statistically significant effect on the directional reflectance of the human skin in near infrared radiation range and little effectiveness for higher wavelengths.

Discussion: The results indicate that the selected products show radiation protection against IR radiation only after several dozen minutes of application, which may suggest that they must penetrate deeper skin layers to be effective. Hemispheric directional reflectance turned out to be an effective method allows to assess the effectiveness of protective properties of cosmetics.

Keywords: IR protection, qualitative assessment, hemispheric directional reflectance, cosmetics products

Introduction

Solar radiation is a factor that has an impact not only on the appearance, condition and rate of skin aging, but also on the general health of human body. Each of the solar radiation ranges has a different wavelength, as well as the associated depth of penetration into the skin. Infrared radiation (IR) has not been considered as a significant factor affecting the skin condition for quite long time.

Sunscreen products contain ingredients intended mainly to protect against ultraviolet radiation, but more often you can also find declared protection against infrared radiation. Therefore, the verification of their actual effectiveness becomes an important issue.[1–3]

The spectral range of sun radiation reaches the surface of the Earth is extremely wide, from 290 to over 1,000,000 nm and divided into short-wave (ultraviolet, visible light, infrared) and long-wave (terrestrial and atmospheric radiation). Infrared radiation (IR) belongs to the invisible electromagnetic radiation ranged from 770 to 15,000 nm. IR carries 47% of the solar radiation energy.[4,5] Some part of IR is reflected, after contact with the skin (about 1/3), the remaining part penetrates deep into the tissues. Penetration ability depends on the wavelength, the longer it is, the shallower the

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penetration. The principle is the basis for the conventional division of IR: short-wave radiation, the so-called near (IR-A) with a wavelength of 770–1500 nm (penetrates about 30 mm deep into the tissues, is absorbed mainly at a depth of 10 mm), medium-wave radiation (IR-B) with a wavelength of 1500–4000 nm (penetrates about 10 mm deep into the tissues, it is absorbed mainly at a depth of 3–5 mm), long-wave radiation (IR-C) with a wavelength of 4000–15,000 nm (penetrates about 0.5–3 mm deep into the skin). There is also the so-called "far infrared" (FIR) with a wavelength that can reach up to 25,000 nm - however, it has no clinical significance in the context of its impact on the skin and its appendages[3].

The biological effect of infrared radiation depends not only on the wavelength and the related ability to penetrate deep into the tissues, but also on the amount of emitted energy and the specific properties of the tissues. These include the heat capacity, which is related to the degree of hydration of the tissue. The feature characterizes both the skin and the subcutaneous tissue.[3,6]

Human skin provides a barrier that separates internal organism from external environment and the related factors that can have a negative impact, such as radiation. The basic defense mechanism is the thickening of the stratum corneum (hyperkeratosis), which physically reflects the radiation. In addition, the lipid layer of the epidermis along with the transurocanic acid have the ability to absorb and scatter radiation. Increased skin pigmentation is a defensive reaction to sun exposure and is a natural protective filter against radiation.[7,8] Since infrared radiation penetrates much deeper, it is important that skin has various types of chromophores, whose scattering and absorption coefficients allow it to react with different wavelengths. It causes dispersion of light in the tissue and decrease of energy density.[8–12]

Infrared radiation, which falls on skin surface, reflects in about 30%, the rest penetrates deeper.[10] The ability to penetrate depends on the wavelength. Tissues containing a large amount of water absorb IR best, when heated to an extent that depends on their heat capacity. Blood circulation transfers the heat generated in the tissues deeper into the body.[4,6]

IR affects the activity of the vascular system, the autonomic nervous system, organ reactions, increases the pain threshold and increases metabolism. An important issue, regards to cosmetology, is also the effect on the skin and its premature aging.[3,13] Due to the fact that one of the IR effects is an increase in tissue temperature, its use is associated with the occurrence of a skin reaction, which is thermal erythema.[3,4] Infrared radiation affects the nervous system, leading to a decrease in muscle tone.[3,4] In addition, the stimulation of endorphin production leads to an increase in the pain threshold.[3] The increase in temperature caused by IR, however, often leads to the appearance of tissue damage, including the skin tissue. The eyes are also vulnerable to infrared radiation. The rays concentrate at nodal points of the eye, where cause protein coagulation. As a consequence, lead to the so-called "glassblower's cataract", or cataract of metallurgists.[14,15] The negative effects of infrared radiation most often occur in conjunction with generated by the ultraviolet (UV) radiation. High near-infrared doses are harmful through two mechanisms. The first is to increase the level of ROS in the skin. The second one is based on inducing an temperature rise.[16,17] The ROS that form after exposure to infrared radiation occurs primarily in the fibroblasts at internal membrane of mitochondria.[16] The matrix metalloproteinases expression in fibroblasts is stimulated by both ultraviolet and IR radiation. Repeated exposure to IR radiation can cause premature skin photoaging in humans.[18]

Considering all the damages caused by sunlight, in particular infrared radiation, the use of protection is curtail against erythema and sunburn, along with the formation of ROS responsible not only for photoaging, but also for carcinogenesis.[19,20] The most important condition that sunscreens must meet is the content of ingredients with a wide range of protection, which are able to preserve against not only the UVA and UVB range of radiation. The proper degree of radiation protection is obtained by using an appropriate combination of both organic (organic filters) and inorganic (physical, mineral filters) ingredients.[21] It is important that the sunscreens are non-volatile, practically colorless and odorless. Compatibility with other ingredients of the cosmetic formula is also required. Taking care of consumer safety, it is important to use compounds with a low penetration ability, low toxicity and no allergenic properties.[21–23]

A wide range of sunscreens in form of creams, emulsions, gels, oils, aerosols and sticks is available on the market.[20,23] In addition to high efficiency, sunscreen products should also be characterized by abrasion resistance, water resistance, and should be evenly distributed on the skin without leaving a white and greasy layer.[23] The growing awareness of the negative effects of IR resulted on the market, where products containing labels saying of protection not only against UVA and UVB, but also IR, began to appear.

Objective

The research aim was to test in vivo whether cosmetics with declared IR protection are indeed effective. For this purpose, the method of hemispheric directional reflectance was used. The method enables a quantitative assessment of the dose of infrared radiation that is reflected/scattered from the skin surface in the spectral range corresponding to solar radiation.

Materials and Methods

The study involved 27 female volunteers, with Fitzpatrick skin type II between the ages 20 and 26, who were examined while applying products with protection against infrared radiation.

The research was conducted at the Department of Basic Biomedical Sciences, Medical University of Silesia. All volunteers agreed to participate in the study.

