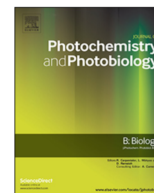
Journal of Photochemistry & Photobiology, B: Biology 182 (2018) 115–121

Contents lists available at ScienceDirect

Journal of Photochemistry & Photobiology, B: Biology

journal homepage: www.elsevier.com/locate/jphotobiol



Photochemical interaction of ascorbic acid and nicotinamide in aqueous solution: A kinetic study

Iqbal Ahmad[a], Muhammad Furqan Mobeen[a,b], Muhammad Ali Sheraz[a], Sofia Ahmed[a], Zubair Anwar[a,*], Ruby Saeed Shaikh[c], Imtiaz Hussain[d], Saiyed Muhammad Ali[b]

[a] *Baqai Institute of Pharmaceutical Sciences, Baqai Medical University, Toll Plaza, Super Highway, Gadap Road, Karachi 74600, Pakistan*
[b] *Pharmatec Pakistan (Pvt.) Ltd., D-86/A S.I.T.E., Karachi, Pakistan*
[c] *Abbott Laboratories (Pakistan) Limited, Karachi, Pakistan*
[d] *GlaxoSmithKline Pakistan Limited, F/268 S.I.T.E., Karachi, Pakistan*

ARTICLE INFO

Keywords:
Ascorbic acid
Nicotinamide
Photodegradation
Spectrometric assay
Kinetics

ABSTRACT

The photodegradation of ascorbic acid (AH_2) in the presence of nicotinamide (NA) at pH 2.0–12.0 has been studied using a 30 W UV radiation source. The reaction follows first-order kinetics and the values of apparent first-order rate constants (k_{obs}) at 1×10^{-3} M NA concentration range from 1.17 (pH 2.0) to 3.61×10^{-3} min^{-1} (pH 12.0). The values of these rate constants (k_0) in the absence of NA range from 0.50 (pH 2.0) to 1.75×10^{-3} min^{-1} (pH 12.0), indicating that the values of k_{obs} for the photodegradation of AH_2 in the presence of NA are about 2 fold compared to those of the AH_2 alone. The second-order rate constants ($k^{'}$) for the photochemical interaction of AH_2 and NA are in the range of 0.67 (pH 2.0) and 1.86×10^{-3} M^{-1} min^{-1} (pH 12.0). The k'-pH profile shows a gradual increase in the rate as a function of pH. This is due to the ionization of AH_2 to give ascorbyl anions (AH^-) which are more susceptible to photodegradation compared to the neutral molecule (AH_2). NA appears to undergo photochemical interaction with AH_2 during the reaction by acting as an electron acceptor to enhance its rate of photodegradation. The concentrations of AH_2 and NA in degraded solutions have been determined by a two-component spectrometric method at 243 and 261 nm (pH 2.0) with a precision of ± 2%. The method has been validated and the results are comparable to the HPLC method.

1. Introduction

Vitamins are among the most widely used pharmaceutical preparations for normal growth and treatment of deficiency diseases. They require careful formulation to preserve the contents of each vitamin present. One of the major problems in vitamin preparations is the possibility of mutual interaction among different vitamins leading to the loss of potency and causing altered bioavailability. Several studies of qualitative nature have been conducted to understand the nature of vitamin interactions, products of degradation and stability profiles. Most of these studies lack quantitative and kinetic aspects to assess the extent and rate of degradation of a particular vitamin alone or in the presence of other vitamins under specific storage conditions [1–8]. The kinetic principles involved in the study of vitamin degradation/interaction are described by Garrett [2], Connors et al. [9], Lachman et al. [10], Sinko [11] and Ahmad et al. [12].

Ascorbic acid (vitamin C) (AH_2) (1) is sensitive to light [13–17] and is degraded to dehydroascorbic acid (DHA) (2) and 2,3-diketogulonic acid (DKA) (3) on UV irradiation [18]. Due to its photosensitivity, AH_2 is unstable in liquid preparations [4]. Nicotinamide (vitamin B_3) (NA) (4) (Fig. 1) is the most stable water-soluble vitamin and its biological activity is not affected by thermal processing, light, acid, alkali, or oxidation [19,20].

