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Photophysical Properties, Solubility and Stability of Curcumin in Surfactant Media: The Role of the Surfactant's Head Group

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Abstract

The yellow-orange color pigment found in the Indian spice plant turmeric is composed primarily of curcumin, a natural poly phenolic molecule[1]. It has attracted a lot of attention due to its widespread biological and pharmacological properties. Despite its extensive spectrum of physiological and therapeutic effects, curcumin's poor water solubility and lack of bioavailability are the two most significant obstacles to its usage as a potential medicine. Furthermore, the lack of stability of curcumin in an aqueous media complicates its utilization[1]. As a result, researchers are concentrating their efforts on encapsulating curcumin in variety of carriers, including micelles, reverse micelles, mixed micelles, liposomes, suspensions, hydrogels, and emulsions[2]. Surfactant-based delivery methods have gotten a lot of interest since they help in faster and more efficient drug absorption[3]. The properties of surfactants are governed by the chain length of the hydrophobic tail and the charge on the hydrophilic headgroup[4]. The goal of the present study is to find out how curcumin interacts with four distinct conventional surfactants that have the same hydrophobic chain length but different head groups *e.g.* anionic, cationic and zwitterionic. The role of the charge on the head group of the surfactants in influencing the photophysics, solubility, and stability of curcumin under various physiological conditions was examined using UV-Visible and fluorescence spectroscopic techniques. The solubility and stability of curcumin exhibited strong dependence on the nature of the surfactant. The effect of surfactant on the antioxidant capability of curcumin has also been studied in the presence of the surfactants.

References

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2. Banerjee, C.; Ghosh, S.; Mandal, S.; Yan, J. K.; Kundu, N.; Sarkar, N. *Journal of Physical Chemistry B*, **2014**, *118*, 3669−3681.
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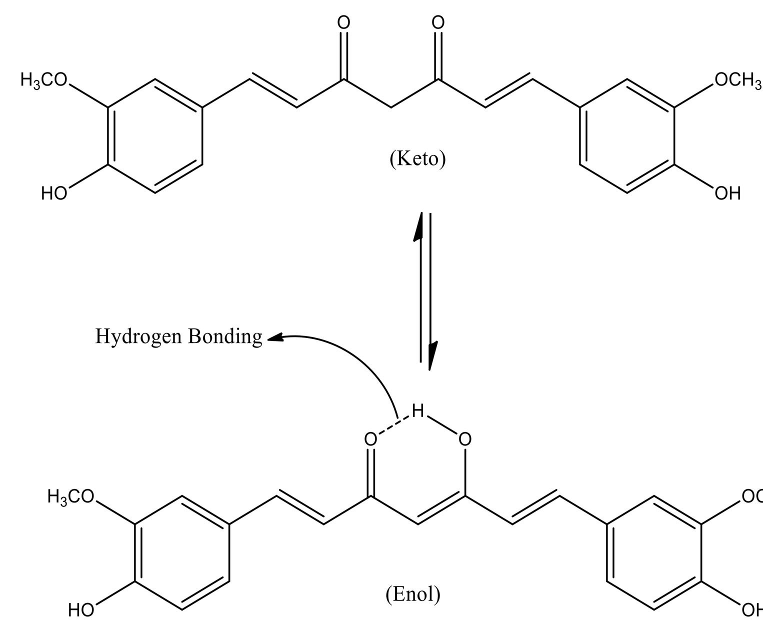
➢Curcumin is the most abundant and biologically active constituent among all the curcuminoids present in turmeric.

➢It consists of two aromatic rings, which are functionalized by hydroxy and methoxy groups at ortho positions and both the rings are connected through a seven carbon chain that contains two α, β unsaturated carbonyl groups and two conjugated double bonds.