Each patient was examined using a SOC 410 Solar DHR reflectometer from Surface Optics Corporation, San Diego, CA, USA, which measures reflectance for seven discrete spectral ranges from 335 to 2500 nm before and after the application of four products marked as providing IR protection. Correctly performed measurement required calibration of the 410-Solar reflectometer using two calibration coupons, certified by the ANIST (American National Institute of Standards and Technology).[24]

SVR Cicavit+ SPF 50+, Pharmaceris SPF 100+, Bella Aurora SPF 50 (combination-oily skin), and Bella Aurora SPF 50 (normal-dry skin) creams were used. The examined area was the skin of the forearm. The skin of each of the volunteers was thoroughly cleansed before products application. The forearm skin was divided into four areas, separate for each tested cream. Measurements were taken before, just after and twenty minutes, one hour, one and a half hour and two hours after product application. The amount of applied products corresponded to the manufacturers recommendations.

A portion of the products, in the size of a rice grain [2 g/ cm^2] was thoroughly smeared with a plastic spatula (separate for each product) on an area of skin measuring three centimeters square. That test scheme was repeated for each cream. The next step was to make the first measurement. During the reflectance measurements, the measuring port was closely adhered to the examined tissue. The sample was exposed to a beam of radiation emitted by the reflectometer falling at an angle of 20 degrees.[24] This action was repeated three times in order to standardize the results. A list of reflectance results for 7 spectral bands was obtained (335–380 nm, 400–540 nm, 480–600 nm, 590–720 nm, 700–1100 nm, 1000–1700 nm and 1700–2500 nm). Detectors built into the integrating sphere measure the amount of reflected radiation and convert it into an analog electrical signal. The device electronics processes the detector signals first by initial gain (constant), filtering, by secondary gain (alternating) and analog-to-digital conversion. The digital signals were processed to determine the reflectance coefficient of the test sample for each wavelength band filtered just before the detectors. The reflectance was measured at wavelengths of 700–1100 nm, 1100–1700 nm and 1700–2500 nm.[24]

Results recording was automatic. Then the test results were analyzed. The results were analyzed using Microsoft Excel 2016 and Statistica 13 software applications. In order to determine the statistical significance, the Shapiro–Wilk test was performed to assess the normality of the distribution and the Friedman ANOVA to compare reflectance differences at different time points. The error bars were used to present the data variability. Results were regarded as significant at $p<0.05$. Based on the obtained averages, the effect of creams with protection against infrared radiation on the skin hemispheric directional reflectance was determined.

Protective Products Used in the Study

SVR Cicavit Crème 50+.[25] Ingredients:

Aqua/water/eau, dicaprylyl carbonate, diethylamino hydroxybenzoyl hexyl benzoate, diethylhexyl butamido triazone, diisopropyl adipate, silica, cetearyl alcohol, bis-ethylhexyloxyphenol methoxyphenyl triazine, ceteareth-20, ethylhexyl triazone, dimethicone, niacinamide, polymethylmethacrylate, pentylene glycol, polyester-7, aminomethyl propanol, beta-carotene, beta-sitosterol, cetearyl dimethicone crosspolymer, Daucus carota sativa (carrot) root extract, glycine soja (soybean) oil, hydrogenated phosphatidylcholine, lecithin, Lepidium sativum sprout extract, squalene, alpha-glucan oligosaccharide, caffeyl glucoside, disodium acetyl glucosamine phosphate, glucose, glycerin, phytic acid, rhamnose, tocopherol, tocopheryl acetate, 1.2-hexanediol, caprylic/capric triglyceride, caprylyl glycol, citric acid, glucuronic acid, hydroxyethyl acrylate/sodium acryloyldimethyl taurate copolymer, lysolecithin, neopentyl glycol diheptanoate, polysorbate 60, propanediol, sodium laureth sulfate, sorbitan isostearate, xanthan gum, potassium sorbate, sodium benzoate.

Pharmaceris SPF 100+.[26] Ingredients:

Aqua Purified, Emollients: Canola Oil, Algae Extract and others, Glycerol, Zinc Oxide, UV Filters, Honeysuckle Extracts, Excipients.

Bella Aurora SPF 50+.[27,28]

Combination-oily skin. Ingredients:

Aqua, Butyl Methoxydibenzoylmethane, Ethylhexyl Methoxycinnamate, Butylene Glycol, Octocrylene, Glycerin, Betaine, Orbignya Oleifera Seed Oil, Hydrogenated Ethylhexyl Olivate, Methylpropanediol, Silica, Thermus Thermophillus Ferment, Akrylaty sodu. Copolymer, Titanium Dioxide, Polysorbate 20, Tocopheryl Acetate, Curcuma longa Root Extract, Alcohol Denat, Lecithin, Caprylyl Glycol, Hydrogenated Olive Oil Unsaponifiables, Disodium EDTA, Phenylpropanol, Sorbitol, Xanthan Gum, Glyceryl Caprylate, Oleic Acid, Phenoxyethanol, sorbate potassium CI 77491, perfumy, linalol, hydroxycitronellal, limonene, Citronellol.

Normal-dry skin. Ingredients:

Aqua, Dibutyl Adipate, Ethylhexyl Methoxycinnamate, Propylene Glycol, Butyl Methoxydibenzoylmethane, Ethylhexyl Salicylate, Bis - Ethylhexyloxyphenol Methoxyphenyl Triazine, Opopentasilxane, Ethylhexyl Triazone, Silica, Polyester-7, Glycerin, Nylon 6/12, V /Hexadecene Copolymer, Neopentyl Glycol Diheptanoate, Thermus Thermophillus Ferment, Tocopheryl Acetate, Tocopherol, Ascorbyl Palmitate, Ascorbic Acid, Arctostaphylos Uva Ursi Leaf Extract, Mitracarpus Scaber Extract, Dimethicone, Bis–PEG/PPG-20/5PEG/PPG-20/5 Dimethicone, Methoxy PEG/ PPG-25/4 Dimethicone, Ethylhexylglycerin, Caprylic/Capric Triglyceride, Acrylates/C10-30 Alkyl Acrylate Magnesium Aluminum Silicate, Butylene Glycol, C13-14 Isoparaffin, Disodium EDTA, Sodium Hydroxide, PEG-8, Laureth-7, BHT, Citric Acid, Pentaerythrityl Tetra-Di-T-Butyl Hydroxyhydrocinnamate, Sodium Bisulfite, Phenoxyethanol, Potassium Sorbate, Parfum, Linalool, Hydroxycitronellal, Limonene, Citronellol

Results

Figures 1–12 show the values of directional reflectance coefficient at particular time points before and after the application of four creams with declared protection against infrared radiation used in the study. The reflectance was measured at wavelengths of 700–1100 nm, 1100–1700 nm and 1700–2500 nm.

The application of the SVR Cicavit+ SPF 50+ cream did not affect significantly the skin reflectance at the wavelength 700–1100 nm (Figure 1).

Statistical analysis showed statistically significant differences in skin reflectance at the wavelength 700–1100 nm caused by the use of Pharmaceris SPF 100+ cream ($p< 0.05$) (Figure 2.). The greatest differences occurred between the reflectance of the skin without the cream (t0) and the reflectance of the skin one hour after the application of the cream (t3), however, in the post-hoc test, statistical significance was not reached between any time points.

