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Solvatochromic study on UV-VIS spectra of hot red pepper extracts

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ABSTRACT

The influence of a series of organic solvents on the UV-VIS spectra of hot red pepper extracts was studied by implementing solvatochromic theory. As a part of our efforts to interpret the effects of solvent polarity and hydrogen bonding on the absorption spectra of extracted capsaicin and capsanthin, the study design was based on the linear solvation energy relationship (*LSER*) concept using *Kamlet-Taft* and *Catalan* solvatochromic multiparameter approach. Accordingly, by dividing the solvents into two groups (protic and aprotic) it was ascertained that improved solvatochromic models for the group of protic solvents were obtained. The data from these experiments were used to establish correlations describing the properties of corresponding models while measured solvatochromic properties. Moreover, the statistical evaluation of the data following some statistical parameters (R, Sd, F-test, PRESS, SSY and Q²) was also presented. The statistical evaluation of obtained correlation models for capsanthin demonstrated that protic solvents models can be only accurately used to appraise the solvent effects. However, the statistical data of obtained correlation models for capsaicin showed unsatisfactory results. To the best of our knowledge, this is the first report of the solvatochromism studies on extracts from hot red pepper with the expectation that this approach will gain more attention in natural matrix study. © 2012 Trade Science Inc. - INDIA

KEYWORDS

Hot red pepper;
Capsaicin;
Capsanthin;
UV-VIS spectra;
Solvatochromic study.

INTRODUCTION

Worldwide distributed varieties of hot pepper (*Cap-sicum annuum* L.) have been cultivated as a vegetable, spice, and medicinal plants in particular with regard to the pungent properties of their fruits. Hot peppers are also described by many traditional medicines and confirmed by various reported study to possess a range of phytochemicals with recognizable medicinal and commercial value for food processing and pharmaceutical industry. Among the most promising groups of phytochemicals found in hot peppers, that have been extensively investigated - over the years, are capsaicinoids and coloured components. Nevertheless, capsaicin, an alkaloid or predominant capsaicinoids, is the major pungent constituent of hot peppers. Many recent reports

provided some pharmacological evidence for capsaicin. Hot peppers have been also utilized as the primary source of pungent capsicum oleoresin (POC). It is an organic oily resin that is derived from the dried ripe fruits of hot pepper varieties, using solid-liquid extraction with solvent of lypophilic characteristics and subsequent solvent removal^[1-13]. POC basically, contains pigments carotenoids (predominantly capsanthin)^[14-16]. In addition, beside the pigments in the POC are also present flavours, taste agents, vitamins and fatty oil^[17,18]. However, a survey of research literature focused on this plant matrix reveals that the currently employed solid-liquid extraction procedures for POC do not involve solvatochromic studies on important hot pepper phytochemicals.

Conventional methods of extraction can be modified to reduce costs and increase convenience of existing

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method. It is perhaps obvious that consideration of physical properties such as melting point, boiling point, viscosity and polarity of a solvent are essential when choosing a solvent for a particular application. Solvent polarity is among the most widely used concepts in chemistry^[19-22]. Most solvent polarity scales are empirical and different empirical solvent polarity scales have been shown to correlate well with each other, pointing to the existence of an underlying common feature^[19,22-28]. Around 35 solvent scales are known. However, only about ten of them have found wider application in the correlation analysis of solvent effects, *i.e.* α , β , π^* , E_T^N , SPP , SA and SB . Empirical solvent polarity scales based on spectroscopic measurements usually employ changes in the UV-VIS absorption maximum as an indicator in different solvents^[19,23-26]. Multiple intermolecular solute/solvent interactions can be described by the linear solvation energy relationship (LSER) of *Kamlet-Taft* and *Catalàn's* solvent polarity scales^[19,29,30]. Although, *Kamlet-Taft* and *Catalàn* approach first was used for determination the solvatochromic behavior of the dyes^[29-31], it was challenging to apply the same approach for natural matrix as is POC.

The overall goal of this paper is to initiate preliminary investigations of solvation of POC which is closely connected with the stabilizing and destabilizing effects of solvent on capsaicin and capsanthin structure. Therefore, the study of solvation processes of PCO in various organic media is important for further studies elucidating the connection between their chemical structure and biological activity. The obtained knowledge will contribute to further successful development of processing method and also will help when choosing the extraction solvents for effective recovery in effort to characterize pungent peppers as a valuable source of certain phytochemicals.

