Characterization of curcumin-nicotine interaction in cetyltrimethylammonium 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 ratio method. The fluorescence spectrophotometric technique, using the Benesi-Hildebrand equation was used to determine the association constant, $K_a$. The value thus obtained is $1.26 \pm 0.02 \times 10^5 \text{M}^{-1}$ and the molar absorptivity, $\epsilon$, of $2.3 \pm 0.06 \times 10^4 \text{M}^{-1}\text{cm}$. The free energy of association, $\Delta G_a$, was subsequently calculated as $-29.1 \text{kJ/mol}$. This value 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](image)

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\textsuperscript{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\textsuperscript{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).

![Curcumin Chemical Structures](image)

**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 fluorescence of curcumin. This fact is consistent with that observed by other workers\textsuperscript{26, 27}.
However, the observed quenching data do not obey the usual Stern-Volmer relation of $I_0/I = 1 + K_S Q$ when $I_0/I$ is plotted against the quencher, $Q$, which is nicotine. This is shown in Figure 4.

This plot clearly shows a curvature that is concave upwards. However, in the above relational equation, $I_0$, $I$ and $K_S$ are the fluorescence intensity of the fluorophore in the absence 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. In view of the non-linearity exhibited as evidenced in Figure 4, Benesi-Hildebrand equation as given in equation 1, with a little modification, op. cit., is therefore used to analyze the obtained fluorescence data.
\[
[F]/\log(I_o/I) = (1/K)(1/C) + 1/\varepsilon
\]

In the above equation, \([F]\), \(K\), \(C\), \(\varepsilon\) 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](image)

**Figure 5.** The B-H Plot for the determination of \(K\) and \(\varepsilon\)

The slope of this plot was used to obtain the association constant, \(K_a\), and the intercept was used to determine the molar absorptivity, \(\varepsilon\), of the curcumin-nicotine complex. The values thus obtained are \(1.26 \pm 0.02 \times 10^5\) M\(^{-1}\) and \(2.3 \pm 0.06 \times 10^4\) 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](image)

**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](image_url)

**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 plateau when the molar ratio of curcumin to nicotine is approximately 1:1. This familiar method for determining the ratio of complexing molecules has also been used recently by Riri et al. In order to substantiate the value obtained from the intercept of Fig. 5, we give in Figure 8 the plot of molar absorptivity of the curcumin-nicotine complex as a function of wavelength.

![Figure 8](image_url)

**Figure 8.** The Plot of Molar Absorptivity as a Function of Wavelength for the Curcumin-Nicotine Complex
As can be seen, a value of $2.3 \times 10^4$ 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 $\Delta G = -RT\ln K_a$ at 298.15 K and 0.993 atmosphere, to estimate the free energy of association, $\Delta G_a$. 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 $1.26 \pm 0.02 \times 10^5$/M. The energy of association, $\Delta G_a$, was calculated as 29.1 kJ/mol while the molar absorptivity, $\varepsilon$, was determined as $2.3 \pm 0.06 \times 10^4$/M-cm.

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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.

**Methodology**

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 $1.0 \times 10^{-4}$ M while that of nicotine was varied from $3.75 \times 10^{-5}$ to $2.5 \times 10^{-4}$ M. All the measurements were made at room temperature, $25.0 \pm 0.2 ^\circ C$.

**References**

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