The application of Bella Aurora SPF 50 cream, intended for combination and oily skin, resulted in statistically significant differences in reflectance at the wavelength 700–1100 nm ($p<0.05$) (Figure 3.) Statistically significant differences in reflectance confirmed in the post-hoc test occurred between clean skin (t0) and skin one hour after the application of Bella Aurora SPF 50 (combination-oily skin) cream (t3) ($p<0.05$), clean skin was characterized by lower reflectance compared to skin one hour after application.

There were high statistical differences ($p<0.001$) in skin reflectance at the wavelength of 700–1100 nm after the application of Bella Aurora SPF 50 cream for normal and dry skin (Figure 4). Skin reflectance was significantly higher two hours after cream application (t5) compared to clean skin (t0) ($p<0.05$), skin immediately after cream application (t1) ($p<0.05$) and twenty minutes after application (t2) ($p<0.05$).

The application of the SVR Cicavit+ SPF 50+ sunscreen cream did not have a significant effect on skin reflectance at the wavelength 1000–1700 nm (Figure 5).

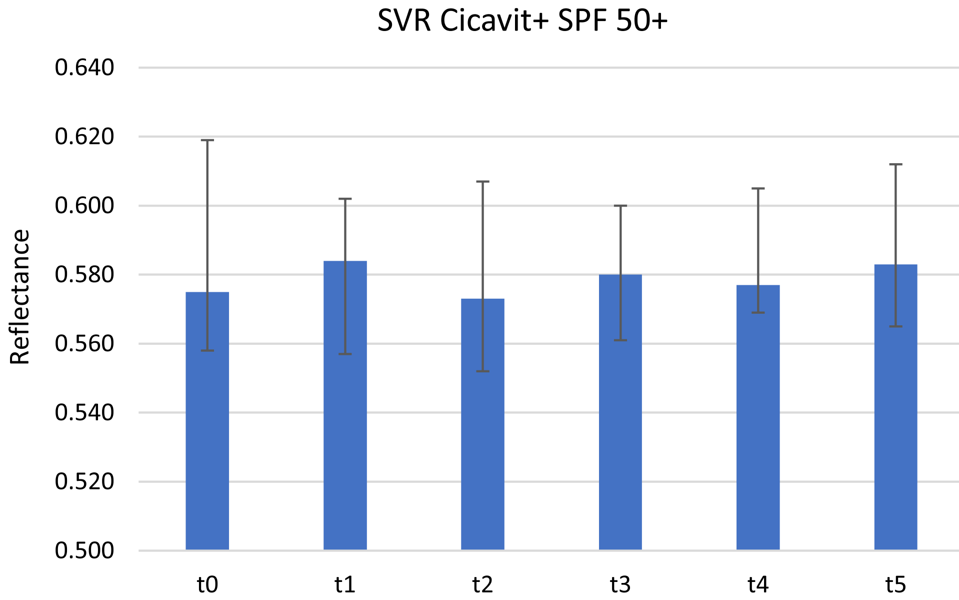

Figure 1 Skin reflectance at 700–1100 nm before application of SVR Cicavit+ SPF 50+ cream (t0), immediately after application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range.

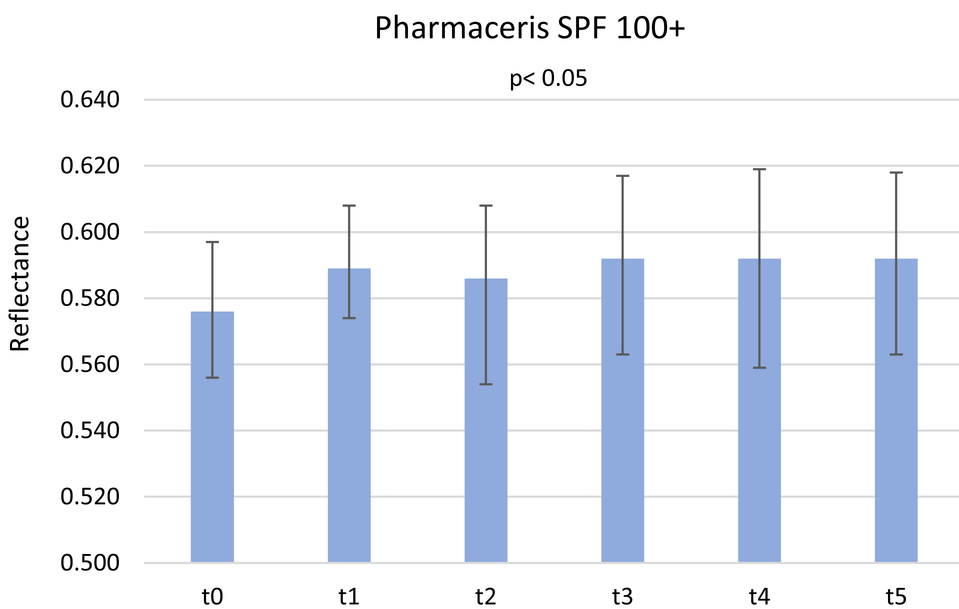

Figure 2 Skin reflectance at the wavelength of 700–1100 nm before application of Pharmaceris SPF 100+ cream (t0), immediately after its application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range.

The application of the Pharmaceris SPF 100+ sunscreen did not create a statistically significant effect on skin reflectance at the wavelength 1000–1700 nm (Figure 6).

The application of Bella Aurora SPF 50 cream, intended for combination and oily skin, resulted in significant differences in reflectance at 1000–1700 nm ($p<0.05$) (Figure 7). Statistically significant differences in reflectance occurred compared the skin immediately after the application of the cream (t1) and the skin one hour after the application of the cream (t3), the skin immediately after application was characterized by lower reflectance.

There were statistically significant differences in skin reflectance at 1000–1700 nm after using Bella Aurora SPF 50 cream for normal and dry skin ($p<0.001$) (Figure 8). Skin reflectance was significantly lower immediately after