EXPERIMENTAL

Materials

Plant material

Red hot dried pepper fruits precisely, pericarp (*Cap-sicum annuum* L., ssp. *microcarpum longum conoides*, convar. *Niska*) used in this study were obtained from Scientific-Rereach Center in Stumica, Republic of Macedonia. The dried pericarp (6.25% dry mater content) was grounded using Retsch ZM1 mill (Haan, Germany) and sieved (0.25 mm particle size). The pepper

samples placed in dark glass bottles were stored at 4°C in refrigerator.

Solvents used for extraction method and for evaluation of solvent effect

Tetrahydrofuran, 1-propanole, 2-propanole, ethanol and ethyl acetate, were used during the extraction of the plant material. For investigation of solvent effects, beside previously mentioned solvents, polar and non polar solvents (water, methanol, acetone and chloroform) were also included. Pro-analysis-grade solvents were purchased from A. D. Alkaloid (Skopje, Republic of Macedonia) and Merck (Darmstadt, Germany).

Methods

Extraction procedure

The samples of 1 g dried red hot pepper (0.0001 g accurately weight), were extracted by means of Soxhlet procedure (AOAC, 920.85)^[32] using solvents with different polarity degree and solid/liquid ratio of 1:100 w/v. After 5 h extraction, the solvent was removed under vacuum (rotary vacuum evaporator, type Devarot, Elektromedica, Slovenia, 35 °C, atm. pressure). After that, solvent traces were discharged by drying the sample at 40 °C, 105 mPa (vacuum drier, Heraeus Vacutherm VT 6025, Langenselbold, Germany). Obtained POCs were cooled in a dessicator and weighted. The steps of drying, cooling and weighting were repeated until the difference between two consecutive weights was smaller than 2 mg. The extraction procedure was performed in duplicate. The extract was transferred into a 100 mL volumetric flask and filled to 100 mL with ethanol (1st dissolution).

Test solutions for solvent effect evaluation

Test solutions for evaluation of solvent effects were prepared by dissolving volume 0.5 mL of 1st dissolution in appropriate solvent into volume of 10 mL volumetric flask (2nd dissolution).

LSER concept - Kamlet-Taf and Catalàn approach for investigation of effects of solvent polarity and hydrogen bonding on the absorption spectra

Multiple intermolecular solute/solvent interactions can be described by the linear solvation energy relationship, concept first described by *Kamlet* and *Taft* using Eq. (1), and later by *Catalàn* using Eq. (2):

$$v_{max} = v_o + a\alpha + b\beta + s\pi^* \quad (1)$$

$$v_{max} = v_o + aSA + bSB + sSPP \quad (2)$$

where π^* , β , α , SPP , SB and SA are solvatochromic parameters and s , b and a are the solvatochromic coefficients^[19]. Solvent parameters: α , β , π^* , SA , SB and SPP of solvent chosen for investigation of solvent effect are given in TABLE 1.

UV-VIS spectra were recorded on Varian Cary Scan 50 spectrophotometer (Varian Inc., Switzerland) in 1cm quartz cells, at 25 °C. The statistical evaluation of the data was performed using ORIGIN 7.0 Professional (OriginLab Corporation, Northampton, USA) and STATISTICA 6 (StaSoft, Inc., Tulsa, USA).

TABLE 1: Solvent parameters^[19]

Solvents	α	β	π^*	SA	SB	SPP
water	1.17	0.47	1.09	1.062	0.025	0.962
methanol	0.98	0.66	0.60	0.605	0.545	0.857
ethanol	0.86	0.75	0.54	0.400	0.658	0.853
1-propanol	0.84	0.90	0.52	0.367	0.727	0.847
2-propanol	0.76	0.84	0.48	0.283	0.762	0.848
ethyl acetate	0.00	0.45	0.45	0.000	0.542	0.795
acetone	0.08	0.48	0.62	0.000	0.475	0.881
chloroform	0.02	0.10	0.69	0.047	0.071	0.786
tetrahydrofuran	0.00	0.55	0.55	0.000	0.591	0.838

RESULTS AND DISCUSSION

To delineate the different interactions of protic and aprotic solvents with previously obtained POC in order to evaluate their limitations and also their further applications UV-VIS spectra of the PCO were recorded in nine solvents and the position of electronic absorption bands were determined. The effects of solvent polarity and hydrogen bonding on the absorption spectra were interpreted by means of LSER.

