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Response surface methodology for the study of interactions between components in a micellar system formulation

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Abstract: This work was aimed at the examination of the interaction of certain physicochemical properties on micellar systems constituting of a polymer (sodium alginate), two surfactants (CTAB and tween 80), and Algerian olive oil. Response surface modelling (RSM) was applied to study the combined effects of systems containing each type of surfactant. The monitoring of four independent parameters, *i.e.*, the interfacial tension (Y_1), the conductivity (Y_2), the viscosity (Y_3) and the turbidity (Y_4) as responses for the experimental design model, allowed the determination of the performance of the established models. Based on statistical analyzes, the coefficients R^2 and Q^2 for the interfacial tension, the conductivity, the viscosity and the turbidity are: 0.998 and 0.805; 0.982 and 0.742; 0.976 and 0.734, and 0.985 and 0.723, respectively. The obtained results indicate that these models showed a good predictive power for an optimal system composed of CTAB, Tween 80, AlgNa, and olive oil. For the CTAB/AlgNa and CTAB/olive oil systems, interfacial tension values of 33.85 and 34.39 mN m^{-1}, respectively, and maximum conductivity values of 4.126 and 4.064 mScm^{-1}, respectively, were obtained. For viscous compounds consisting of AlgNa/Olive Oil and AlgNa/Tween 80, maximum viscosity values of 202.5 and 196.6 mPa s, respectively, were obtained. For the same systems as those for viscosity, turbidity values of 300 and 304 NTU, respectively, were obtained.

Keywords: polymer; modelling; interfacial tension; conductivity; viscosity; turbidity.

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INTRODUCTION

In recent years, the combined effects between a polymer and a surfactant have aroused great interest due to their multiple applications. In the petroleum industry, and more particularly, in improving the recovery of petroleum, the droplets of oils trapped in porous media could be displaced under the combined effect of viscous and interfacial forces. It is therefore important to have a system allowing very low interfacial tensions to be reached and to maintain high viscosities to be able to transport the oil present in the pores.[1,2] Solutions containing polymers and surfactants can give rise to molecular interactions liable to affect their rheological and physicochemical properties.[3] In addition, these interactions have characteristics that depend on the electrical charges of the polymer, the surfactant, the hydrophobicity, the conformation, the flexibility of the polymer, and the presence of additives.[4,5] Most studies in this area have focused on complexes of anionic surfactants with polymers.[6–8]

The interactions between the polymer and the surfactant could be investigated in two ways: first, the polymer is considered to be the substance influenced by the surfactant adsorbed on the sites of the polymer that disrupt the formation of the micelles. Second, the surfactant is considered to be the substance influenced by the polymer. In this case, the association of surfactant molecules with macromolecules facilitates the phenomenon of micellization.[9,10] The evolution of the physicochemical and rheological properties as a function of the chemical nature and the concentrations of components allows the establishment of relations between these factors and the responses of the system, such as conductivity, turbidity, and critical micellar concentration.

The use of the experiment plan method allows predictive models of the studied responses to be obtained as well as the optimal conditions with the minimum number of tests and a maximum of credibility. Given the assigned objective (determination of the effects of three constituents), the most adequate experimental planning strategy is based on a response surface modelling (RSM) by a two-order model taking into account all the interactions between the factors. In the industrial field, the use of the experimental design is constantly evolving and can be used to support the optimization of manufacturing and control processes, as well as the formulation of products. The method consists in gathering a set of statistical techniques intended to analyze the behaviour of an experimental system to understand and improve its functioning.[11]

The experimental plans allow the organization of the tests to be optimized, which makes it possible to obtain both a maximum of information with the minimum of number of experiments and with the best possible precision on the modelling of the results. This method is based on strict mathematical rules and requires a rigorous approach on the part of the experimenter.[12]

Several authors have used one factor at a time, which not only consumes time and increases costs, but also neglects the effect of the interaction between the factors. Although the traditional orthogonal method is able to consider several factors at once, it cannot give a function expression between the factors and the response values.

