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Characterization of curcumin-nicotine interaction in cetyltrimethyammonium bromide micelle

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Abstract: A combination of fluorescence and UV-Vis spectrophotometric techniques were used to characterize the interaction of curcumin and nicotine in a cetyltrimethylammonium bromide (CTAB) micellar system. It is observed that in this medium curcumin and nicotine interact in a 1:1 ratio using the UV-Visible molar ration method. The fluorescence spectrophotometric technique, using the Benesi-Hildebrand equation was used to determine the association constant, K_a. The value thus obtained is 1.26 ± 0.02 x 10^5 M^{-1} and the molar absorptivity, ε, of 2.3 ±0.06 x 10^4/M-cm. The free energy of association, ΔG_a, was subsequently calculated as -29.1 kJ/mol. This vale together with the value obtained for K_a implies that the complex formed by curcumin and nicotine in this medium is not only spontaneous but it also very stable.

Keywords: Curcumin; nicotine; Fluorescence; Absorbance; Complexation.

Introduction

Nicotine is an organic alkaloid of formula $C_{10}H_{14}N_2$. It is a hygroscopic alkaline compound that is soluble in water. It is found in the nightshade of family plants but it is predominant in the tobacco plant and its major concentration is in the leaves of this plant where it is observed that its concentration is about 0.3 to 0.5 % [1-5]. The chemical structure of nicotine is shown in Figure 1.

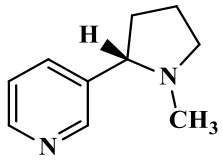

Figure 1. The chemical structure of Nicotine

The additive nature of this alkaloid is well known[6-10]. The literature is replete of these notorious features of nicotine. Among other negative features of this compound is its effect in increasing heart rate, increase in blood pressure and respiration for those indulged in smoking cigarette which produces enormous amount nicotine[1, 5].However, despite the negative effects of nicotine, there have been positive effects reported.

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These range from neuro-protection from reactive oxygen species (ROS) to antioxidative properties[11-20].

On the other hand, it has been reported that curcumin, a phytochemical, derived from curcuma-Longa, among its numerous beneficial effects on human health, has been used to ameliorate a nicotine-induced toxicity and inhibit colon cancer cell growth[21-25].

Although curcumin and nicotine exhibit the above referenced pharmacological and toxicological effects on humans, there has not been, to the author's knowledge, any systematic study of the physico-chemical properties of the complex formed by these compounds. The theme of this work, therefore, is aimed at determining the complexation properties of nicotine with curcumin.

Results and Discussion

We show in Figure 2 the chemical structures of curcumin. The keto and enol forms of curcumin are shown because it has been observed that between pH 1 and the neutral pH the predominant isomer of curcumin is the keto-enol form (a and b).

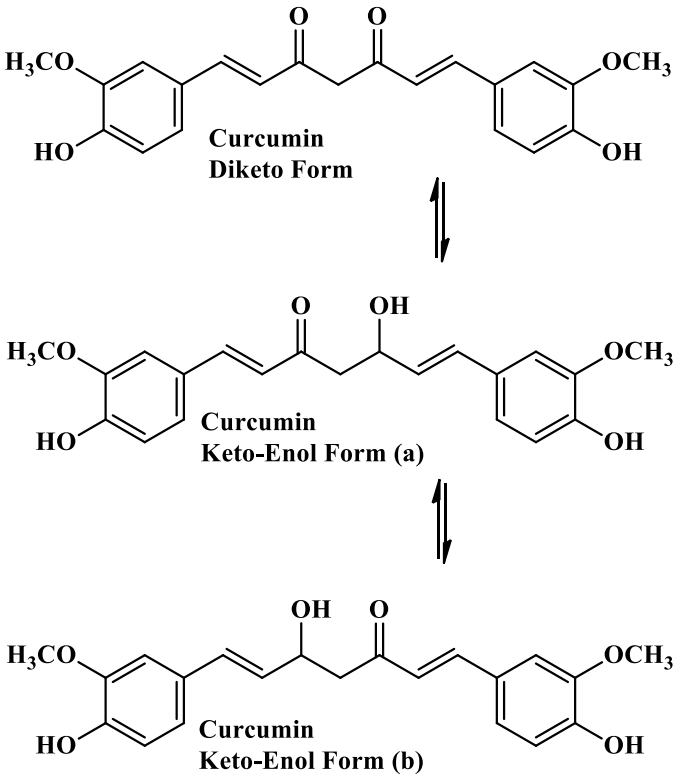

Figure 2. The Chemical Structure of Curcumin and its Keto-Enol Forms

Figure 3 is the fluorescence spectra of curcumin with and without nicotine. It can be seen that nicotine quenched the fluorscence of curcumin. This fact is consistent with that observed by other workers[26, 27].