Investigation of solvent effects on the UV-VIS spectra of the POC

Modelling of solvent effects is one of the most useful methods to obtain information about the mechanism of all reactions which include organic compounds, such as solute present constituents in POC. A solvent would provide not only a background for the reaction to occur but it would also stabilize the reactants and the transition state species by solvating process. This solvation is due to solvent-solute interactions during which a solvent act either as a nucleophile or an electrophile by donating or accepting electron pairs

from the solute. It can also form hydrogen bonds with the specific sites of the solute molecules. For that reasons, it is important to explore solvent effects on the UV-VIS spectra of the POCs.

UV-VIS absorption spectra of POC

In order to explain the difference in the influence of solvents on the POCs obtained by five chosen solvents (ethanol, ethyl acetate, 1-propanol, 2-propanol and tetrahydrofuran), first step includes recording their UV-VIS spectra in solvents as given in TABLE 1. In accordance with the reported data^[33,34], we also considered that λ_{max} absorption at around 282 nm ($\nu_{max} = 35.46 \times 10^3 \text{ cm}^{-1}$) is characteristic for capsaicin while, λ_{max} absorption at around 462 nm ($\nu_{max} = 21.64 \times 10^3 \text{ cm}^{-1}$) is characteristic for capsanthin.

For the lowest absorption band generally, absorption frequencies ($\nu_{max} = 1/\lambda_{max}$) are at about: $35.09 \times 10^3 \text{ cm}^{-1}$ in water; $35.21 \times 10^3 \text{ cm}^{-1}$ in methanol and $34.96 \times 10^3 \text{ cm}^{-1}$ in ethanol. Moreover, $35.09 \times 10^3 \text{ cm}^{-1}$; $34.96 \times 10^3 \text{ cm}^{-1}$ and $35.34 \times 10^3 \text{ cm}^{-1}$ are obtained in 1-propanol, 2-propanol and in ethyl acetate, respectively. For the highest absorption band, absorption frequencies are at about: $21.55 \times 10^3 \text{ cm}^{-1}$ in water; $22.22 \times 10^3 \text{ cm}^{-1}$ in methanol; $22.08 \times 10^3 \text{ cm}^{-1}$ in ethanol; $22.03 \times 10^3 \text{ cm}^{-1}$ in 1-propanol; $22.08 \times 10^3 \text{ cm}^{-1}$ in 2-propanol; $22.03 \times 10^3 \text{ cm}^{-1}$ in ethyl acetate; $21.98 \times 10^3 \text{ cm}^{-1}$ in acetone; $21.65 \times 10^3 \text{ cm}^{-1}$ in chloroform, and $21.83 \times 10^3 \text{ cm}^{-1}$ in tetrahydrofuran.

The spectral band shifts were also related to solvent parameter $\phi(\epsilon, n)$ which is given as follows Eq. 3,^[35]:

$$\phi(\epsilon, n) = f(\epsilon, n) + 2g(n) \quad (3)$$

The function takes into account two important properties of the solvents namely, the dielectric constant (ϵ) and the refractive index (n). The function is a sum of two independent terms, $f(\epsilon, n)$ and $g(n)$, as given in Eq. 4 and 5:

$$f(\epsilon, n) = [(2n^2+1)/(n^2+2)] \{[(\epsilon-1)/\epsilon+2] - \{(n^2-1)/(n^2+2)\}\} \quad (4)$$

$$g(n) = 3/2 [(n^4-1)/(n^2+2)^2] \quad (5)$$

where the dielectric constant and the refractive index or both these values reflect the freedom of the electrons motions in the solvent and the dipole moment of the molecules. Specific solvent effects occur by interactions of the solvent and the chromophores. Figure 1 shows the trend when the spectral position (ν_{max}) of the POC in protic solvents were plotted against the solvent

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polarity parameter $\phi(\epsilon, n)$.

Next step included correlation of the absorption frequencies with the total solvatochromic Eqs. (1) and (2). The *Kamlet-Taft* (α , β and π^*) and *Catalàn* (*SA*, *SB* and *SPP*) solvatochromic parameters are shown in TABLE 1.