Response surface modeling (RSM) is a statistical method that uses quantitative data from appropriate experiments to determine several regression equations between factors and experimental results. The main advantage of this method compared to other methods of experimental statistical design is the reduced number of experimental tests necessary to evaluate several parameters and their interactions.[13]

This study aims to assess the effects of four factors, *i.e.*, a cationic surfactant, CTAB, non-ionic surfactant, Tween 80, Algerian olive oil and sodium alginate as a polymer on the physicochemical properties. Properties of aqueous solutions, such as turbidity, conductivity, viscosity, and turbidity, were used as responses for the experimental design model through a response surface methodology, namely D-optimal design.

EXPERIMENTAL

Experimental design

A D-optimal design was used to study the main effects of four independent factors such as the concentration of CTAB (X_1), the concentration of Tween 80 (X_2), olive oil (X_3) and the concentration of alginate sodium (X_4). The D-optimal criterion was developed to select the design points to minimize the variance associated with the estimates of the specified model coefficients.[14] This method is useful more than the central composite design method, which requires fewer experiments to be carried out, and it can also address the categorical factors included in the design of the experiments.[15,16] The high D value plans were constructed from the data by a computer algorithm. The variables were subsequently coded according to Eq. (1):

$$X_\mathrm{i} = \frac{U_\mathrm{i} - U_\mathrm{i}^0}{\Delta U_\mathrm{i}} \tag{1}$$

where X_i is the independent variable coded value; U_i independent variable: real value; U_i^0 independent variable: real value on the centre point; and ΔU_i is the step change value (Table S-I of the Supplementary material to this paper).

Materials and methods

The cationic surfactant (CTAB) was purchased from Fluka (Switzerland), the non-anionic surfactant (Tween 80), and the sodium alginate polymer (AlgNa) were supplied from Panreac Chimica (Spain). The sodium alginate used in this study was in the form of a white to creamy white powder; it is odorless, tasteless, and very soluble in water. The density of Algerian olive oil was 0.92 g cm^{-3}, it was mainly composed of 99 % fat divided into a fat-soluble fraction (triglycerides and 1 % fatty acids) and non-fat-soluble (secondary components).[17-19] The interfacial tensions and the critical micellar concentrations of the mixtures were measured at a room temperature of 22 °C with a Du Noüy tensiometer (model 70545). The turbidimetry was measured using a turbidimeter (turbo 550 IR, reference 600110) to determine the degree of turbidity of a suspension in solution. The conductivity of the solutions was determined using a Hanna EC 214 type conductivity meter with a cell constant of 0.475 cm^{-1}. The Haak RVT5 type viscometer with a rotating mobile was used to determine the viscosity of Newtonian liquids. This device is equipped with six mobiles of different shapes and geometries, where each mobile is used within a well-defined range of viscosity and sheer speed. Polymer dispersions were prepared by dissolving the polymer in water with moderate stirring at room temperature. After 24 h, different amounts of surfactant and oil were added to the polymer solutions. The surfactant was dissolved under slow mixing of 30 rpm in a propeller mixer (Heidolph RZR 2020, Germany). Depending on the case, the surfactant concentrations were chosen to be equal to, greater than or less than the critical micellar concentration (*CMC*) of the surfactant. However, the polymer concentrations were chosen to give variations in the viscosimetric and turbidimetric properties of the solution.[20-22]

Establishment of the experimental matrix

The D-optimal matrix type experience was used. It responds to the error minimization strategy in the estimation of the coefficients and the overall error. The matrix contains 16 tests in different zones, to minimize the error and to estimate the standard deviation of the natural values. Table I shows the matrix of experiments based on this strategy, in which the factors (X_i) and the responses (Y_i) are defined as follows. X_1: mass concentration of CTAB, which varied between 0.01and 0.2 %; X_2: mass concentration of Tween 80, which varied between 0.01 and 0.04 %; X_3: mass concentration of sodium alginate, which varied between 0.3 and 0.8 %; X_4: mass concentration of the olive oil range of 0.1 and 0.3 %; Y_1: interfacial tension, mN m^{-1}; Y_2: conductivity, mS cm^{-1}; Y_3: viscosity, mPa s; Y_4: turbidity, NTU.