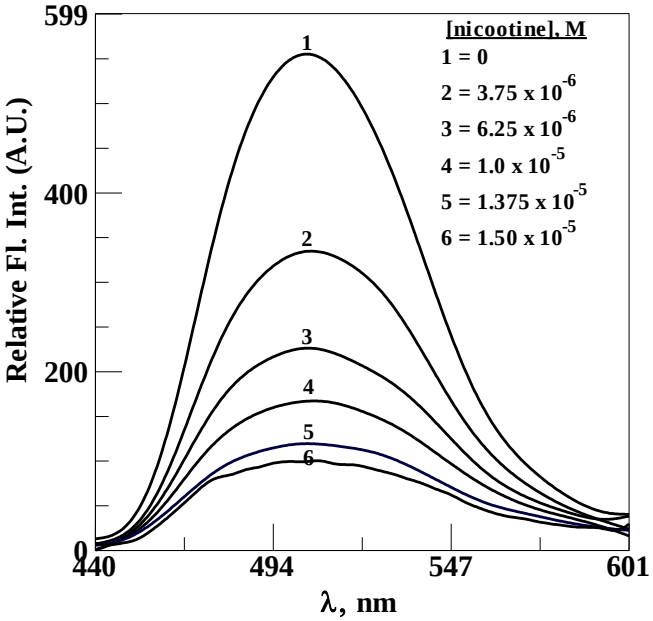

Figure 3. The Florescence Spectra of curcumin with increasing [Nicotine]

However, the observed quenching data do not obey the usual Stern-Volmer relation of $I_o/I = 1 + K_SQ$ when I_o/I is plotted against the quencher, *Q*, which is nicotine. This is shown in Figure 4.

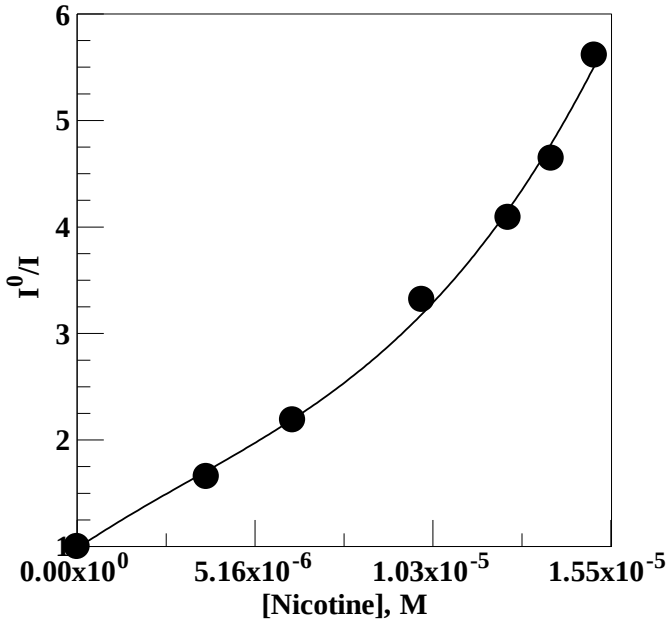

Figure 4. The SV Plot for the curcumin-nicotine complex

This plot clearly shows a curvature that is concave upwards. However, in the above relational equation, I_o, I and K_S are the fluorescence inensity of the fluorophore in the abscence and presence of the quencher, nicotine, and the Stern-Volmer quenching constant, respectively. This plot indicates a static quenching phenomenon as has been noticed by Cheng and Wang[26, 27] In view of the non-linearity exhibited as evidenced in Figure 4, Benesi-Hildebrand equation [28] as given in equation 1, with a little modification, op. cit., is therefore used to analyze the obtained fluorescence data.

$$[F]/\log(I_o/I) = (1/K)(1/C) + 1/\varepsilon \qquad 1$$

In the above equation, *[F], K, C,* ε are the concentration of the fluorophore, the binding or association constant, the quencher concentration and the molar absorptivity of the complex, respectively. Using this equation, a good linear plot was obtained as can be seen in Figure 5.