The results of the correlation of the absorption frequencies with the solvatochromic parameters are presented by Models 1 - 11. The study is based on the quantitative values and the sign of the coefficients in the corresponding models, and the comparison of these coefficients among themselves. Basic statistical parameters such as: correlation coefficient (*R*), standard deviation (*Sd*) and *F*-test were used to preliminary evaluation of the regression models.

Evaluation of correlation models obtained using the absorption frequencies of the lower energy bands (previously mentioned as characteristic band for determination of capsaicin and Eqs. (1) and (2) showed unsatisfactory results. According the values for $R < 0.2$ and $Sd > 1$ it is obviously that unacceptable correlation models were obtained. Due to this finding, we didn't take into consideration those models.

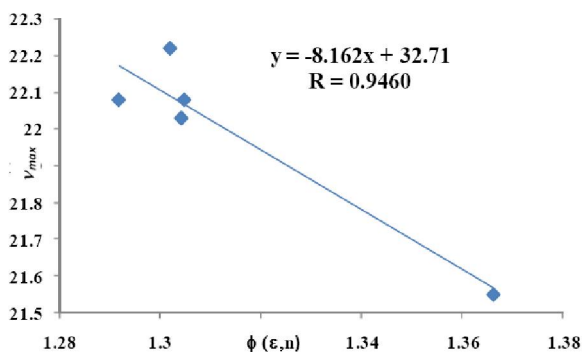


Figure 1 : Plot of absorption frequency (in cm^{-1}) of POC in protic solvents versus the $\phi(\epsilon, n)$ values

Kamlet - Taft approach

Three- and bi-correlation models were developed using experimental obtained data (Model 1-3). Thus, in all models are included important contribution from the classical solvent effect (π^*) which is represent by the higher negative value of the coefficient *s*. Statistical evaluation of Models 1-3 showed satisfactory values ($R = 0.86 \div 0.90$; $Sd = 0.11 \div 0.13$).

Model 1 $\nu_{\max} = 22.58 \pm 0.37 + 0.27 \pm 0.19\alpha - 0.09 \pm 0.38\beta - 1.18 \pm 0.42\pi^*$
 $a = 17.53\%$ $b = 5.84\%$ $s = 76.63\%$
 $R = 0.9025$ $Sd = 0.1193$ $F_{(3,5)} = 7.3162$

$n = 9$ $R_{\text{adj}}^2 = 0.7031$ $p < 0.0281$

Model 2 $\nu_{\max} = 22.49 \pm 0.13 + 0.24 \pm 0.09\alpha - 1.10 \pm 0.22\pi^*$
 $a = 17.91\%$ $s = 82.09\%$
 $R = 0.9013$ $Sd = 0.1096$ $F_{(2,6)} = 12.98$
 $n = 9$ $R_{\text{adj}}^2 = 0.7496$ $p < 0.0001$

Model 3 $\nu_{\max} = 22.13 \pm 0.24 + 0.38 \pm 0.20\beta - 0.68 \pm 0.26\pi^*$
 $b = 35.84\%$ $s = 64.15\%$
 $R = 0.8578$ $Sd = 0.1299$ $F_{(2,6)} = 8.3617$
 $n = 9$ $R_{\text{adj}}^2 = 0.6479$ $p < 0.0184$

However, it is expected that protic and aprotic solvents should have different solvations and specific interactions with capsanthin, due to their polarity and hydrogen bonding. As a result of this fact, we divided the spectral-solvent correlation into two groups (protic/aprotic). In line with this, statistical data confirm improved models only for group of protic solvents (Models 4 - 6).

Since the obtained values for *R* and *Sd* for aprotic solvents models, are not statistically significant ($R < 0.65$; $Sd > 1.72$), and they are not discussed in this paper. Hence, further discussion is focused on the sign and value of Models 4-6.

