Evaluating the Efficiency of a Prototype UV LED System in Producing Vitamin D₃ in Surgically Obtained Skin

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Abstract

Vitamin D deficiency is a worldwide pandemic resulting from the lack of vitamin D in one’s diet or insufficient exposure to sunlight. The goal of this experiment was to evaluate the efficiency of a prototype device containing nine-LEDs, that emit at a peak wavelength of 293 nm. Nine borosilicate ampoules containing 7-DHC were exposed directly to the LEDs and four ampoules were placed 7mm from the center of the LED system. A Fitzpatrick type III surgically obtained human skin sample was placed epidermis face down, in a quartz petri dish 7mm above the LED system. Separately, the ampoules and skin sample were exposed to 0.16 J/cm² for 3 minutes 56 seconds. Punch biopsies of the skin were taken at regions at the core of LED exposure and at the periphery to be run on HPLC for vitamin D₃ quantification. The results supported the concept that irradiating the skin with our LED prototype is successful in generating vitamin D₃. The nine-LED system can effectively produce the Recommended Dietary Allowance (RDA) of Vitamin D in 2 minutes and 50 seconds in the average person. Further research can use this data to create a wearable medical device for providing vitamin D to patients who cannot absorb adequate levels through their diet.

Methods

• The 9-LED prototype, having a surface area of 44 cm², emitted UV radiation at a peak wavelength of 293 nm.
• Holes were created in a piece of styrofoam of regions directly above each LED and 7mm to the center LED where nine and four, respectively, borosilicate ampoules were placed.
• In addition, a Fitzpatrick Type III skin sample was placed, epidermis face down, in a quartz petri dish 7mm above the LED system.
• Separately, the ampoules and skin sample were exposed to 0.16 J/cm² for 3 minutes 56 seconds.
• 8mm diameter skin punch biopsies were taken at regions directly at the site of LED exposure and at 7mm from the center of the LED.
• After being submerged in 2.5mL of ethyl acetate, sonicated for 10 seconds, and incubated overnight at 50°C, the skin samples were run on HPLC at a flow rate of 1.5 mL/min for vitamin D₃ quantification.

Discussion

In the surgically obtained skin sample, the total amount of vitamin D₃ produced was 472.9 ng (210 IU), which shows that the LED system is successful in generating the conversion of 7-DHC to vitamin D₃. The amount of vitamin D₃ produced per area of direct exposure is 56.3 ng/cm² while the amount of vitamin D₃ produced per area of peripheral exposure is 18.8 ng/cm². This supports the concept that direct exposure is more efficient that peripheral exposure.

The concentration of total vitamin D₃ produced per total area of skin sample is 22.4 ng/cm² (18.9 IU/cm²). The Recommended Daily Allowance (RDA) of vitamin D is 600 IU for the average person. Using the nine-LED prototype, exposure of 3.5% and 4.2% of an average male and female’s body, respectively, (1/3 of his/her arm) would provide adequate vitamin d production to meet his RDA. Thus, it is highly efficient in producing vitamin D₃. Those who have fat malabsorption issues can use this LED system to produce a sufficient amount without taking vitamin D supplements.

Introduction

Vitamin D deficiency affects almost 50% of the world’s population. While it can be obtained from the diet, most of the vitamin D that humans produce comes directly from the sunlight, or an artificial source. It is produced cutaneously when ultraviolet B (UVB) radiation penetrates into the skin and is absorbed by 7-dehydrocholesterol (7-DHC). The subsequent bond breaking results in the conversion of 7-DHC to previtamin D₃ which rearranges into a more thermodynamically stable form called vitamin D₃, induced by body temperature.

Gallium nitride light emitting diodes (LEDs) have been developed at Boston University to emit ultraviolet radiation. These LEDs can be tuned to emit certain wavelengths in order produce Vitamin D₃ in skin. Those who have fat malabsorption issues struggle to absorb sufficient amounts of vitamin D from the diet and must rely on cutaneous production of vitamin D₃ to maintain acceptable levels. Although the efficiency of one LED has been tested, it has not been tested if a system of multiple LEDs is as successful in generating vitamin D₃.

The nine-LED system was provided by a group of MIT researchers. The energy output of each LED was measured using a Solar meter. This meter estimates the output in terms of Minimal Erythemal Dose (MED) per hour.

Results

Absorbance (in AU)

Figure 5. HPLC Chromatographs display the previtamin D₃, vitamin D₃ and 7-DHC content for ampoules.

How many minutes do I stand under an LED to produce the RDA of Vitamin D₃?

A. The standard.
B. The ampoule directly exposed to LED 1.
C. The ampoule placed 7mm diagonally from LED 1.

Time (minutes)

Figure 6. This graph shows the concentration of vitamin D₃ produced per area of skin between direct and peripheral exposure to the prototype LED. The direct exposure contains 56.3 ng/cm² and the peripheral exposure has a concentration of 18.8 ng/cm².

Conclusions

The nine LED prototype is effective in generating vitamin D₃ in surgically obtained human skin. It takes exposure to 1/3 of the arm for less than 4 minutes to produce the recommended allowance of vitamin D using this LED system for an average person.

References


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Figure 1. The exposure of sunlight stimulates the conversion of 7-DHC to previtamin D₃ to vitamin D₃.

Figure 2. The prototype LED system.

Figure 3. The ampoules irradiated above the LEDs.

Figure 4. Human skin type III irradiated with four LEDs.

Figure 7. Each LED emits UVB radiation in a cone shaped manner. As the distance from the LED increases, the area receives a larger amount of radiation, as shown above by the inverse square law. The skin sample that was not exposed directly to the LED produced vitamin D₃, demonstrating that the nine LEDs spaced 25mm apart are indeed efficient in producing vitamin D₃ even with the distance.