Several studies on the photochemical interaction of vitamins have been reported including those of thiamine HCl [21,22]; riboflavin, NA, α-tocopherol [17,23] and cyanocobalamin with AH_2 [24–26], riboflavin with folic acid [27], cyanocobalamin [28] and NA [29], and NA with cyanocobalamin [30].

AH_2 and NA both are components of vitamin B-complex with C and multivitamin preparations. In such a complex mixture there is a considerable possibility of mutual interaction between the two vitamins or among the several vitamins present. It has been reported that AH_2 and NA interact with each other to form a 1:1 molecular complex [31–36]. This is a yellow reaction product, ($C_6H_4NCONH_2{=}C_6H_8O_6$), formed by a linkage between the ring nitrogen of NA and AH_2. The solution phase interaction of NA with AH_2 has been observed indicating a charge

* Corresponding author.
E-mail address: zubair_ana@hotmail.com (Z. Anwar).

https://doi.org/10.1016/j.jphotobiol.2018.04.011
Received 19 February 2018; Received in revised form 6 April 2018; Accepted 6 April 2018
Available online 08 April 2018
1011-1344/ © 2018 Published by Elsevier B.V.

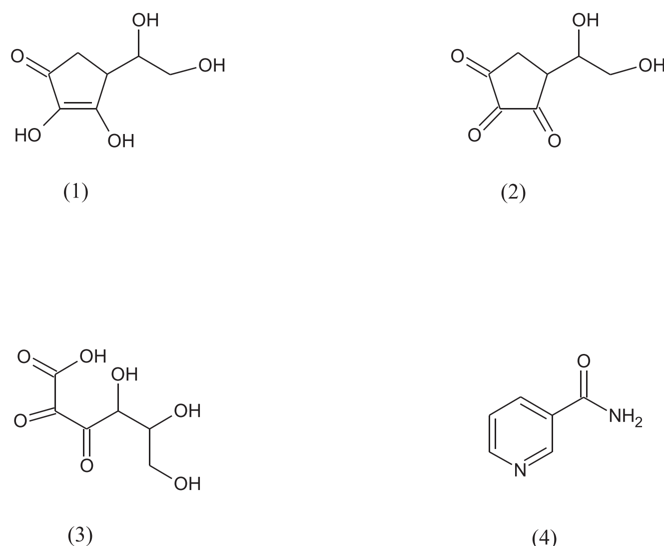


Fig. 1. Chemical structures of ascorbic acid (1), dehydroascorbic acid (2), 2,3-diketogulonic acid (3) and nicotinamide (4).

transfer interaction between the two vitamins. The extent of association between NA and AH_2 is pH dependent and is exhibited by the formation of an absorption maximum (365 nm) at a pH around 3.8 as a result of the interaction between the protonated NA and AH_2 [35]. NA is known to enhance the solubility of riboflavin by molecular interaction [37–40]. The thermal degradation of NA-AH_2 complex has also been studied. It is greater than that of AH_2 alone at pH 3.4–3.8 and 7.4 [41].

The present investigation is based on a kinetic study of the effect of NA on the photodegradation of AH_2 over a wide range of pH using a specific two-component spectrometric method for the simultaneous determination of the two vitamins. The rate-pH relation would enable to establish the pharmaceutically useful pH range for the optimum stability of AH_2 in vitamin preparations on exposure to light. It is also intended to present a reaction scheme for the photochemical interaction of AH_2 and NA in aqueous solution. The study would facilitate the development of optimal formulation characteristics to achieve better stability and prolonged shelf-life of vitamin preparations.

2. Materials and Methods

NA (99%) was obtained from Scharlau (Spain) and AH_2 (99%) from Sigma-Aldrich (USA). All reagents and solvents were of the purest form available from Merck & Co. (USA). The following buffer systems were used. KCl—HCl, pH 1.0–2.0; citric acid-Na_2HPO_4, pH 2.5–8.0; Na_2B4O_7—HCl, pH 8.5–9.0; $Na_2B_4O_7$—NaOH, pH 9.5–10.5; Na_2HPO_4—NaOH, pH 11.0–12.0. The ionic strength of the solutions was maintained at 0.002 M in each case. Freshly boiled distilled water was used throughout the work.