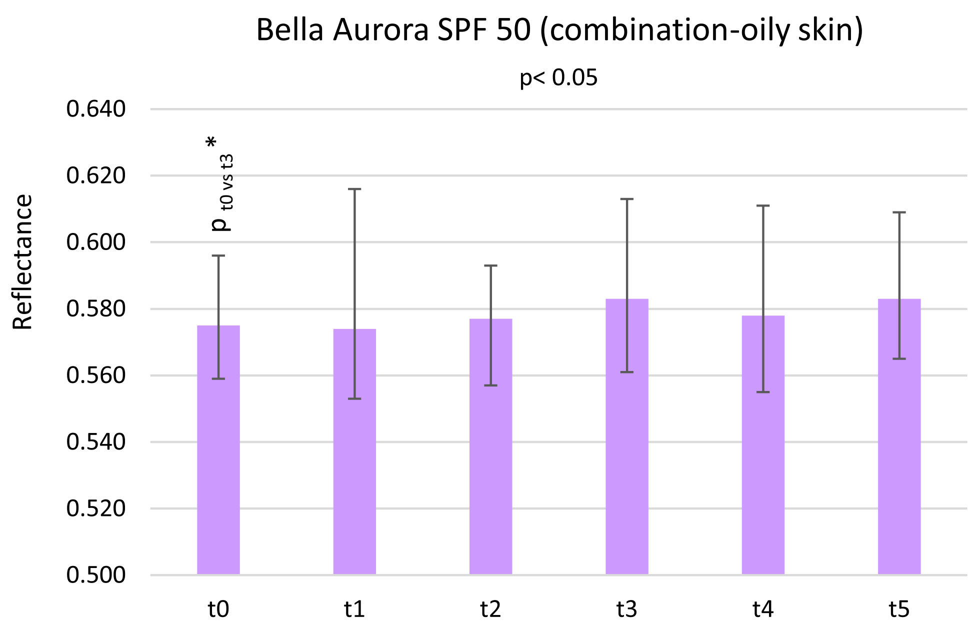

Figure 3 Skin reflectance at the wavelength of 700–1100 nm before applying Bella Aurora SPF 50 (combination-oily skin) cream (t0), immediately after its application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range, *Statistically significant, p – level of significance.

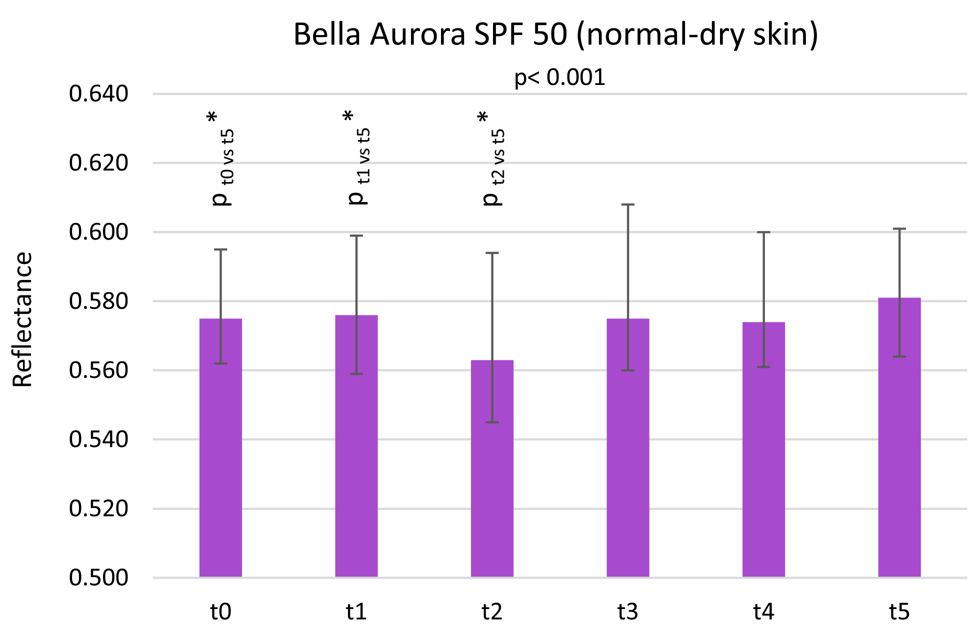

Figure 4 Skin reflectance at the wavelength of 700–1100 nm before the application of Bella Aurora SPF 50 (normal-dry skin) cream (t0), immediately after its application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range, *Statistically significant, p – level of significance.

application (t1) compared to skin reflectance two hours after (t5) ($p<0.05$). Skin reflectance twenty minutes after application of the cream (t2) was significantly lower compared to skin reflectance one hour (t3) and two hours (t5) after the application ($p<0.05$).

Statistically significant differences in skin reflectance at 1700–2500 nm caused by the use of SVR Cicavit+ SPF 50+ cream ($p<0.01$) (Figure 9) were showed. Statistically significant differences in reflectance occurred between clean skin (t0) and skin one hour after application of the cream (t3) ($p<0.05$), clean skin was characterized by lower reflectance.

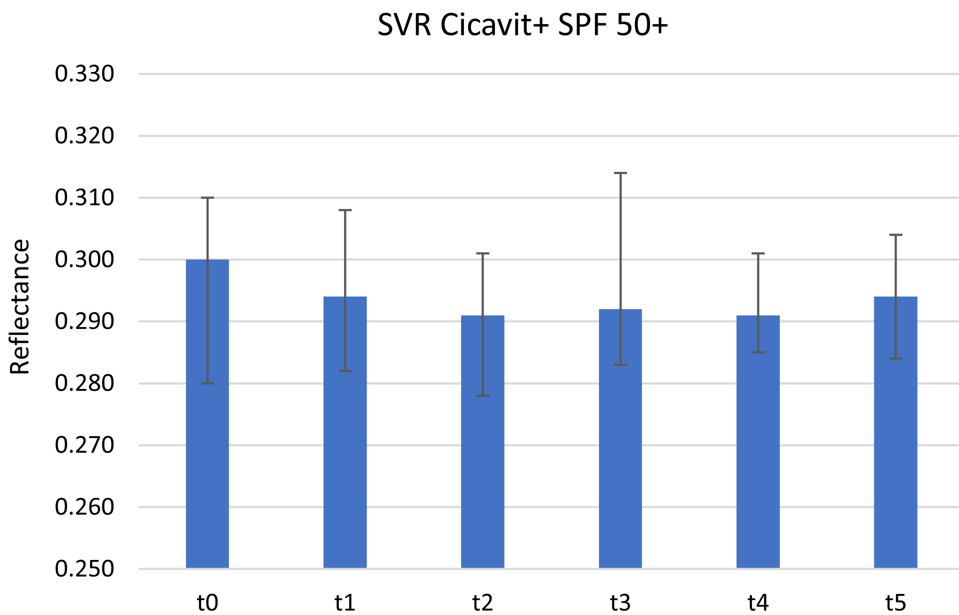

Figure 5 Skin reflectance at a wavelength of 1000–1700 nm before applying SVR Cicavit+ SPF 50+ cream (t0), immediately after its application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range.