RESULTS AND DISCUSSION

Statistical analysis

First, a first-order experimental plan was created:

$$Y_i = b_0 + \sum_{i=1}^{3} b_i X_i \tag{2}$$

The results obtained were analyzed using first-order linear models. This design was rejected due to a mismatch between predicted and experimental values. The lack of fit is significant and the model error was significantly larger than the pure error (reproducibility). Using multiple regression analysis, the responses were correlated with the three design factors *via* a second-order polynomial:

$$Y_i = b_0 + \sum_{i=1}^{3} b_i X_i + \sum_{i=1}^{3} b_{ii} X_i^2 + \sum_{i=1}^{3}\sum_{j=2}^{3} b_{ij} X_i X_j \tag{3}$$

where b_0, b_i, b_{ii} and b_{ij} are constant regression coefficients of the model, while X_i, X_j are the independent variables. The statistical significance of the regression coefficients was determined by Fisher's analysis of variance, *F*-test and the proportion of variance explained by the model obtained was given by the multiple coefficients of determination, R^2.

Establishment of responses according to formulation factors

The values obtained from Q^2 and R^2 show that the established model could be predictive (Table S-II of the Supplementary material). The coefficients of the polynomial model were determined by the multilinear regression method (MLR).

Table S-II shows the values of R^2 and Q^2, the stress, the interfacial tension, and the conductivity. The quality of the results obtained after adjustments was determined by the coefficient of determination R^2 and the coefficient of prediction Q^2.

A value close to 1 means that the predicted values are in very good agreement with the observed values and a Q^2 value greater than 0.7 indicates that the model has good predictive power. The arrangements for D-optimal experiments are listed in Table S-III, which includes 16 sets of experiments.

The quadratic regression model for interfacial tension (Y_1), conductivity (Y_2), viscosity (Y_3) and turbidity (Y_4) in terms of coded factors are given as follows:

$$Y_1 = 35.56 + 0.57X_1 + 0.15X_2 - 1.125X_3 - 1.55X_4 - 0.16X_1X_2 + \\ + 0.18X_1X_3 - 0.012X_1X_4 + 0.88X_2X_3 + 0.71X_2X_4 - 0.78X_3X_4 \quad (4)$$

$$Y_2 = 386.87 + 13.12X_1 + 13.75X_2 + 18.75X_3 + 15.62X_4 - 74X_1X_2 - \\ - 6.24X_1X_3 + 3.12X_1X_4 + 6.87X_2X_3 - 1.41X_2X_4 - 2.50X_3X_4 \quad (5)$$

$$Y_3 = 162.43 + 9.68X_1 + 15.31X_2 + 24.93X_3 + 24.93X_4 - 4.4X_1X_2 + \\ + 0.93X_1X_3 + 1.56X_1X_4 + 2.81X_2X_3 - 0.06X_3X_4 \quad (6)$$

$$Y_4 = 271 + 15.25X_1 + 18.25X_2 + 26.87X_3 + 0.75X_4 - 3.12X_1X_2 - \\ - 0.62X_1X_3 + 2.3X_1X_4 - 2.87X_2X_3 + 14.75X_3X_4 \quad (7)$$

ANOVA analysis of the models used to estimate the interfacial tension, the conductivity, the viscosity, and the turbidity *versus* the concentrations of CTAB, Tween 80, olive oil and sodium alginate are represented in Table S-IV of the Supplementary material.

The statistical significance of the second-order model was assessed by the analysis of variance of the Fisher test (F-test), which revealed that this regression was statistically significant ($P < 0.001$) at the 95 % confidence level. For interfacial tension, the model presented the highest coefficient of determination ($R^2 = 0.998$) showing 99.8 % validity in the response.