➢Curcumin is known to have a broad spectrum of medicinal benefits

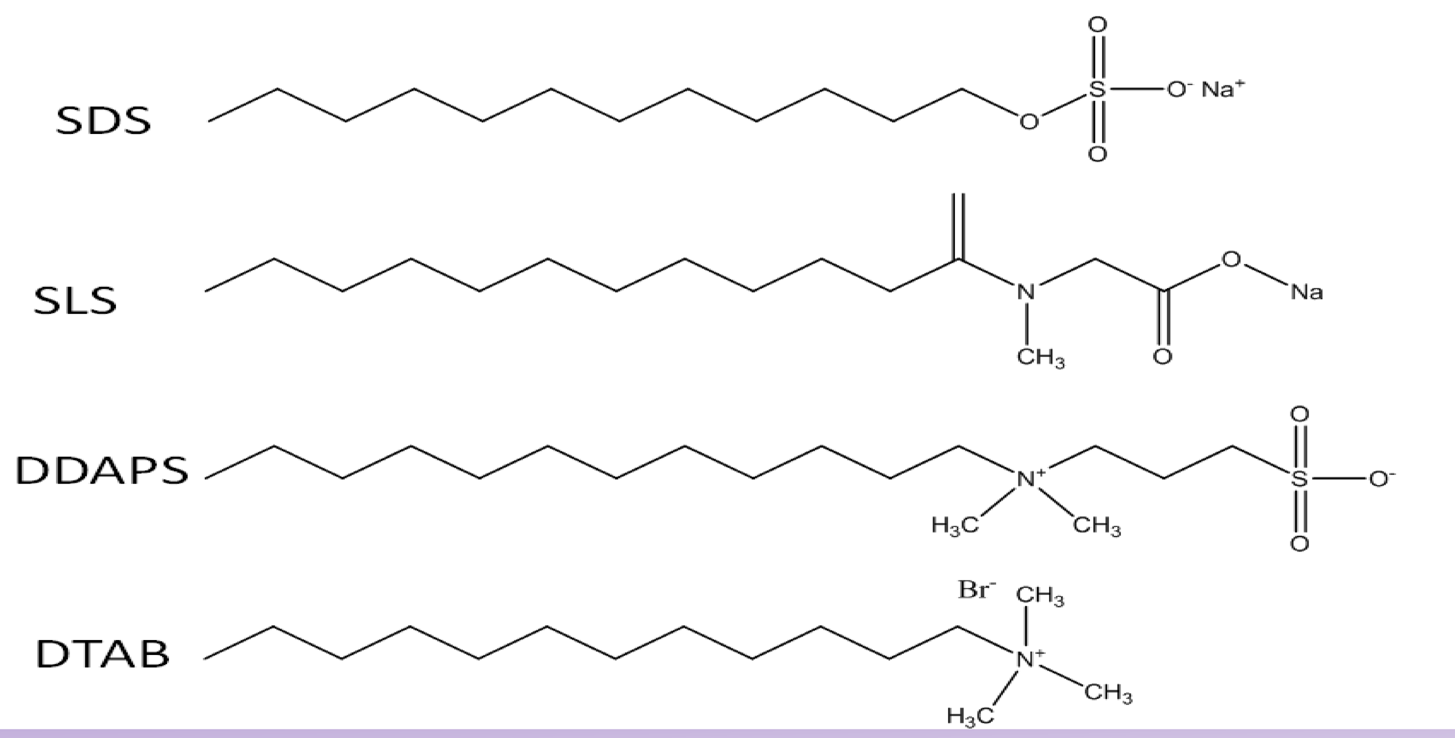
➢Poor aqueous slubility and lack of bioavailability are the two major challenges in using Curcumin as a potential drug.



Keto-enol Form of curcumin

✓Curcumin-surfactant interaction would help to design more efficient carrier for solubilizing and stabilizing curcumin.

✓The hydrophobic chain length and charge on the head group play crucial roles in determining the photophysical properties.solubility and stability of curcumin.