Model 4 $\nu_{\max} = 22.68 \pm 0.72 + 1.23 \pm 0.57\alpha - 0.68 \pm 0.43\beta - 2.07 \pm 0.28\pi^*$
 $a = 30.90\%$ $b = 17.09\%$ $s = 52.01\%$
 $R = 0.9957$ $Sd = 0.04729$ $F_{(3,1)} = 39.057$
 $n = 5$ $R_{\text{adj}}^2 = 0.9661$ $p < 0.1169$

Model 5 $\nu_{\max} = 21.61 \pm 0.32 + 1.81 \pm 0.58\alpha - 2.01 \pm 0.37\pi^*$
 $a = 47.38\%$ $s = 52.62\%$
 $R = 0.9850$ $Sd = 0.0625$ $F_{(2,2)} = 32.773$
 $n = 5$ $R_{\text{adj}}^2 = 0.9407$ $p < 0.0296$

Model 6 $\nu_{\max} = 24.01 \pm 0.63 - 1.28 \pm 0.56\beta - 1.70 \pm 0.374\pi^*$
 $b = 42.95\%$ $s = 57.05\%$
 $R = 0.9756$ $Sd = 0.0797$ $F_{(2,2)} = 19.766$
 $n = 5$ $R_{\text{adj}}^2 = 0.9037$ $p < 0.0481$

According the values of *s*, *b* and *a*, the solvent effects on the absorption spectra of capsanthin in protic solvents (Models 4 - 6), generally include important contribution from the classical solvent effect (π^*) assign by the higher negative value of the coefficient *s*. In Model 4, although β parameter acts in same direction as π^* , its influence can be ignored, due to the smaller value of the coefficient *b*. The percentage contribution of the calculate solvatochromic parameters also confirm those conclusions. The *negative* values of *s* indicated better stabilisation of the *transition* state by the classical solvent. The HBD effects, in Models 4 and 5, work in the opposite direction to the classical solvent effects, indicating better stabilization of the ground state by the

HBD solvent effects. Regarding the correlation coefficient ($R > 0.97$) and standard deviation ($Sd < 0.07$), satisfactory values in bi- and tri-correlation Models (4-6) have been achieved.

Catalàn approach

In the present study, we implement the same method (Eq. 2) to involve the *Catalàn* approach, where experimentally obtained v_{max} are correlated with *Catalàn* solvatochromic parameters (*SPP*, *SB* and *SA*, TABLE 1).

As we expected, the results have showed that no correlations were found for the lower energy band. The results of the correlation of the higher energy band with *SPP*, *SB* and *SA* are presented by Models 7-11. Concerning *Kamlet-Taft* concept (Model 1), it has been shown that obtained *Catalàn* tri-parametric model (Model 7) is not statistically significant ($R = 0.87$).

$$\begin{aligned} \text{Model 7 } v_{max} &= 22.55 \pm 1.28 + 0.18 \pm 0.22SA + 0.71 \pm 0.19SB - \\ & 1.19 \pm 1.55SPP \\ a &= 8.65 \% \quad b = 34.13 \% \quad s = 57.22 \% \\ R &= 0.8660 \quad Sd = 0.1385 \quad F_{(3,5)} = 5.0011 \\ n &= 9 \quad R^2_{adj} = 0.6001 \quad p < 0.0576 \end{aligned}$$

When biparametric model (Model 8) is concern using *SB* and *SPP*, it has been confirm that this model was statistically unreliable. In addition, bi-model with *SA* and *SPP* indicate to even worst statistically results ($R = 0.2896$).

$$\begin{aligned} \text{Model 8 } v_{max} &= 21.81 \pm 0.85 + 0.68 \pm 0.19SB - 0.24 \pm 0.97SPP \\ b &= 73.91 \% \quad s = 26.09 \% \\ R &= 0.8473 \quad Sd = 0.1343 \quad F_{(2,6)} = 7.6363 \\ n &= 9 \quad R^2_{adj} = 0.6239 \quad p < 0.0224 \end{aligned}$$

The approach of grouping solvents into protic and aprotic reviled much better fits to the results for protic solvents. Moreover, the excellent bi- and tri- correlation models (Models 9-11) were obtained in water and alcohols ($R > 0.983$, $Sd < 0.08$).