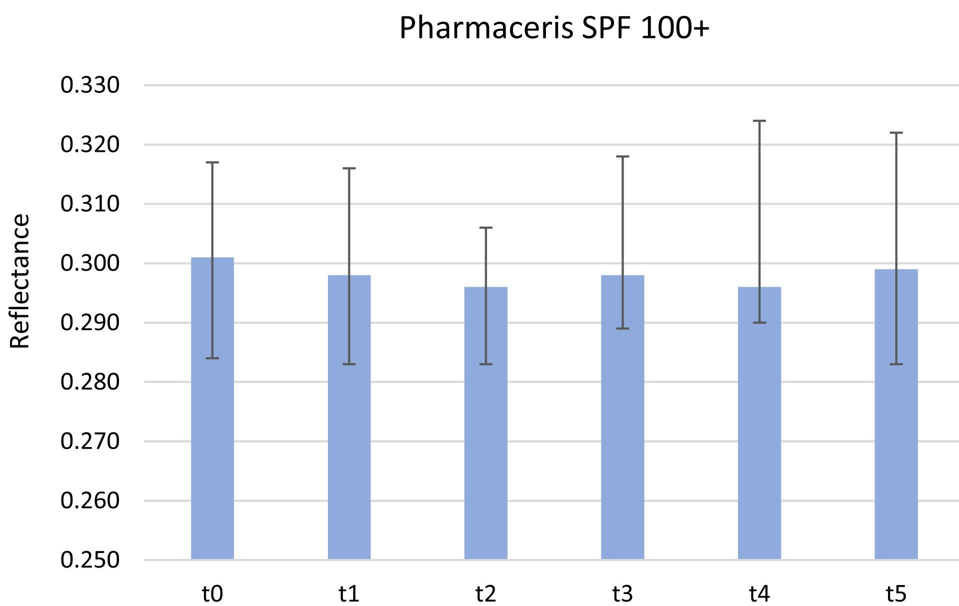

Figure 6 Skin reflectance at the wavelength of 1000–1700 nm before applying the Pharmaceris SPF 100+ cream (t0), immediately after its application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range.

Statistically significant differences in skin reflectance at the wavelength of 1700–2500 nm caused by the application of Pharmaceris SPF 100+ cream ($p< 0.001$) (Figure 10) have been shown. The reflectance of clean skin (t0) was significantly lower compared to skin reflectance one hour (t3) ($p<0.05$) and one and a half hours (t4) ($p<0.05$) after product application. The reflectance of the skin immediately after the application (t1) was lower than one hour after the application (t3) ($p<0.05$).

The application of Bella Aurora SPF 50 cream, intended for combination and oily skin, resulted in statistically significant differences in reflectance at the wavelength of 1700–2500 nm ($p<0.01$) (Figure 11). Statistically significant

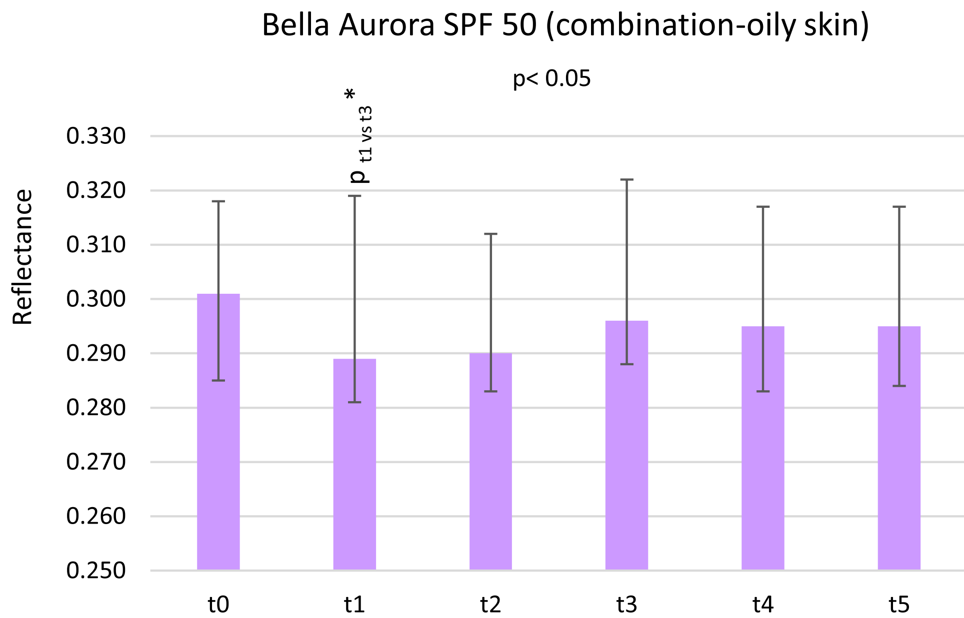

Figure 7 Skin reflectance at 1000–1700 nm wavelength before application of Bella Aurora SPF 50 (combination-oily skin) cream (t0), immediately after its application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range, *Statistically significant, p – level of significance.

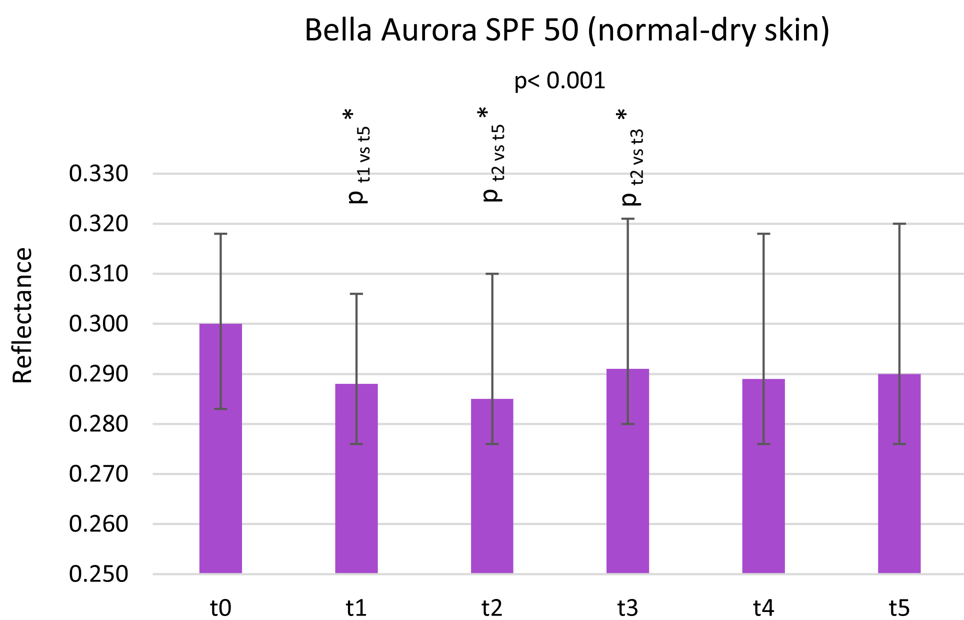

Figure 8 Skin reflectance at the wavelength of 1000–1700 nm before the application of Bella Aurora SPF 50 (normal-dry skin) cream (t0), immediately after its application (t1), and after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Bar – median, whiskers – quartile range, *Statistically significant, p – level of significance.

differences in reflectance confirmed in the post-hoc test occurred between clean skin (t0) and skin one hour after product application (t3) ($p<0.05$), clean skin was characterized by lower reflectance.

There were statistically significant differences in skin reflectance at 1700–2500 nm after the application of Bella Aurora SPF 50 cream for normal and dry skin ($p < 0.01$) (Figure 12). Skin reflectance was significantly lower immediately after cream application (t1) compared to skin one hour after the application (t3) ($p<0.05$).