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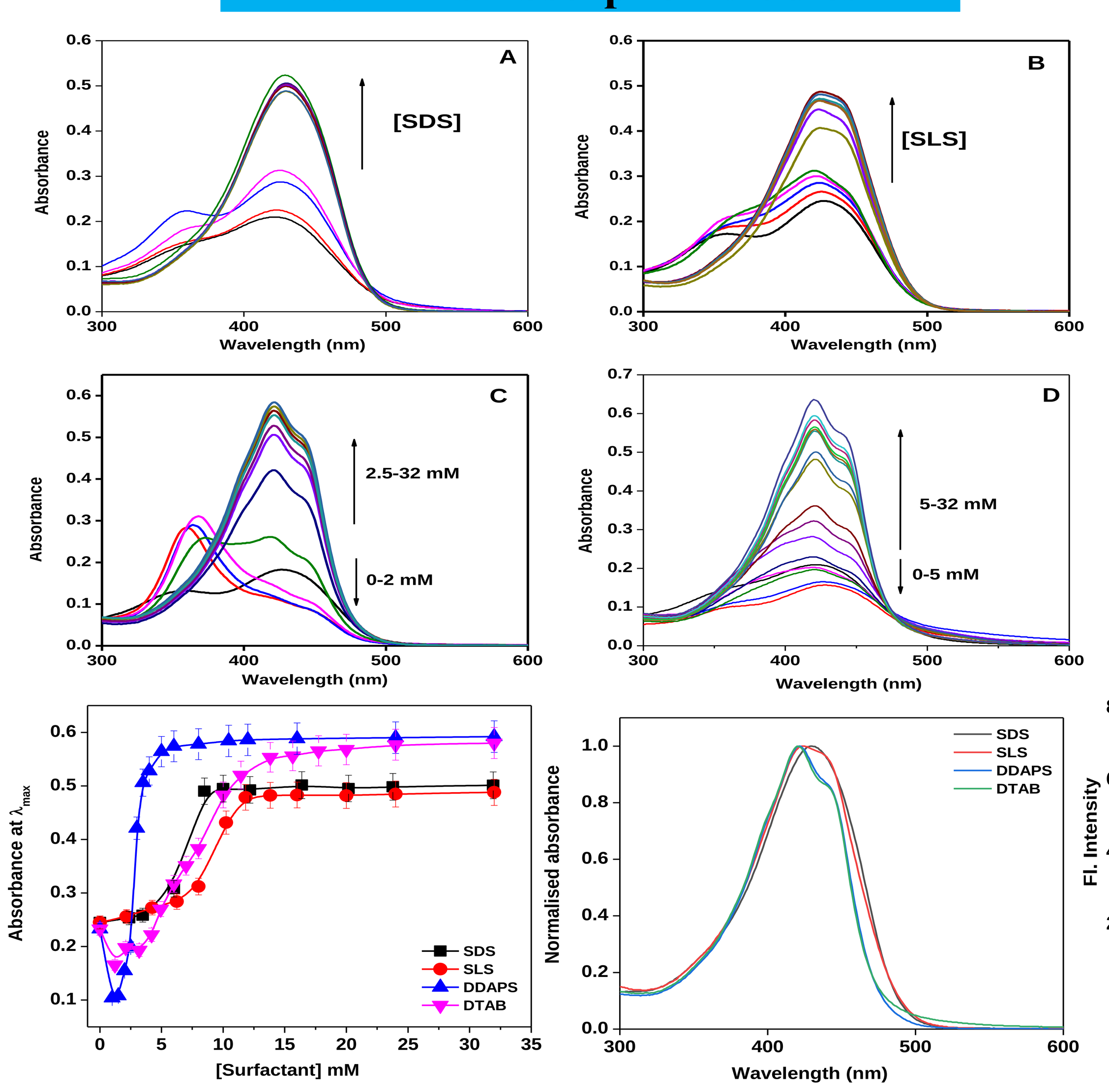
Objective: To comprehend the role of the surfactants having different head groups but with similar hydrocarbon chain lengths, in modulating the photophysical properties of curcumin.

