Fluid Phase Equilibria 373 (2014) 63–71

Contents lists available at ScienceDirect

Fluid Phase Equilibria

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

Probing effect of lipophilic butylated hydroxytoluene on anionic surfactant properties for potential food and pharmaceutical applications: Thermo-acoustic and spectroscopic study

Varun Bhardwaj[a], S. Chauhan[b], Poonam Sharma[a,*]

[a] Department of Biotechnology, Bioinformatics and Pharmacy, Jaypee University of Information Technology, Waknaghat, Solan 173234, Himachal Pradesh, India
[b] Department of Chemistry, Himachal Pradesh University, Summer Hill, Shimla 173005, Himachal Pradesh, India

ARTICLE INFO

Article history:
Received 14 September 2013
Received in revised form 27 March 2014
Accepted 31 March 2014
Available online 12 April 2014

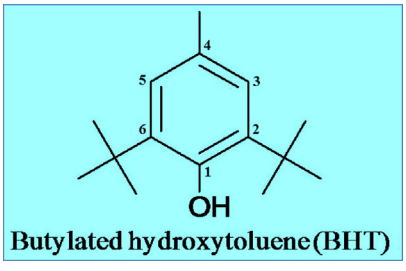
Keywords:
Butylated hydroxytoluene
Interaction
Micelle
Sodium dodecyl sulfate

ABSTRACT

Butylated hydroxytoluene (BHT), a lipophilic bio-active organic molecule and chemically, a phenol derivative added to many food materials to prevent fat spoilage and moreover, as additive to many pharmaceutical products. On the other hand, sodium dodecyl sulfate (SDS) has also been employed as major raw material by many industries. Taking into account the advantages of surfactant micelles as carriers, the impact of BHT on SDS micellar system has been studied in ethanol and in different percentage compositions of ethanol + water mixtures. Therefore, it would be interesting and of great value to evaluate the type of interactions occurring between BHT and SDS in order to design such system which could prove its validity in food or pharmaceutical formulations. In order to examine the micellar properties more clearly, we use simple and easily controlled approach to obtain critical micelle concentration (CMC) values using conductance (κ) along with experimentally determined density and speed of sound data to evaluate, apparent molar volume (ϕ_v), apparent molar adiabatic compression (ϕ_κ) and isentropic compression (κ_s) of SDS in presence of BHT at variable temperatures (25, 30, and 35 °C). Further, the thermo-acoustic parameters have also been evaluated using viscosity measurement. In addition, spectroscopic analysis (FTIR and proton NMR) confirmed the interaction between BHT and SDS and locus of BHT in micellar structure. Conclusively, this physicochemical study provides a hint to assess and develop surfactant immobilized BHT for better biological action.

1. Introduction

From many years, phenolic compounds and their interactions have attracted a great interest in research because of their potential application in functional foods, nutraceuticals and pharmaceutical industries, as they provide potential health benefits to humans [1,2]. However, their effectiveness mainly depends on preserving the stability, bioavailability and bioactivity of the active molecules [3,4]. One of the most convenient ways to achieve the aim of preserving the stability and bioactivity is either to create a packing or encapsulate the active components within a system [5–7]. The amphiphilic structure of surfactant adopts specific orientations in solution by which physical stability of active compounds can be attained [5]. Mostly, food products are subjected to various stresses during production, storage and shipping which sometimes results in the loss of concentration and activity [8]. Although, antioxidants with surfactants and co-surfactants/co-solvent like ethanol have been commonly used to achieve stabilization [9] but their mechanism of action has not been yet completely known or explained. Butylated hydroxytoluene (BHT) acts as potential antioxidant, neutralizing free radicals that damage cell membranes and cause inflammation. It is a lipophilic molecule with phenolic group and having two *tert*-butyl substituent at position 2 and 6. The structure of BHT is as follows:



Butylated hydroxytoluene (BHT)

* Corresponding author. Tel.: +91 1792 239389; fax: +91 1792 245362.
E-mail addresses: drpoonamsharma@rediffmail.com, varunmilton@yahoo.com (P. Sharma).

http://dx.doi.org/10.1016/j.fluid.2014.03.032
0378-3812/

In the recent past, BHT has attracted much attention because several experimental studies have confirmed its anti-viral activity against different human and animal viruses including CMV (cytomegalovirus) [10], pseudo-rabies [11], genital herpes [12], HIV [13] and some strains of influenza [14]. A major challenge of using BHT is its concentration since at very low concentration it has no effect whereas at higher concentration, it becomes toxic [15]. Generally, surfactant interactions can be studied using various indirect or direct methods [16,17]. The similar kind of literature reveals the importance and application of physicochemical parameters/evaluation in pharmaceutical and food science [18–23]. In continuation of our ongoing project on bioactive compounds [24], the present work deals with the influence of temperature, SDS concentration and ethanol compositions on micellar properties of SDS in the presence of antioxidant (BHT). The rationale of the study is based upon the utilization of surfactant and ethanol in topical formulations as well as to some extent in food industries. Alcohols are organic molecules that can be employed in various concentrations depending on their desired functionality. However, empirically there are different opinions concerning influence of short-chain alcohols especially having 1 to 3 carbon chain length. According to Rosen [25], short-chain alcohols can behave like the structure breakers, decreasing the dielectric constant of the solvent and increasing the CMC but on the other side, they can also get incorporated in the micelle, decreasing repulsive interactions between ionic heads of the surfactant and thereby resulting in reduced CMC values. In this context and to best of our knowledge, this study for BHT has not been reported so far. In particular, we employed specific conductance, thermodynamic analysis, FTIR and ^{1}H-NMR spectroscopy, viscosity, volumetric and compressibility measurements to analyze the interactions and determination of micellization phenomenon.