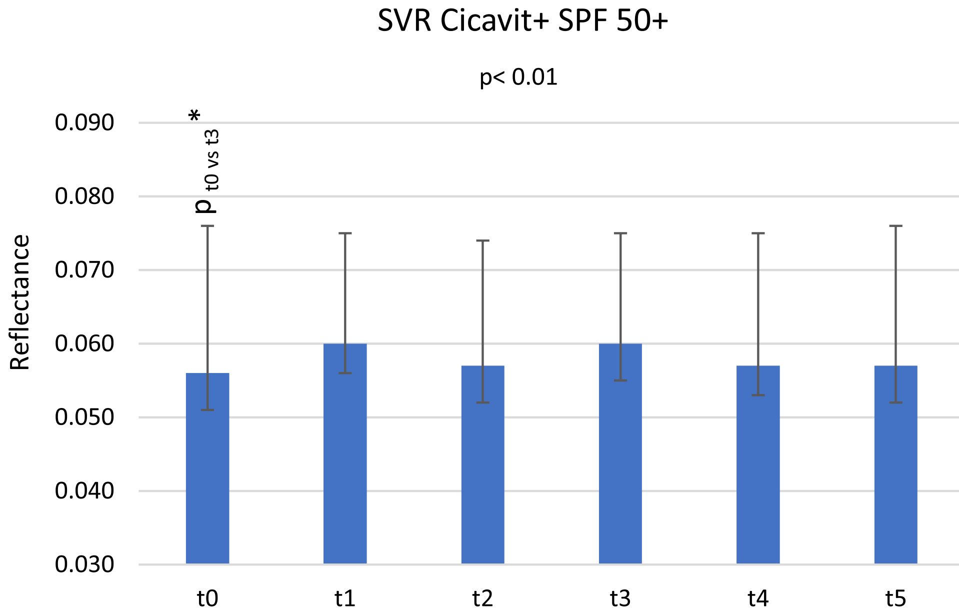

Figure 9 Skin reflectance at 1700–2500 nm wavelength before application of SVR Cicavit+ SPF 50+ cream (t0), immediately after application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range, *Statistically significant, p – level of significance.

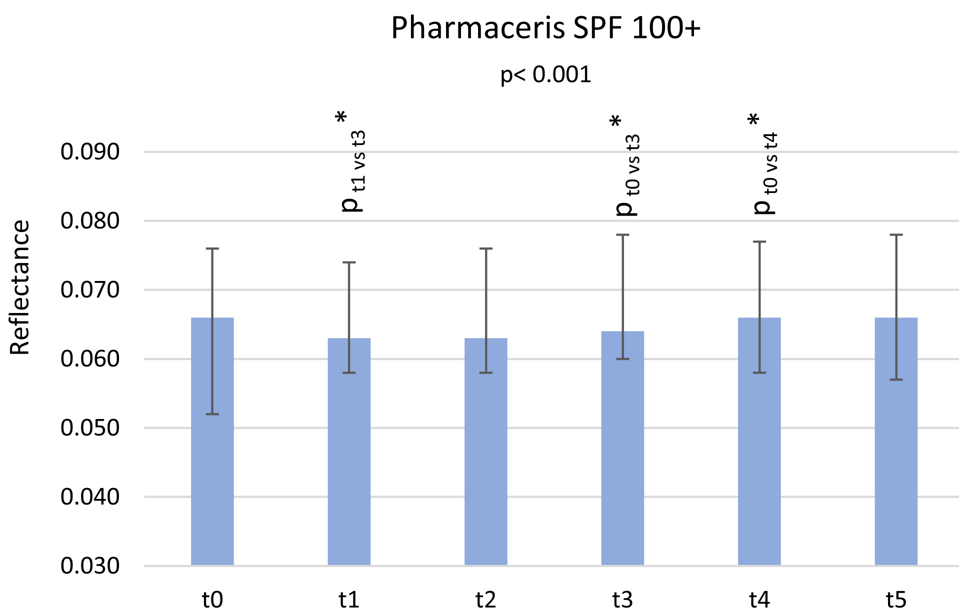

Figure 10 Skin reflectance at the wavelength of 1700–2500 nm before applying the Pharmaceris SPF 100+ cream (t0), immediately after the application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range, *Statistically significant, p – level of significance.

Discussion

In this study the hemispheric directional reflectance was used performing a measurements before and after the application of products containing sunscreens to assess their effectiveness against infrared radiation. The increase in reflectance, ie radiation reflection in all of the tested ranges, have been monitored. It should be emphasized that the higher the reflectance, the more effective protection against radiation, because only radiation absorbed by tissues can induce biological effects. At the wavelength of 700–1100 nm, corresponding mainly to the near infrared (IR-A), the application of Pharmaceris and Bella Aurora creams resulted in a significant increase in skin reflectance. In the case of the SVR

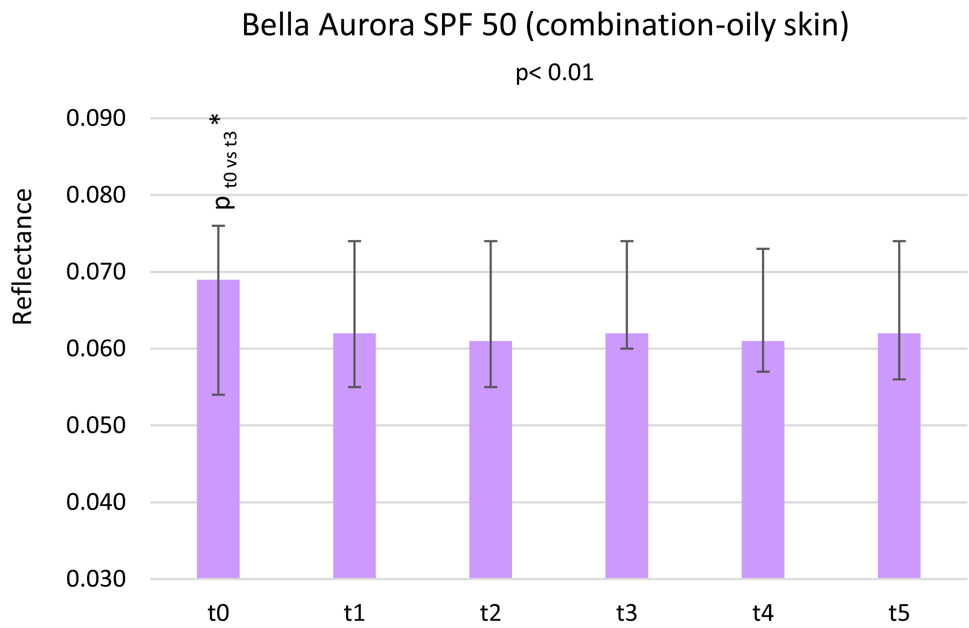

Figure 11 Skin reflectance at the wavelength of 1700–2500 nm before Bella Aurora SPF 50 (combination-oily skin) cream application (t0), immediately after the application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box – median, whiskers – quartile range, *Statistically significant, p – level of significance.