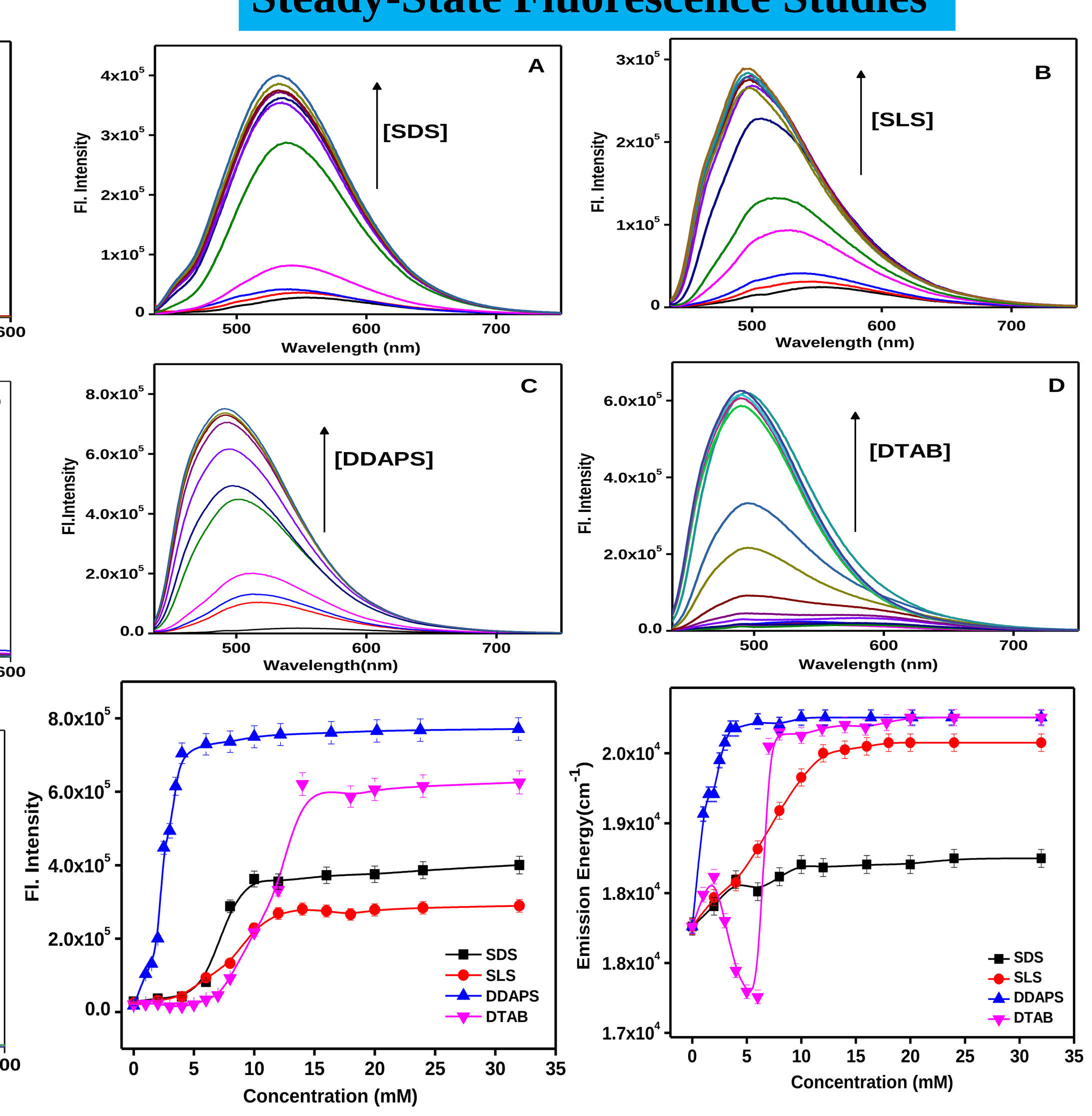
UV−Vis Absorption Studies



❑Increase in the absorbance is found to be similar for DDAPS and DTAB and is relatively higher than that in SDS, which is similar to SLS.

❑A shoulder peak around 445 nm at the higher concentrations of the surfactants (> CMC), attributed to the vibronic transitions of curcumin in the nonpolar micellar environment.

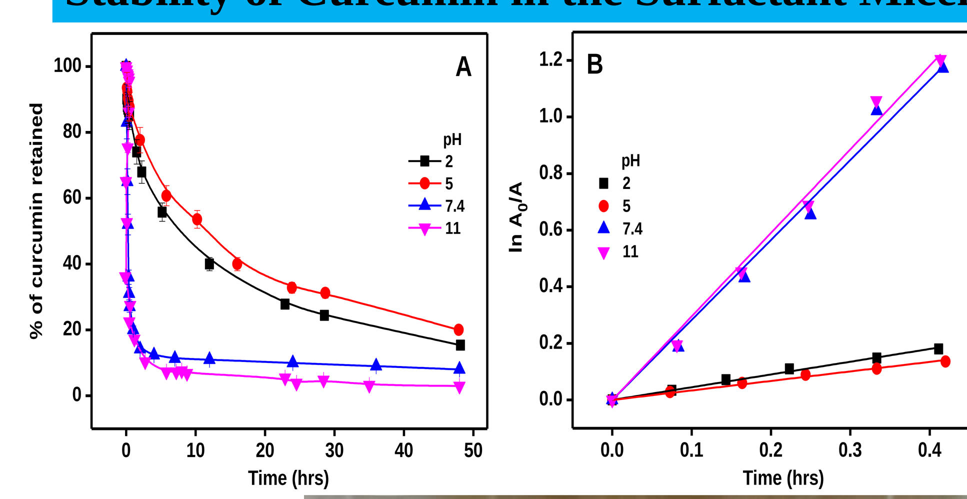
Steady-State Fluorescence Studies



❑The fluorescence intensity clearly depends on the nature of the surfactants and follows the order DDAPS (38 folds) > DTAB (25 folds) > SDS (14 folds) > SLS (12 folds).