For conductivity, the regression was less significant, it has a good coefficient of determination ($R^2 = 0.982$) showing 98.2 % of the validity of the response. The model used for the estimation of the viscosity showed the very strong significance of the model ($P = 0.001$) and presents a good coefficient of determination ($R^2 = 0.976$), indicating that only 2.4 % of the total variations were not explained by the model. For turbidity, the value of the adjusted coefficient of determination $R^2_{(adj)} = 0.976$ was also very high and indicates the great importance of the model. The values of Q^2 obtained were of the order of 0.723 for the turbidity and

0.805 for the interfacial tension, which makes it possible to conclude that the model has an acceptable predictive power.[11–16] The results obtained are given in Table S-IV.

Influence of factors on interfacial tension: IFT

The interaction of water-soluble polymers with anionic surfactants is generally controlled by surface tension and specific or equivalent conductivity measurements depending on the concentration of surfactant.[23] The IFT method is also used to explain the process of micellization of surfactant solutions, as well as the distribution of molecules in the presence of an additive, the surface activity, and the micelle formation of ionic surfactants in combination with a charged polymer and salt. The behavior in surface tension of a multi-component system can be obtained from classical thermodynamic relationships for interfacial properties. The formulation adopted is that due to Gibbs equation and is represented by:[24,25]

$$\mathrm{d}\gamma = -\sum \Gamma_i \mathrm{d}\mu_i \tag{8}$$

where γ is the surface tension or the interfacial tension; Γ_i, is the surface excess component, μ_i is the chemical potential of the component defined as follows:

$$\mu_i = \mu_i^{\ominus} + RT\ln a_i \tag{9}$$

where $\mu_i^{\ominus}$ is the standard chemical potential and a_i is the activity of the component i.

Eq. (10) was obtained assuming for dilute solution $a_i = C_i$ and the substitution of Eq. (9) in Eq. (8):

$$\mathrm{d}\gamma = -RT\sum \Gamma_i \,\mathrm{d}\ln C_i \tag{10}$$

In a mixed multicomponent system of constant composition, C can be written as:

$$C_1 = KC_2 = KC_3 = \dots \tag{11}$$

Differentiation of the logarithm of C leads to:

$$\mathrm{dln}C_1 = \mathrm{dln}C_2 = \mathrm{dln}C_3 = \dots \tag{12}$$

The Gibbs adsorption equation for a system containing three components becomes:

$$\mathrm{d}\gamma = -RT\,(\Gamma_{\mathrm{CTAB}} + \Gamma_{\mathrm{Tween80}} + \Gamma_{\mathrm{AlgNa}} + \Gamma_{\mathrm{olive\ oil}})\mathrm{dln}\, C_1 \tag{13}$$

For ionic compounds, complete dissociation of CTAB (CTAB = $CTA^+ + Br^-$, AlgNa $= Alg^- + Na^+$) was assumed, and the dissociation of Tween 80 and olive oil were negligited, hence:

$$\Gamma_{\mathrm{CTAB}} = \Gamma_{\mathrm{CTA}^+} + \Gamma_{\mathrm{Br}^-} \text{ and } \Gamma_{\mathrm{AlgNa}} = \Gamma_{\mathrm{AlgNa}} + \Gamma_{\mathrm{Alg}^-} \tag{14}$$

This hypothesis allows the adsorption process to be consider as being positive in nature. Thus, only the solute occupies the surface (the superficial excess of pure solvent (water)). The variation of Γ due to the variation in concentration of one of the components leads to the evaluation of the total excess:

$$\Gamma_{\text{tot}} = \Gamma_{\text{CTAB}} + \Gamma_{\text{Tween 80}} + \Gamma_{\text{AlgNa}} + \Gamma_{\text{olive oil}} \qquad (15)$$

A sample of iso-response plots for IFT at different coded values of CTAB and AlgNa is shown in Fig. 1. Tween 80 and olive oil are kept at their zero levels: 0.25 % for the Tween 80 and 0.20 % for the olive oil. It could be observed that the IFT values decrease with increasing concentration of CTAB and increase with increasing concentration of sodium alginate.

