

Short Communication

Ascorbic Acid (AA) Versus Dehydroascorbic Acid (DHA) in the Aqueous Humor - A Novel Functional Unit

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Abstract

Purpose: To evaluate the significance of AA versus DHA in the aqueous humor of diurnal mammals.

Material and Methods: Previous observations are presented in a new context.

Results: The ciliary epithelium, the corneal endothelium, and the lens are working together as a functional unit ensuring high content of AA in the aqueous humor.

Conclusion: The joint efforts by these three mechanisms to create high AA concentration in the aqueous humor at the expense of DHA, indicate that high AA content in this area is needed for some purpose. The reason could be that only AA, of the two, is useful for UV-B absorption. Thus, the existence of this functional unit may support the hypothesis that the aqueous humor acts as a UV-B filter in addition to the cornea.

INTRODUCTION

The significance of AA in the anterior segment of the eye has been in focus for decades. The current view is that the negative impact of UV-B radiation on the anterior segment of the eye is countered by a redox system which consists of complex enzymatic and non-enzymatic mechanisms working in concert within the cornea. There is less focus on UV-B protective mechanisms located in the aqueous humor. However, it should be kept in mind that conditions may be different in the aqueous humor compared to the cornea.

The actinic dose of UV-B below 300 nm wavelength is low. However, these are very potent rays with regards to biological injury, and, specifically, the lens is at risk through cumulative damage over the years. Furthermore, lens cells are trapped within the capsule without any cellular exchange, unlike most other tissues and organs. This underlines the importance of UV-B absorbance in the anterior segment of the eye.

The vast majority of actinic UV-radiation is absorbed by the cornea, - at the 300 nm wavelength, up to 90% [1], and DNA damage is minimized through antioxidants (like AA) acting as radical scavengers. However, UV-radiation entering the aqueous humor in diurnal animals is mitigated through its direct absorption by single molecules [2]. That UV-B absorption by the aqueous humor may be one element of the eye's total UV-protection system is also well illustrated in a paper by Maeda

et al. [3], which concludes that: «At a high concentration, AA can preferentially filter wavelengths shorter than 300 nm. Although broadband UVB contains extremely small amounts of short wavelengths, shorter than 300 nm (less than 5% of total irradiance), these shorter wavelengths of UVB have much stronger cytotoxic effects through the production of UV damage.» The aim of this report is to present a novel argument supporting this view whereby the aqueous humor acts as a UV-B filter. The following three mechanisms are involved:

- 1) The high content of AA in the anterior eye segment in diurnal mammals is well documented. It was shown 70 years ago that AA, injected intra-peritoneally in rabbits, is transferred to the posterior chamber by an active secretory process [4]. Indeed, intravenous injection of DHA raises the content of AA, but not DHA, in the aqueous humor [4]. This indicates that, of the two compounds, AA is preferred in the aqueous humor.
- 2) This is interesting because one important function of the aqueous humor is nutrition of the lens, and ascorbate seems to be a significant metabolite in this process. However, while the ciliary epithelium pumps AA into the aqueous humor, the lens has preferential DHA-uptake [5], even though this compound may be toxic to several tissues. Thus, vitamin C-uptake by the lens helps reducing the DHA content in the posterior chamber,

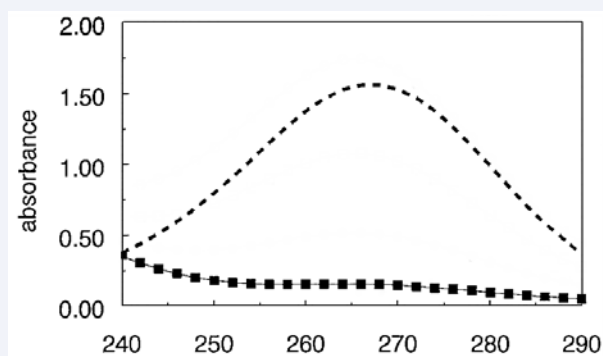


Figure 1 Wavelength scans of AA (---) and DHA (•) are shown, - adapted from relevant curves in fig. 2 by Jung & Wells (1998). DHA (5mM) was incubated at 25°C in 0.5M phosphate buffer, pH 7.0, and scanned 3 min after mixture. As DHA is a rather unstable substance under these conditions (i.e. UV-exposure and pH >5), the short time-lag (3 min) is essential. Wavelength scan of AA (0.1mM in triple-distilled water) is shown for comparison. The marked concentration difference between the two solutions should be noted.

underlining the importance of having AA, not DHA, in the aqueous humor.

- 3) Furthermore, regarding vitamin C in the anterior chamber, Bode et al. [6], demonstrated that corneal endothelial cells take up DHA at least seven times more rapidly than they absorb AA, even though DHA, in contrast to AA, does not have any antioxidant capacity. They concluded: «These results suggest that the cornea has transport and metabolic capacity to extract dehydro-L-ascorbic acid from aqueous humor and reduce it, thus providing a source of ascorbic acid for corneal protection. This also would maintain «total» ascorbic acid of aqueous humor in the reduced state». Again, this indicates that AA, not DHA, is the substance of choice in the aqueous humor.

In short, AA is actively transported into the aqueous humor by the ciliary body, whereas DHA is simultaneously and selectively being removed from the aqueous by a cellular uptake both in the lens and the corneal endothelium. Together these three processes

ensure that vitamin C is largely present as AA in the aqueous humor at the highest possible concentration, with DHA making up only some 10% of the total. It seems reasonable to focus on why so much effort is invested in maintaining this high content of AA in the aqueous humor. The answer could lie in that, of the two, only AA is useful for UVB-absorption (Figure 1, [7]). Indeed, each of these three independent mechanisms (Kinsey 1950; Kern & Zolot 1987; Bode et al. 1991) have long been identified, but they have thus far never been presented as a functional unit making UV-absorption by the aqueous humor possible.

CONCLUSION

The ciliary epithelium, the corneal endothelium, and the lens together make up a functional unit ensuring that the high AA concentration of the aqueous humor remains high. This supports the hypothesis that the aqueous humor acts as a UV-B filter in addition to the cornea.

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