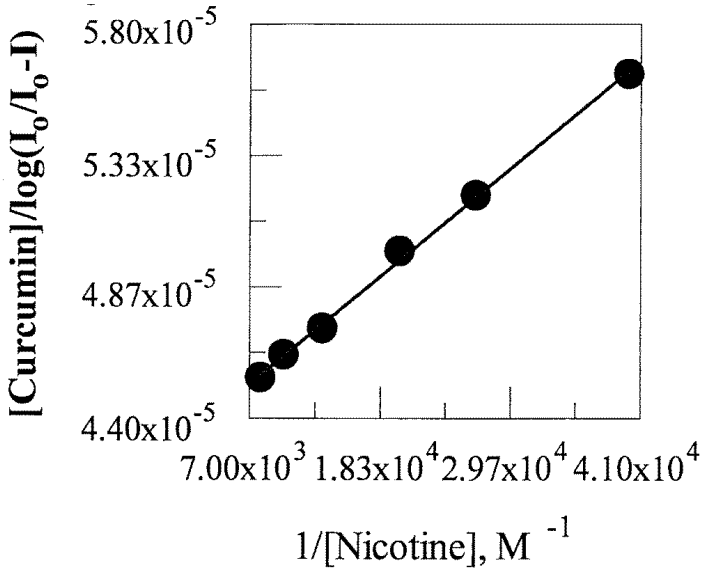

Figure 5. The B-H Plot for the determination of *K* and *ε*

The slope of this plot was used to obtain the association constant, K_a, and the intercept was used to determine the molar absorptivity, *ε*, of the curcumin-nicotine complex. The values thus obtained are 1.26 ± 0.02 x 10^5 M^{-1} and 2.3 ± 0.06 x 10^4 M^{-1}-cm^{-1}, respectively.
The observed absorbance as a function of wavelength of this complex was obtained and is shown in Figure 6.

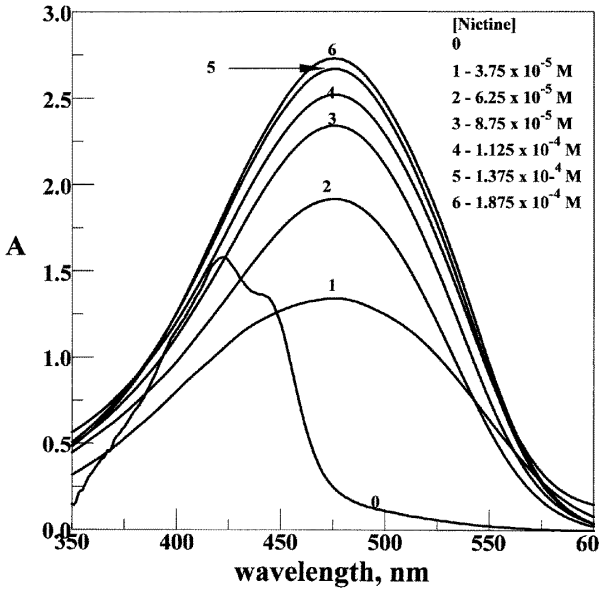

Figure 6. The UV-Vis Spectra of curcumin and curcumin-nicotine complex

It can be seen that the absorbance of the complex increased as the concentration of nicotine is increased. A plot of the observed absorbance of the complex as function of the molar ratio of curcumin and nicotine is shown in Figure 7.

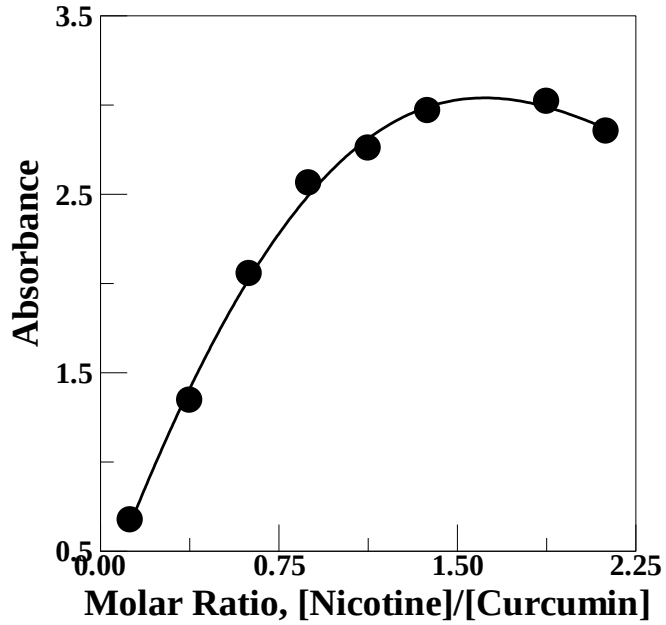

Figure 7. The Plot of the Absorbance of the curcumin-nicotine complex as a Function of their Molar Ratio