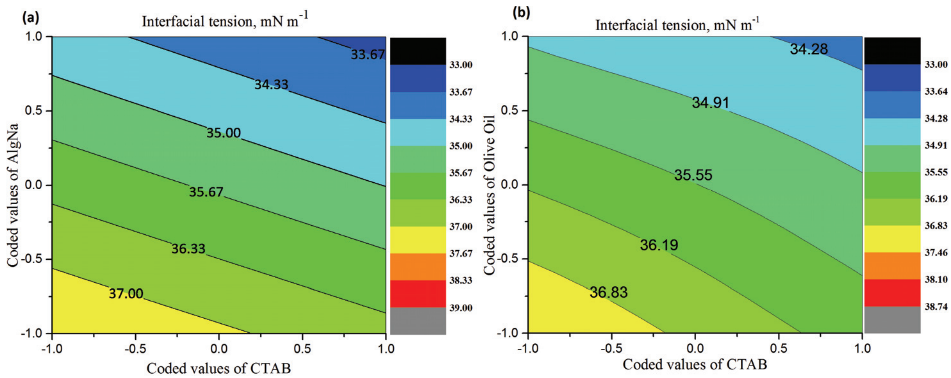

Fig. 1. Contour plots of independent variables: coded values of CTAB, AlgNa and olive oil on the interfacial tension.

Furthermore, the minimum of the IFT 33.85 mN m^{-1}, was obtained near the concentration of CTAB 0.8 g L^{-1} and for the concentration of AlgNa close to 0.125 in the coded values. The critical micellar concentration of CTAB decreased in the presence of AlgNa, and the number of aggregations of individual micelles increased with the polymer concentrations. Likewise, the addition of polymer to the CTAB solution allowed to decrease the concentration of critical aggregation (CAC) and to increase the number of sizes of the micellar aggregates which attach to the polymer coil. This indicates that the significant effect of the presence of a surfactant is to be expected in the solution with the polymer. On the other hand, an excess of sodium ions in solution should filter the electrostatic repulsions between the micellar aggregates attached to the polymer chain, thus reducing the degree of expansion of the latter.

Despite the electrolytic affinity of the dissolved AlgNa molecule, the presence of Na^{+} does not affect an extension of the thickening behaviour of the solution.

Moreover, Fig. 1b shows the iso-responses of the surface tension at different coded values of CTAB and olive oil. The AlgNa and the Tween 80 were maintained at their zero levels: 0.55 and 0.025 %, respectively. The IFT values decreased with increasing concentrations of CTAB and olive oil (minimum IFT 34.39 mN m^{-1} was obtained for CTAB (0.5) and concentration of olive oil close to 0.75 in the coded values). The decrease of IFT could be explained in the same way as in Fig. 1a, at constant concentrations of AlgNa 0.55 % and Tween 0.025 %.

Influence of factors on conductivity

Conductivity measurements have been widely used to study the interactions between polymers and surfactants in an aqueous solution that are very important for the evaluation of electrostatic interactions in solutions when charged substances such as ionic surfactants, charged polymers, and electrolytes are used. This method was used by Goddard[26] to study the effect of salt on the interaction between the polymer (polyethylene oxide and SDS) and by Sovilj *et al.*[27] to study the influence of hydroxypropyl methylcellulose-SDS interactions.

The specific conductivity curves obtained from Eq. (5) are given in Fig. 2a and b. They represent the plots of isoresponses at different coded values of CTAB, Tween 80, AlgNa and olive oil. The obtained graphs show the effects of two factors while the other two factors are kept constant at their zero levels. Assuming that the total conductivity of the free ions is independent of any electrolyte present in the solution, the specific conductivity of each species at any calculated concentration is the sum of the conductivity of each ion present.Given this assumption, the specific conductivity of the solution containing total sodium σNa^+ is the sum of the conductivity of the charged polymer AlgNa, CTAB, Tween 80 and olive oil:

$$\sigma = \sigma_{CTA^+} + \sigma_{Br^-} + \sigma_{Tween\ 80} + \sigma_{Alg^-} + \sigma_{Na^+} + \sigma_{Oliveoil^+} \qquad (16)$$