2. Material and methods

2.1. Material

Butylated hydroxytoluene (BHT) as white crystalline powder, sodium dodecyl sulfate (SDS) (AR grade and purity >99%) and ethanol absolute (purity ≥99.9%) were obtained from Merck Chemicals. The whole study was carried out by using freshly prepared double distilled water by double distillation unit obtained from HARCO & Co. The double distilled water with specific conductance of $\approx(1–4)\times10^{-7}$ S cm^{-1} at 25 °C and pH in the range of 6.5–7.0 was utilized in the study. In all the experiments, the concentration of BHT was fixed at 0.02 mol dm^{-3} (within limit of ADI for average adult i.e. 60 kg) and SDS concentration ranging from 1 to 14 mmol dm^{-3}. The specification of material used is also provided in Table 1.

2.2. Conductance measurement

Specific conductance was obtained by using digital conductivity meter Cyber Scan CON-510. The conductivity cell was calibrated with 0.01 M KCl sample solution supplied by Merck Chemicals. The reproducibility of the conductance measurement was estimated to be ±0.5%. The temperature was maintained constant at ±0.1 °C by circulating water from thermostat through a double walled vessel containing the solution. From the obtained plots between conductivity and surfactant concentration, CMC were then determined and used for calculating the thermodynamic parameters of micellization.

2.3. Density and ultrasonic sound velocity measurements

DSA-5000 from Anton Paar, a digital high precision instrument was used for all the density (ρ) and ultrasonic velocity (u) measurements at three different temperatures (25, 30 and 35 °C). The calibration of the instrument was carried out with de-ionized water (Millipore–Elix system); the conductivity and the pH of water was $1–2\times10^{-7}$ S cm^{-1} and 6.8–7.0, respectively. All the samples were prepared 24 h in advance to let the time dependent effect settle [26]. The reproducibility of ultrasonic velocity and density was ±0.2 ms^{-1} and $\pm2\times10^{-6}$ g cm^{-3}, respectively.

2.4. Viscosity measurement

The viscosity (η) measurements for various solutions were obtained in a calibrated jacketed ubbelohde viscometer with a calibrated stopwatch. The flow time of water was approximately 460 s at 25 °C and a constant volume of solution through the capillary was measured. The ubbelohde viscometer was always placed vertically in a water thermostat having a digital temperature controller of accuracy ±0.05 °C. The samples within viscometer were waited in thermostat for 10 min before the measurements were made. The viscosity measurements for SDS in presence of BHT were determined at three different temperatures at an interval of 5 °C and accounted for 100%, 70% and 30% (v/v) ethanol compositions with water. The precision achieved in viscosity measurement was well within ±0.01%.

2.5. Spectroscopic analysis

FTIR spectra were recorded at a wave number range of 4000–400 cm^{-1} using Shimadzu Infra Red Spectrometer, (model FTIR-8400S). ^{1}H-NMR spectra of the compounds were recorded with Bruker Avance-II 400 NMR spectrometer operating at 400 MHz (SAIF, Panjab University, Chandigarh). The chemical shifts are reported in parts per million (ppm).

3. Results and discussion

3.1. Conductance measurement

The CMC values of SDS have been determined from the plots of specific conductance (κ) versus concentration of SDS (1–14 mmol dm^{-3}) in ethanol and water–ethanol mixtures at three different temperatures by standard conductivity procedure [27]. The influence of ethanol on the behavior of surfactant can be explained on the basis of several different roles of alcohols in presence of surfactants [28]. It is also suggested that specific CMC values at very higher alcoholic concentrations becomes difficult to obtain which is because of clustering and very small micellar structures but still the intersection point could be considered of CMC value [29,30]. A representative plot of specific conductance versus SDS concentration in ethanol containing BHT at different temperatures is presented in Fig. 1. The concentration corresponding to the break point has been observed at all temperatures. From least square regression analysis, the value of CMC were then determined by fitting the data above and below the break point to two equations of the form $A = Bx + C$ and solving them simultaneously to get the point of intersection which corresponds to the CMC of surfactant at particular BHT concentration [31].

In addition, the CMC values were found to increase with increment in temperature in both hydro-ethanolic and ethanolic solutions, whereas it decreases with diminution of the ethanol content in the studied solution systems (Table 2). This magnitude of CMC values is attributed to primary effect of ethanol, resulting in decrease of CMC value up to a certain lower alcoholic concentration (30% v/v), thereafter at higher concentration the value of CMC increases. It can also be explained as quantitatively with higher concentration of water within the solution system might decrease CMC values via hydrophobic hydration as behaved in aqueous rich