$$\begin{aligned} \text{Model 9 } v_{max} &= 35.25 \pm 9.61 - 0.35 \pm 1.99SA - 1.86 \pm 3.23SB \\ & - 13.81 \pm 7.96SPP \\ a &= 2.19 \% \quad b = 11.61 \% \quad s = 86.20 \% \\ R &= 0.9874 \quad Sd = 0.0812 \quad F_{(3,1)} = 13.03 \\ n &= 5 \quad R^2_{adj} = 0.9002 \quad p < 0.2003 \end{aligned}$$

$$\begin{aligned} \text{Model 10 } v_{max} &= 29.86 \pm 1.69 - 0.77 \pm 0.34SA - 9.48 \pm 2.14SPP \\ a &= 7.51 \% \quad s = 92.49 \% \\ R &= 0.9832 \quad Sd = 0.0662 \quad F_{(2,2)} = 29.12 \\ n &= 5 \quad R^2_{adj} = 0.9336 \quad p < 0.03320 \end{aligned}$$

$$\text{Model 11 } v_{max} = 33.71 \pm 2.81 - 1.31 \pm 0.48SB - 12.61 \pm$$

2.93SPP

$b = 9.41 \% \quad s = 90.59 \%$

$R = 0.9871 \quad Sd = 0.0583 \quad F_{(2,2)} = 37.88$

$n = 5 \quad R^2_{adj} = 0.9486 \quad p < 0.0257$

Implementation of the *Catalàn* approach showed that protic solvent effects on the absorption spectra of capsanthin include dominant influence of solvent dipolarity/polarizability in all Models.

In tri-parametric model (Model 9), the influence of the β and α parameters can be ignored, because of the smaller values of $b = 11.61\%$ and $a = 2.19\%$.

Validation

We have also undertaken a cross-validation methodology for choosing predictive power of the proposed models. The mention methodology is essential because a model with good statistics may not have good predictive potential. Thus, the various cross-validation parameters calculated for the proposed models are presented in TABLE 2 and are discussed below. To test the quality of the regression models, beside basic parameters R , Sd and F -test, the additional statistical parameters were also used such as PRESS (Predictive residual error Sum of Squares = $\sum(Y_{pred} - Y_{exp})^2$); SSY (Sum of squares of deviation of the experimental values from their mean = $\sum(Y_{exp} - Y_{mean})^2$, where Y_{pred} -predicted, Y_{exp} -experimental and Y_{mean} -mean values of the target properties v_{max} respectively and Q^2 - Cross-validation squared correlation coefficient ($Q^2 = 1 - \text{PRESS}/\text{SSY}$).

Kamlet - Taft approach

Good cross-validation values ($Q^2 > 0.72$) obtained for models in protic solvents ($Q^2 = 0.9494 - 0.9914$) suggest that the Models 4 - 6 are useful tool for predicting solvent effects on the capsanthin UV-VIS spectra extracted from hot red pepper. PRESS appears to be important cross-validation parameter accounting for a good estimate of the real predictive error of the model. Its value less than SSY indicate that the model predicts better than chance and can be considered statistically significant. In order to present a reasonable model, PRESS/SSY should be smaller than 0.4. In our case, PRESS/SSY ranges between 0.0085 - 0.0506 (TABLE 2).