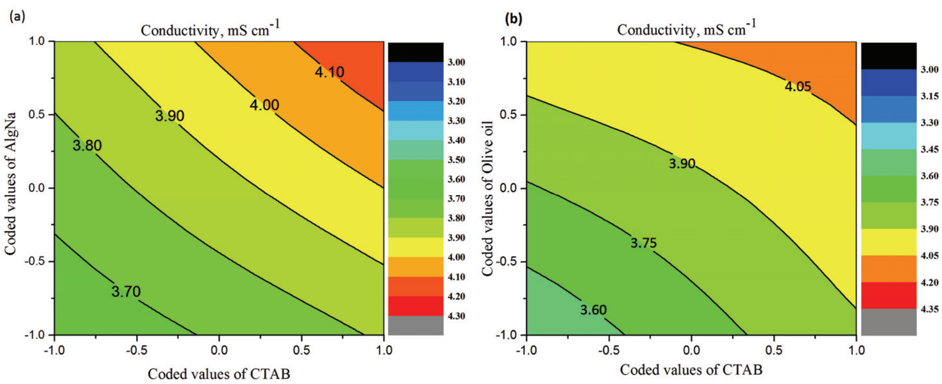

Fig. 2. Contour plots of independent variables: coded values of CTAB, AlgNa and olive oil on the conductivity.

In this context, only the total conductivity of the solution, σ, was obtained from the conductivity measurements. The effect of the factors on the conductivity is illustrated in Fig. 2. The curves obtained show the effects of the concentrations in coded values of CTAB and AlgNa on the conductivity when the concentrations of Tween 80 and olive oil are kept constant at their level zero. As expected, the presence of AlgNa (charged polymer) slightly increases the conductivity values with increasing CTAB at a constant concentration of Tween 80 (0.025 %) and olive oil (0.2 %).

By adding AlgNa to CTAB solutions at constant concentrations of Tween 80 and olive oil, the total conductivity of the solution strongly depends on the concentration of CTAB, as indicated by the model presented in Eq. (15). In this case, it could be supposed that complete dissociation of all the ionic species in solution occurred because Tween 80 and olive oil were at their constant concentrations.

The effects of the concentrations CTAB and olive oil, as coded values, on the conductivity when the concentrations of Tween 80 of (0.025 %) and AlgNa (0.55 %) were kept constant at their zero levels are shown in Fig. 2a and b. From these figures, it could be noted that the presence of olive oil with CTAB increased the conductivity in a less pronounced manner compared to the previous case. The conductivity varies from 3552 mS cm^{-1} for low concentrations to 4064 mS cm^{-1} for values close to the maximum concentrations of CTAB and olive oil. By adding olive oil to CTAB solutions at constant concentrations of Tween 80 and AlgNa, the total conductivity of the solution strongly depended on the charged surfactant (CTAB) and the charged polymer (AlgNa). As in the previous case, complete dissociation of all the ionic species in the solution was assumed because Tween 80 and the polymer were at their constant concentrations.

Effect of factors on viscosity

The behavior of the viscosity was mainly due to the presence of polymers and viscosimetric compounds, such as olive oil. Viscosity measurements are a practical way to study the hydrodynamic volume in the solution. The viscosity values of the solutions lower and higher than the concentrations of critical aggregations were determined and presented in the form of values of apparent viscosity. The surface response curves obtained from Eq. (6) for the viscosity at different coded values of CTAB, Tween 80, AlgNa, and olive oil are presented in Fig. 3a and b.

The viscosity values increased with increasing concentrations of AlgNa and Tween 80, as seen in Fig. 3a. The maximum viscosity value of 196.6 mPa s was obtained at concentrations of AlgNa and Tween 80 close to 0.8 and 0.4 in olive oil in incoded values corresponding to coded values of 0.2 % and CTAB of 0.105 %. Furthermore, this figure showes that the maximum value obtained of viscosity is less than the maximum value for the viscosity of 202.5 mPa s obtained in the previous case. This could be explained by the high viscosity of olive oil compared to that of Tween 80.