2.1. pH Measurements

The pH of the aqueous solution containing AH_2 and NA was measured with an Elmetron LCD display pH meter, Poland (model CP501, sensitivity ± 0.01 pH units) using a combination electrode. The calibration of the electrode was automatic in the specific pH range (25 °C) using phthalate (pH 4.008), phosphate (pH 6.865) and disodium tetraborate (pH 9.180) buffer solutions.

2.2. Spectral Measurements

The measurements of UV absorption spectra and absorbance values of pure and photodegraded solutions of AH_2 and NA were carried out on a Thermoscientific UV–Vis spectrophotometer (Evolution 201, USA) using quartz cells of 10 mm path length.

2.3. Determination of Light Intensity

The intensity of the Philips 30 W TUV tube was determined using potassium ferrioxalate actinometry [42] as $2.21 \pm 0.10 \times 10^{17}$ quanta s^{-1}.

2.4. Photolysis

A series of 1×10^{-3} M AH_2 solutions were prepared in 100 ml pyrex beakers at pH 2.0–12.0 and sufficient amount of NA ($0.2–1.0 \times 10^{-3}$ M) was added to each solution to produce several dilutions in this range. The beakers were immersed in a water bath maintained at 25 ± 1 °C in a radiation chamber. The solutions were irradiated with a 30 W TUV tube fixed horizontally at a distance of 25 cm from the center of the beakers. AH_2 (1×10^{-3} M) alone was also photolyzed in the same manner. Control solutions of AH_2 under the same conditions were placed in the dark to evaluate the effect of air on the oxidation of AH_2. Samples were withdrawn at appropriate intervals for thin-layer chromatography (TLC) and spectrometric assay.

2.5. Thin-Layer Chromatography

The photolyzed solutions of AH_2 and those kept in the dark were subjected to thin-layer chromatography (TLC) using silica gel GF 254 (250-μm) pre-coated plates (Merck) and the solvent systems: (a) acetic acid-acetone-methanol-benzene (5:5:20:70,v/v) [43], (b) ethanol-10% acetic acid-water (90:10, v/v) and (c) ethanol-water (10:90, v/v) [44]. The detection of AH_2 and NA was carried out under UV (254 nm) using an UVitec lamp (UK). Dehydroascorbic acid and 2, 3-diketogulonic acid were detected by spraying with a 3% aqueous phenylhydrazine hydrochloride solution.

2.6. Spectrometric Assay

One millilitre of the photodegraded solution was pipetted out in a 10 ml volumetric flask and the volume made up with 0.2 M KCl—HCl buffer solution adjusting the pH to 2.0. The contents of the solution were mixed and the absorbance was measured at 243 nm and 261 nm. The concentrations of AH_2 and NA were calculated by the solution of simultaneous equations for a two-component assay [45]. The assay method was validated under the experimental conditions used before its application to the degradation studies of AH_2.

2.7. HPLC Assay

The HPLC system (model LC-20AT, Shimadzu, Japan) used in this study was equipped with a UV detector (SPD-20A) connected to a microsystem. The analytical column used was Waters μBondapak C18 (5 μm, 250 × 4.6 mm). The HPLC analysis was carried out at room temperature (25 ± 1 °C) using isocratic condition. The mobile phase consisted of a mixture of 0.04% 1-hexane sulfonic acid sodium in water: methanol: acetic acid (80:200:1, v/v). The injection volume was 10 μl and the flow rate was 1.5 ml min^{-1}. All the solutions and mobile phase were filtered (with 0.45 μm filter) and sonicated before use. The analysis was carried out at 275 nm wavelength. The validation of the assay method was carried out under the conditions used in this study prior to its application to the photodegradation studies of AH_2.

2.7.1. Validation of HPLC Method

The validation of the HPLC method was carried out according to International Conference on Harmonization (ICH) and Food and Drug Administration (FDA) guidelines with respect to parameters including system suitability, linearity, accuracy, precision, limit of detection

Download English Version:

https://daneshyari.com/en/article/6493312

Download Persian Version:

https://daneshyari.com/article/6493312

Daneshyari.com