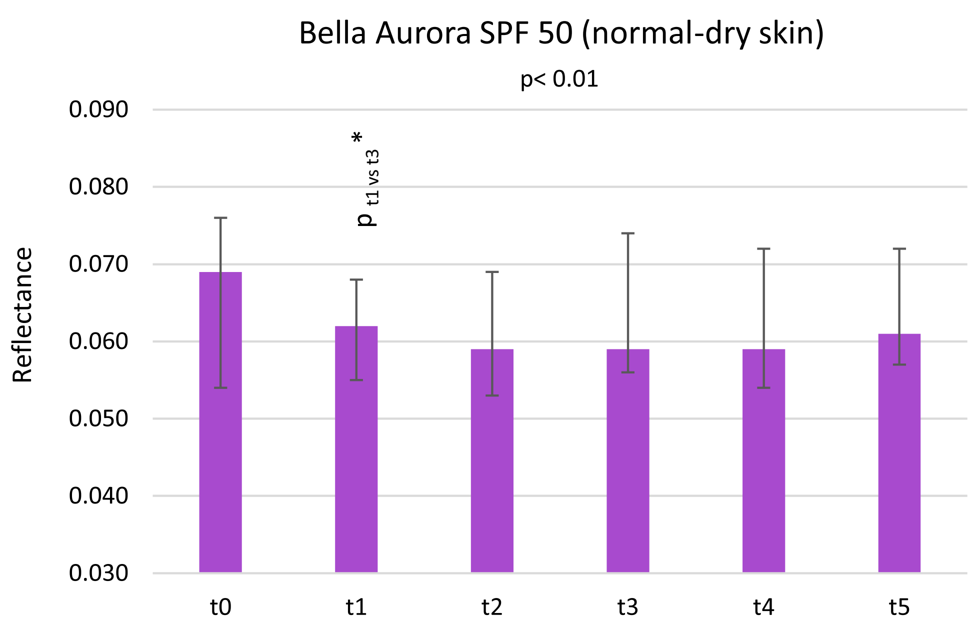

Figure 12 Skin reflectance at the wavelength of 1700–2500 nm before Bella Aurora SPF 50 (normal-dry skin) cream application (t0), immediately after the application (t1), after 20 minutes (t2), 1 hour (t3), 1.5 hours (t4) and 2 hours (t5). Box– median, whiskers – quartile range, *Statistically significant, p – level of significance.

Cicavit cream, the changes were not so noticeable. The results at subsequent time points allowed to observe an increase in the level of reflectance, and thus also the protection values of the tested products, although the differences were not always significantly noticeable. At the wavelength of 1000–1700 nm, corresponding to the near infrared, but also partially to the mid-wave infrared (IR-B), the application of SVR and Pharmaceris creams did not affect skin reflectance significantly. A significant increase in reflectance occurred in the case of Bella Aurora products. An important issue was a clear difference between the level of reflectance immediately after application in the comparison of further time points (one hour, two hours after application). Immediately after application, the reflectance was lower, suggesting that higher and more significant protection in the stated radiation range is only achieved over time. This is why it is necessary to follow the manufacturers recommendations. At the wavelength of 1700–2500 nm, which corresponds to mid-wave infrared (IR-B) radiation, there were statistically significant differences in reflectance values, but mainly observed when comparing clean skin to skin after application (the greatest increase in reflectance one hour after application). Differences in participant's skin reflectance at subsequent time points did not differ significantly, with the few exceptions. In addition, the reflectance values were significantly lower than those obtained in the lower ranges of radiation. This may suggest that the tested products presented lower protection in this IR ranges. The results show that the creams used in the study gradually lost their effectiveness along with increasing wavelength of radiation reaching the skin. Therefore, the used products cannot be considered as sufficient protection in the case of rays penetrating deeper through the skin and its layers. Few literature sources describe effects of infrared radiation on human skin aging,[29] but the use of a reflectometer to examine the skin and cosmetic products exposed to IR is a new method recently implemented by the Department of Basic Biomedical Sciences at Medical University of Silesia in Poland.[30] The method of directional reflectance is groundbreaking because it is the only method that allows quantitative identification of the effect of sunscreen preparations in various wavelength ranges in vivo. It is not only a way to determine the effectiveness and quality of filters protecting against ultraviolet radiation, but also against infrared radiation. Sławomir Wilczyński taken up the subject in manuscript entitled "The Use of Directional Reflectance Measurement for in vivo Assessment of Protective Properties of Cosmetics in the Infrared Radiation Range".[30] The filters protecting against infrared radiation were analyzed and it has been shown that creams containing sunscreens do not provide as effective protection against IR radiation as in the case of ultraviolet radiation, this result was confirmed in this paper. It should be noted that it is difficult to talk about effective protection against IR radiation if the methodology for the quantitative assessment of filters in this spectral range is just being developed. Further research about IR rays effect and properties are needed, and after that expanding the knowledge among both consumers and producers.[30,31] This may influence the appearance of filters with a wider range of protection against radiation in the future, with noticeable effectiveness in blocking infrared radiation. The method of directional reflectance presented in this paper can be a valuable method both in the verification of the accuracy of the methodology and in the study of other potentially effective ingredients designed to protect the skin against infrared radiation.

Conclusion

After analyzing the efficacy of sunscreens claiming skin protection against IR radiation using the directional reflectance method, the following conclusions have been drawn:

1. The use of hemispheric directional reflectance can be an effective method that analyze the effectiveness of sunscreens against infrared radiation in in vivo conditions.
2. The products used in the study show a statistically significant effect on the skin directional reflectance in the near infrared range and little effectiveness for higher wavelengths, which confirms the tendency that the higher the wavelength of radiation, the more difficult it is to protect against the radiation. The results indicate that the selected creams show radiation protection against IR radiation only after several dozen minutes of application, which may suggest that they must penetrate into the deeper skin layers to be effective.
3. The obtained results allow us to conclude that the tested products have a limited spectrum of protection, which is so narrow that it does not provide enough infrared protection.

Abbreviations

IR, infrared radiation; IR-A, short-wave IR; IR-B, medium-wave IR; IR-C, long-wave IR; FIR, far infrared; UV, ultraviolet radiation; ROS, reactive oxygen species; ANIST, American National Institute of Standards and Technology.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Bioethics Committee of the Medical University of Silesia (PCN/CBN/0052/KB1/62/22). Written informed consent was obtained from all participants.

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Disclosure

The authors report no conflicts of interest in this work.