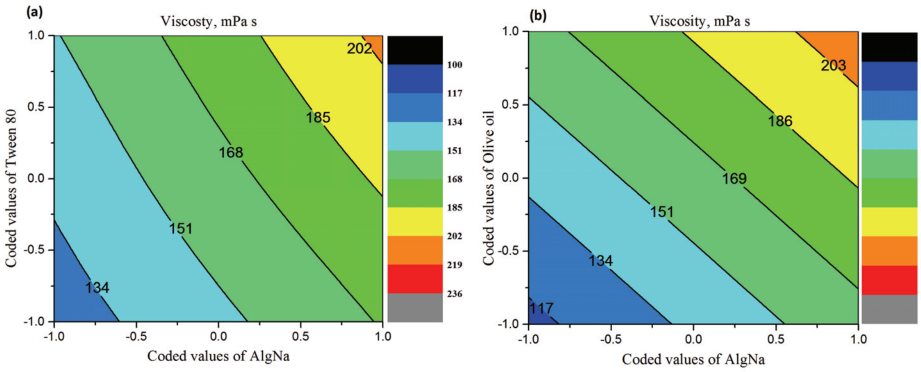

Fig. 3. Contour plots of independent variables: coded values of AlgNa, Tween 80 and olive oil, on the viscosity.

As shown in Fig. 3b, the apparent viscosity values increase with increasing concentrations of AlgNa and olive oil. The maximum viscosity value of 202.5 mPa s was obtained for olive oil concentration close to 0.75 in coded values at constant concentrations of CTAB of 0.105 % and of Tween 80 of 0.025 %.This behavior could be explained by the dispersion of the molecules of the charged polymer in the presence of the viscous oil, which shows significant changes in viscosity values with increasing concentrations of AlgNa and olive oil. In this region (maximum viscosity), the behavior could be attributed to the interactions of surfactant micelles with the polymer chains[28,29] and the associative interaction between the CTAB micelles and the polymer chains may be responsible for leading to the formation of another type of molecules called composite micelles.

Influence of factors on turbidity

Turbidity designates the content of the fluid in the materials that disturb it. In rivers, it is usually caused by suspended matter and colloidal particles that absorb, scatter, or reflect light. In eutrophic waters, it could also be bacteria and micro-algae. The transmittances of solutions containing various amounts of charged polymer, cationic, and nonionic surfactant in the presence of oil could be determined by the turbidimetric method.

The turbidity curves obtained from Eq. (7) are shown in Fig. 4a, which represents plots of iso-response at different coded values of AlgNa and olive oil, with the constants amounts of Tween 80 (0.025 %) and CTAB (0.105 %). The iso-response curves show the effects of these concentrations while the two others were kept constant. The curves show that the minimum turbidity of 200 NTU was obtained for the lowest concentrations of 0.3 % of AlgNa and of 0.1 of olive oil. The turbidity increases with increase in the cloudiness of the solution, with the increase in the concentration indicated by the curves in Fig. 4a and the maximum turbidity of 300 NTU was obtained for the maximum concentrations of AlgNa and olive oil.

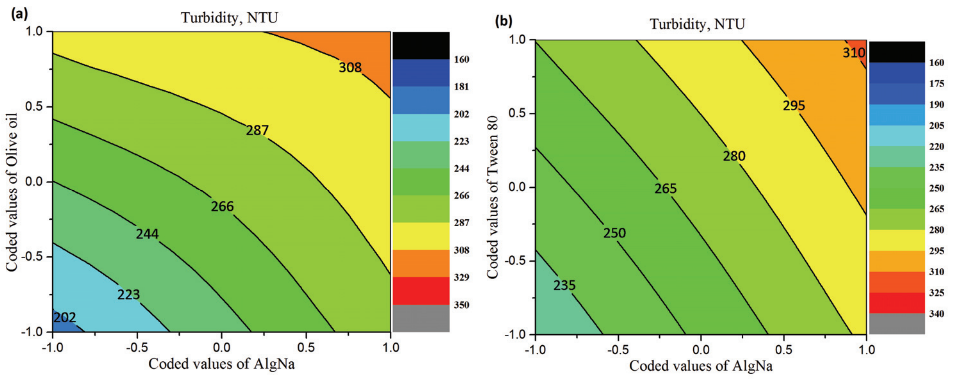

Fig. 4. Contour plots of independent variables: coded values of AlgNa, olive oil and Tween 80 on the turbidity.