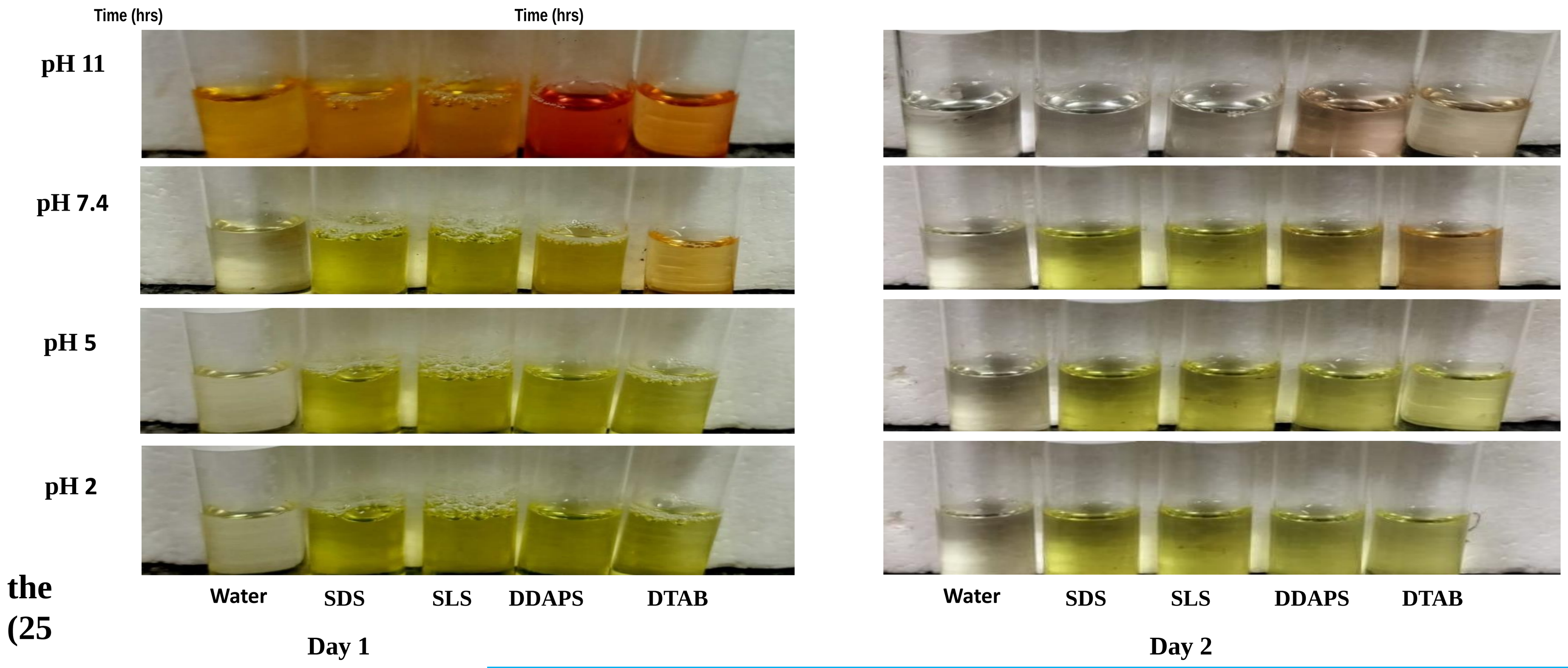
❑The increase in the emission energy is due to enhancement in the non-polar environment surrounding curcumin due to its encapsulation into the micelles.