References

1. Surber C, Osterwalder U. Challenges in sun protection. *Curr Probl Dermatol*. 2021;55:1–43.
2. Tsai S, Hamblin M. Biological effects and medical applications of infrared radiation. *J Photochem Photobiol*. 2017;170:197–207. doi:10.1016/j.jphotobiol.2017.04.014
3. Skotarczak K, Osmola-Mańkowska A, Lodyga M, Polańska A, Mazur M, Adamski Z. Photoprotection: facts and controversies. *Eur Rev Med Pharmacol Sci*. 2015;19(1):98–112.
4. Holick MF. Biological effects of sunlight, ultraviolet radiation, visible light, infrared radiation and vitamin D for health. *Anticancer Res*. 2016;36(3):1345–1356.
5. Grandi C, D'Ovidio MC. Balance between health risks and benefits for outdoor workers exposed to solar radiation: an overview on the role of near infrared radiation alone and in combination with other solar spectral bands. *Int J Environ Res Public Health*. 2020;17(4):1357. doi:10.3390/ijerph17041357
6. Kasprzak W, Mańkowska A. *Fizjoterapia w kosmetologii i medycynie estetycznej [Physiotherapy in cosmetology and aesthetic medicine]*. Warszawa: Wydawnictwo Lekarskie PZWL; 2010:181–188. Polish.
7. Rittié L, Fisher GJ. Natural and sun-induced aging of human skin. *Cold Spring Harb Perspect Med*. 2015;5(1):a015370. doi:10.1101/cshperspect.a015370
8. Ash C, Dubec M, Donne K, Bashford T. Effect of wavelength and beam width on penetration in light-tissue interaction using computational methods. *Lasers Med Sci*. 2017;32(8):1909–1918. doi:10.1007/s10103-017-2317-4
9. Vatansever F, Hamblin MR. Far infrared radiation (FIR): its biological effects and medical applications. *Photonics Lasers Med*. 2012;1(4):255–266. doi:10.1515/plm-2012-0034
10. Holzer AM, Athar M, Elmets CA. The other end of the rainbow: infrared and skin. *J Invest Dermatol*. 2010;130(6):1496–1499. doi:10.1038/jid.2010.79
11. Lee JH, Roh MR, Lee KH. Effects of infrared radiation on skin photo-aging and pigmentation. *Yonsei Med J*. 2006;47(4):485–490. doi:10.3349/ymj.2006.47.4.485
12. Barolet D, Christiaens F, Hamblin MR. Infrared and skin: friend or foe. *J Photochem Photobiol B*. 2016;155:78–85. doi:10.1016/j.jphotobiol.2015.12.014
13. Horton L, Torres AE, Narla S, et al. Spectrum of virucidal activity from ultraviolet to infrared radiation. *Photochem Photobiol Sci*. 2020;19(10):1262–1270. doi:10.1039/d0pp00221f
14. Cheng YC, Lung CW, Jan YK, et al. Evaluating the far-infrared radiation bioeffects on micro vascular dysfunction, nervous system, and plantar pressure in diabetes mellitus. *Int J Low Extrem Wounds*. 2020;19(2):125–131. doi:10.1177/1534734619880741
15. Balasubramanian D. Ultraviolet radiation and cataract. *J Ocul Pharmacol Ther*. 2000;16(3):285–297. doi:10.1089/jop.2000.16.285
16. Akhalaya MY, Maksimov GV, Rubin AB, Lademann J, Darvin ME. Molecular action mechanisms of solar infrared radiation and heat on human skin. *Ageing Res Rev*. 2014;16:1–11. doi:10.1016/j.arr.2014.03.006
17. McDaniel D, Farris P, Valacchi G. Atmospheric skin aging-Contributors and inhibitors. *J Cosmet Dermatol*. 2018;17(2):124–137. doi:10.1111/jocd.12518
18. Bonté F, Girard D, Archambault JC, Desmoulière A. Skin changes during ageing. *Subcell Biochem*. 2019;91:249–280.
19. Holick MF. Sunlight, UV Radiation, Vitamin D, and skin cancer: how much sunlight do we need? *Adv Exp Med Biol*. 2020;1268:19–36.
20. Sample A, He YY. Mechanisms and prevention of UV-induced melanoma. *Photodermatol Photoimmunol Photomed*. 2018;34(1):13–24. doi:10.1111/phpp.12329
21. Serpone N. Sunscreens and their usefulness: have we made any progress in the last two decades? *Photochem Photobiol Sci*. 2021;20(2):189–244. doi:10.1007/s43630-021-00013-1
22. Bens G. Sunscreens. *Adv Exp Med Biol*. 2014;810:429–463. doi:10.1007/978-1-4939-0437-2_25
23. He H, Li A, Li S, Tang J, Li L, Xiong L. Natural components in sunscreens: topical formulations with sun protection factor (SPF). *Biomed Pharmacother*. 2021;134:111161. doi:10.1016/j.biopha.2020.111161
24. 410 Solar [user manual]. Surface Optics Corporation 11555 Rancho Bernardo Rd San Diego. CA 92127, MODEL 0410-0001 / 0410-0200 Command Module, MODEL 0410-0004 SOC410 Solar Measurement Head (US Patent #7,236,243). Available from: https://surfaceoptics.com/. Accessed September 19, 2023.
25. SVR Laboratoire Dermatologique. INCI Cicavit+Creme SPF50+. Available from: https://pl.labo-svr.com/products/cicavit-cremespf50. Accessed September 19, 2023.
26. Pharmaceris. INCI Pharmaceris SPF 100+ cream MEDIC PROTECTION. Available from: https://pharmaceris.com/produkt/10M16007-01-01/pharmaceris-a-krem-specjalna-ochrona-spf-100-do-twarzy-i-ciala-medic-protection-75-mL-31253. Accessed September 19, 2023.
27. Bella Aurora Labs. INCI Bella Aurora SPF 50+ (combination-oily skin) cream. Available from: https://bella-aurora.com/pl-pl/bella-aurora/168-zel-przeciwsloneczny-przeciw-plamom-pigmentacyjnym-cera-tlusta-i-mieszana.html. Accessed September 19, 2023.
28. Bella Aurora Labs. INCI Bella Aurora SPF 50 (normal-dry skin) cream. Available from: https://bella-aurora.com/pl-pl/bella-aurora/167-krem-przeciwsloneczny-przeciw-plamom-pigmentacyjnym-normalna-i-sucha-skora.html. Accessed September 19, 2023.
29. Cho S, Shin MH, Kim YK, et al. Effects of infrared radiation and heat on human skin aging in vivo. *J Investig Dermatol Symp Proc*. 2009;14(1):15–19. doi:10.1038/jidsymp.2009.7
30. Wilczyński S, Deda A, Koprowski R, Banyś A, Błońska-Fajfrowska B. The use of directional reflectance measurement for in vivo assessment of protective properties of cosmetics in the infrared radiation range. *Photochem Photobiol*. 2017;93(5):1303–1311. doi:10.1111/php.12786
31. Kim SJ, Bae J, Lee SE, et al. A novel in vivo test method for evaluating the infrared radiation protection provided by sunscreen products. *Skin Res Technol*. 2019;25(6):890–895.