The turbidity curves obtained from Eq (7) are illustrated in Fig. 4b, which represents the plots of isoresponse at different coded values of AlgNa and Tween 80 at constants olive oil of 0.2 % and CTAB of 0.105 %. The iso-response curves show the effect of these variable concentrations while the two others were kept constant. The curves show that the minimum turbidity of 200 NTU was obtained as expected at the lowest concentrations of 0.3 % of AlgNa and of 0.4 % of Tween 80. This is expected since the turbidity increases with increasing cloudiness of the solution. This is verified by the curves of Fig. 4b and by the obtained maximum value of the turbidity of 300 NTU.

CONCLUSIONS

The combined effects of the concentrations of CTAB, Tween 80, sodium alginate and olive oil on the physicochemical and viscosimetric properties (interfacial tension, conductivity, viscosity and turbidity) of aqueous solutions were studied using an RSM statistical experimental model to determine if interaction could occur. The study of polymer/surfactants/oil interactions allowed the following conclusions to be drawn:

The conductivity results showed that the tested factors strongly influence this property due to a loading of these factors whenever an increase in conductivity is observed. For the interfacial tension, the obtained values of R^2 and Q^2 were 0.998 and 0.805, respectively. However, the analysis of variance for the model used to estimate the conductivity gave an R^2 value of 0.982 (explaining 98.2 % of the validity of the response) and a Q^2 value of 0.742.

Analysis of the variance for the model obtained for viscosity presented a good R^2 value of 0.976, indicating that only 2.4 % of the total variations were not explained by the model and a Q^2 value of 0.734. For turbidity, the values of the adjusted coefficients of determination R^2 and Q^2 were 0.985 and 0.723, respectively. These values indicate that the model exhibits a good predictive power. For IFT, systems composed of CTAB/AlgNa and CTAB/olive oil, minimum values of 33.85 and 34.39 mN m^{-1} were obtained, respectively. For the same samples, the maximum conductivity values were of 4.126 and 4.064 mS cm^{-1}, respectively. In the case of systems composed of AlgNa/olive oil and AlgNa/Tween80, the maximum viscosity values were 202.5 and 196.6 mPa s, respectively. For the same systems, the maximum turbidity values were 300 and 304 NTU, respectively.

ИЗВОД

МЕТОДОЛОГИЈА ОДЗИВА ПОВРШИНЕ ЗА ПРОУЧАВАЊЕ ИНТЕРАКЦИЈА У ФОРМУЛАЦИЈИ МИЦЕЛАРНОГ СИСТЕМА

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Циљ овог је у испитивање интеракције одређених физичко–хемијских својстава на мицеларним системима који се састоје од полимера (натријум-алгинат), два тензида (CTAB и Tween 80) и алжирског маслиновог уља. Моделирање одзива површине (RSM) примењено је за проучавање комбинованих ефеката система који садрже се врсту површински активних средстава. Праћење четири независна параметра као што су површински напон (Y_1), проводљивост (Y_2), вискозност (Y_3) и турбидитет (Y_4), и упоређивање са експерименталним моделом дизајна омогућили су да се утврде перформансе успостављених модела. На основу статистичких анализа, коефицијенти R^2 и K^2 за површински напон, проводљивост, вискозност и турбидитет су: 0,998 и 0,805; 0,982 и 0,742; 0,976 и 0,734 и 0,985 и 0,723, редом. Добијени резултати указују да су ови модели показали добро предвиђање за оптималан систем састављен од CTAB, Tween 80, AlgNa и маслиновог уља. За системе CTAB/AlgNa и CTAB/маслиново уље, вредности површинског напона од 33,85 и 34,39 mN m^{-1}. Такође су добијене максималне вредности проводљивости од 4,126 и 4,064 mS cm^{-1}. За вискозне системе који се састоје од AlgNa/маслиновог уља и AlgNa/Tween 80, добијене су максималне вредности вискозности од 202,5 и 196,6 mPa s. За исте системе, добијене су вредности турбидитета од 300 и 304 NTU.

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