Stability of Curcumin in the Surfactant Micelles

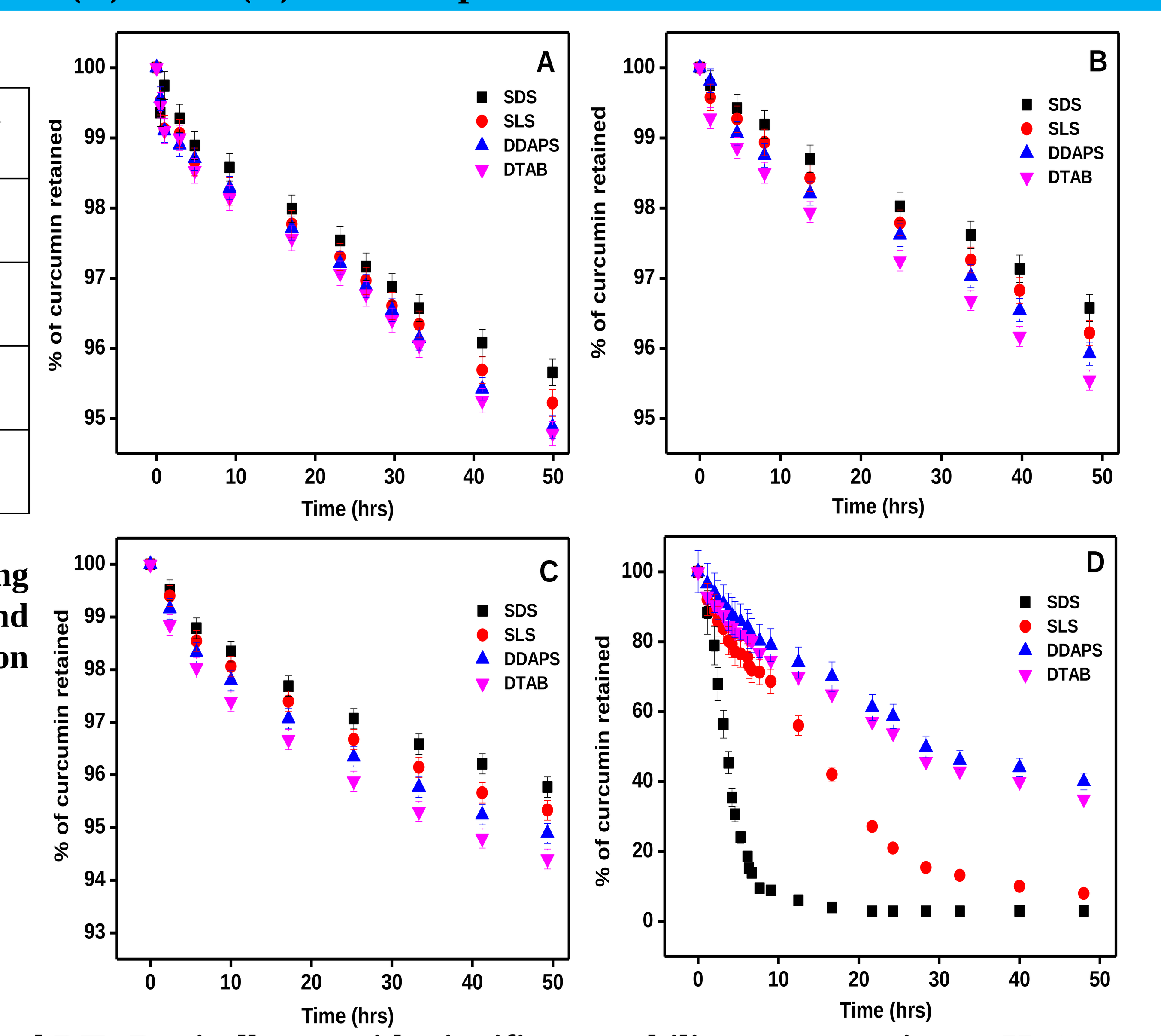


	Rate constants (h^{-1})			
	pH			
	2	5	7.4	11
Aqueous Medium	0.45 ± 0.04	0.33 ± 0.03	2.82 ± 0.2	2.95 ± 0.2

The degradation rate has been suppressed significantly at pH 2, 5 and 7.4 suggesting the enhanced stability of curcumin inside the surfactant micelles.



Variation of % of curcumin retained with time at pH, (A) 7.4, (B) 2 and (C) 5 and (D) 11 in the presence of the surfactants.



DDAPS and DTAB micelles provide significant stability to curcumin at pH=11.