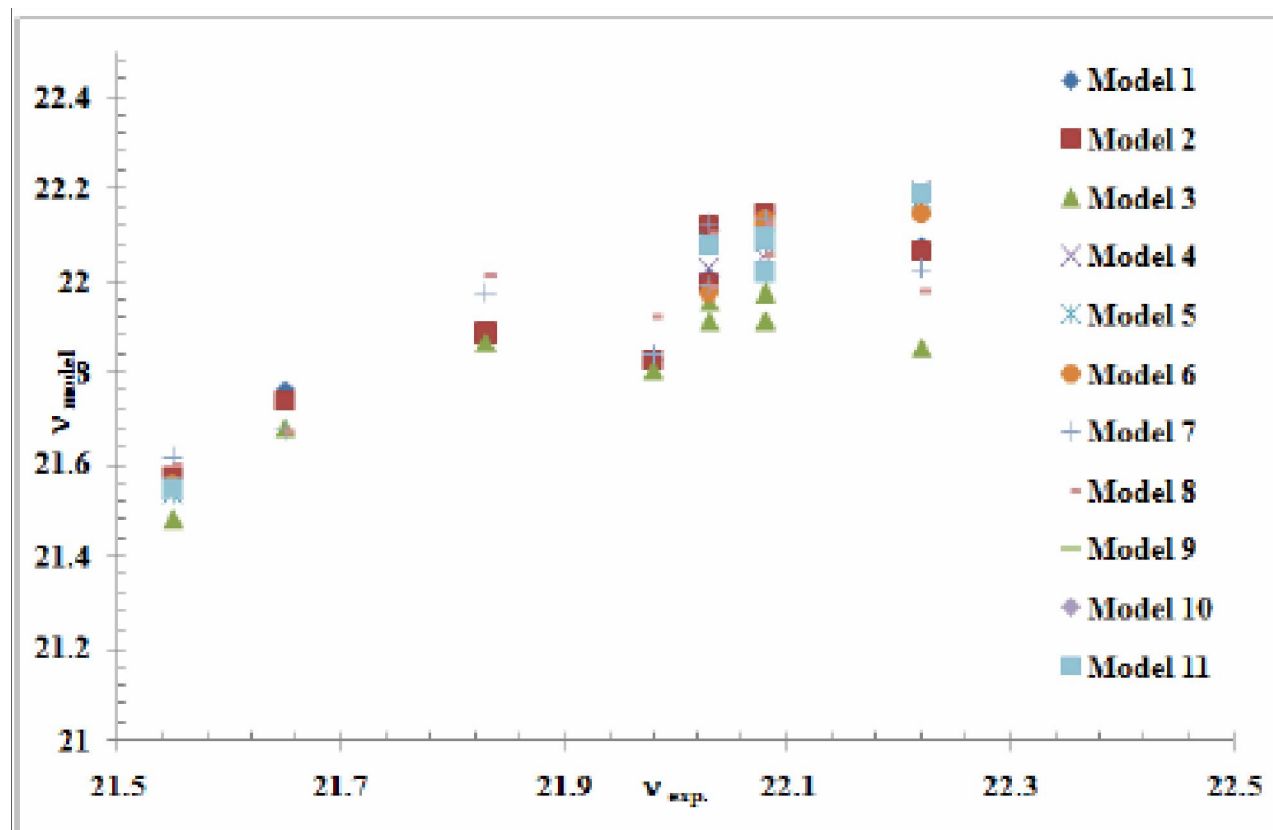
Catalàn approach

Based on the values of Q^2 (0.9657 - 0.9744) and

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TABLE 2 : Validation parameters for models 1-11

Model	Kamlet - Taft approach			Model	Catalàn approach		
	Q ²	PRESS	PRESS/SSY		Q ²	PRESS	PRESS/SSY
1	0.7722	0.071189	0.2278	7	0.66610	0.0959	0.3339
2	0.7688	0.0720	0.2311	8	0.6071	0.1082	0.3929
3	0.6410	0.1013	0.3587	9	0.9744	0.0066	0.0256
4	0.9914	0.0022	0.0085	10	0.9657	0.0088	0.0343
5	0.9494	0.0127	0.0506	11	0.9736	0.0068	0.0264
6	0.9648	0.0078	0.0305				
				$v_{max.ob.} = 0.95 v_{max.cal.} + 1.12$ $R_{pre}^2 = 0.95$			

Figure 2 : Values of $v_{experimental}$ and v_{model} for models 1 - 11

PRESS/SSY (0.0264 - 0.0343), it has been confirmed that only Models 9 -11 were statistically significant (TABLE 2).

In order to confirm our solvatochromic findings, v_{\max} values calculated by corresponding *Kamlet-Taft* and *Catalàn* models (v_{model}) are compared with those v_{\max} values, experimental obtained (v_{exp}). Within the range of acceptable experimental error, the values agree well, for protic solvents only. From the plot, constructed between the experimental and calculated v_{\max} values (Figure 2) we have calculated predictive correlation coefficient (R_{pre}), (TABLE 2). Once again, the obtained predictive correlation coefficient, confirmed our findings for protic solvents.

CONCLUSION

An effort has been made to interpret the effects of solvent polarity and hydrogen bonding on the UV-VIS absorption spectra of capsaicin and capsanthin present in POC by means of linear solvation energy relationship through implementation of two concepts, *Kamlet-Taft* and *Catalàn*.

The statistical evaluation of obtained correlation models for capsanthin demonstrated that protic solvents models can be only accurately used to appraise the solvent effects. However, statistical evaluation of obtained correlation models for capsaicin showed unsatisfactory results.

To the best of our knowledge, this is the first report of the solvatochromism studies on extracts from hot red pepper, and we expect that obtained results will draw more attention in natural matrix study.

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