It can be seen that this plot grows to a pleateu when the molar ratio of curcumin to nicotine is approxmtely 1:1. This familiar method for determinining the ratio of complexing molecules has also been used recently by Riri et al[29]. In other to subtantiate the value obtaied from the intercept of Fig . 5, we give in Figure 8 the plot of molar absptivity of the curcumin-nicotine complex as a function of wavelength.

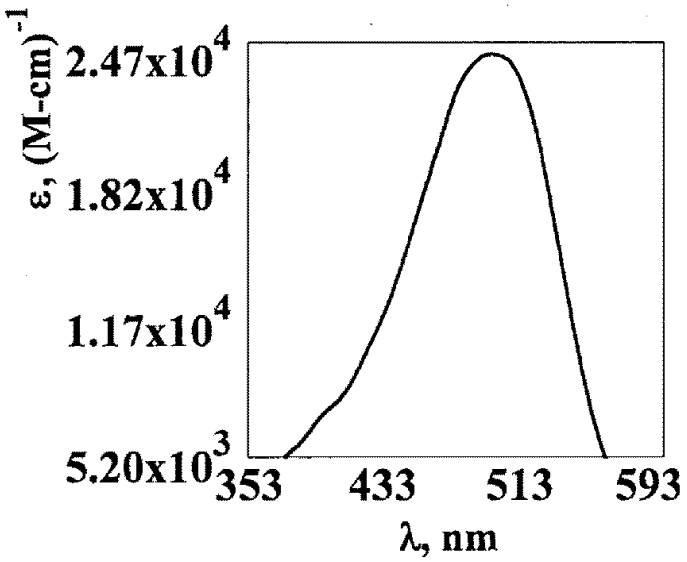

Figure 8. The Plot of Molar Absorptivity as a Function of Wavelength for the Curcumin-Nicotine Complex

As can be seen, a value of 2.3 x 10^4 M^{-1}-cm^{-1} was estimated. This plot was determined using the familiar Beer-Lambert's law ($\varepsilon = A/bC$). We used the relation of $\Delta G = -RTlnK$,at 298.15 K and 0.993 atmosphere, to estimate the free energy of association, ΔG_a. A value of -29.1 kJ/mol was calculated. This value together with the the value of K_a implies that the association of curcumin with nicotine is not only spontaneous but also stable.
We believe that the observed/calculated parameters in this work will provide positive guideline in the prognosis of nicotine-induced rectal/colon cancer and any other ailments associated with nicotine.

Conclusion

It has been shown in this work that curcumin complexes with nicotine in a 1:1 ratio. The observed complexation or association constant, K_a, was determined to be 1.26 ± 0.02 x 10^5/M. The energy of association, ΔG_a, was calculated as 29.1 kJ/mol while the molar absorptivity, ε, was determined as 2.3 ± 0.06 x 10^4/M-cm.

Acknowledgement

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Experimental Section

Chemicals

98.0 % pure curcumin, 98.0 % nicotine and 99.0 % pure cetyltrimethylammonium bromide (CTAB) were obtained from Acros Organics. These compounds were used as received.

Instruments

The fluorescence spectra were obtained from Perkin Elmer's luminescence spectrophotometer, model LS 50B. The Cary spectrophotometer, model 1E, supplied by Varian Analytical Instrument Co. was used in obtaining the UV-Vis spectra.

Methodogy

All the fluorescence spectra were obtained using a four-clear sided quartz cuvette. The excitation wavelength was set at 346 nm. and the emission was observed between 505 and 508 nm. On the other hand, the absorption measurements were made using a two-clear sided quartz cuvette. The concentration of curcumin was kept constant at 1.0 x 10^{-4} M while that of nicotine was varied from 3.75 x 10^{-5} to 2.5 x 10^{-4} M. All the measurements were made at room temperature, 25.0 ± 0.2 ºC.

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