Binding Constant

Surfactants	Binding Constant (M^{-1})
SDS	8.6×10^4
SLS	3×10^4
DDAPS	6.2×10^5
DTAB	2.3×10^5

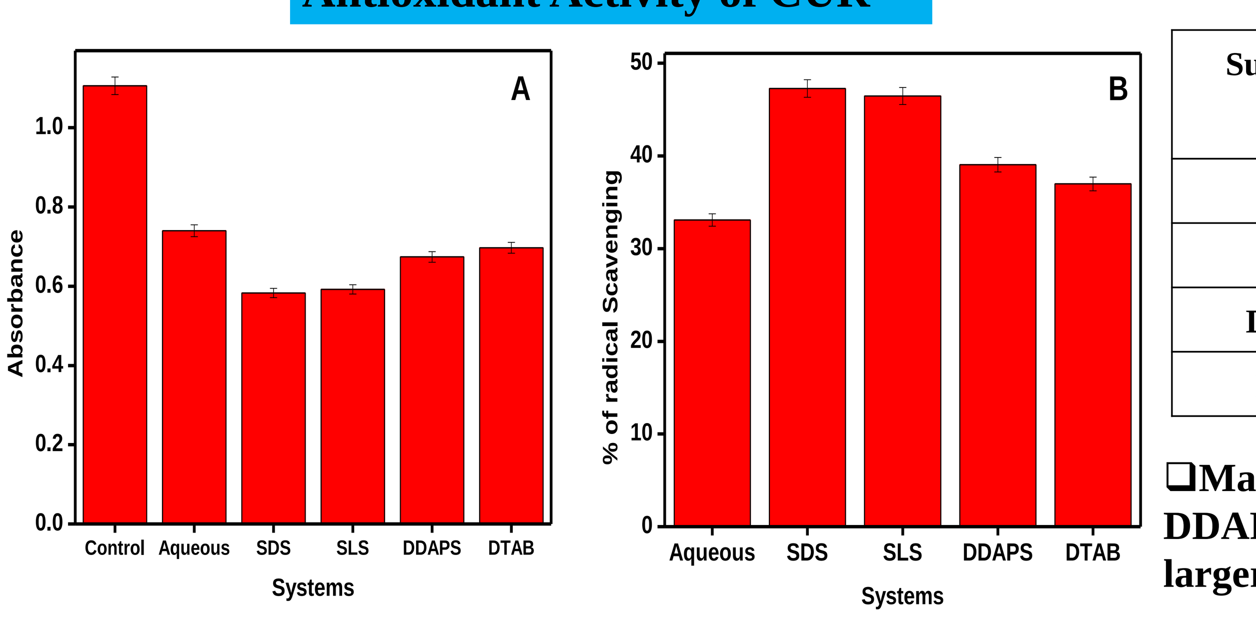
❑Curcumin exhibits a higher partitioning efficiency towards the zwitterionic and cationic surfactant micelles in comparison to the anionic.

Maximum solubilized CUR

Surfactant	Concentration of curcumin (10^{-4} M)	
	Conventional method	pH driven method
SDS	2.9	4.5
SLS	1.6	4.1
DDAPS	6.5	10.4
DTAB	5.6	6.6

❑Maximum solubilized curcumin is the highest in the DDAPS micelles which can probably be attributed to its larger micellar size.

Antioxidant Activity of CUR



❑The decrease in absorbance indicating the enhanced antioxidant properties of curcumin.

❑The surfactant micelles provide a more stable environment and enhance its solubility.

❑DDAPS and DTAB show electrostatic interaction resulting in a slight decrease in the radical scavenging property of curcumin.

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Conclusion

❑The extent of increase in the absorbance and fluorescence of curcumin in the presence of the surfactants follows the order DDAPS ≈ DTAB > SDS ≈ SLS. Thus, the surfactants are capable of enhancing the aqueous solubility of curcumin.

❑The fluorescence intensity of curcumin are enhanced remarkably in the presence of the surfactants and the extent of enhancement is in the order DDAPS > DTAB > SDS > SLS which clearly indicates that the charge on the head group of the surfactants modulates the photophysical properties of curcumin.

❑The solubility of curcumin was enhanced 15000 times inside the surfactant micelles in comparison to the aqueous medium. DDAPS micelles are found to encapsulate a higher amount of curcumin than the other surfactants, which is most probably due to their larger micellar size.

❑The surfactant micelles provide significant stability to curcumin against the degradation process at pH 2, 5 and 7.4. At pH 11, DDAPS and DTAB micelles are only able to stabilize curcumin, whereas, SDS and SLS are not efficient enough to do so.

❑The antioxidant activity of curcumin was found to be enhanced in the presence of the surfactants.