**Effect of substituent on the 13C - NMR chemical shifts of substituted 5-benzylidenebarbituric acids**

**P. Mohandass1, K. Radhakrishnan\*1,S.Manimekalai2,V.Suriyanarayanan3 and S. Radhakrishnan4**

1Research Department of Chemistry, Saraswathi Narayanan College, Perungudi, Madurai – 625022, Tamil Nadu, India.

2Department of Chemistry,E.M.G. Yadava Women’s College,Madurai, Tamil Nadu, India.

3Electro-organic chemistry division, CSIR-CECRI, Karaikudi-630003, Tamil Nadu, India

4Central Instrumentation facilities, CSIR-CECRI, Karaikudi-630003, Tamil Nadu, India.

\*Corresponding author: Email: prskradha61@gmail.com; Contact:9443686474

**Abstract**

Substituted 5-benzylidenebarbituric acids have been prepared and characterized by 1H and 13C NMR spectral analysis. Investigation of substituents effect and mode of transmission of electronic effects have been carried out by 13C NMR chemical shifts measurement and correlated it with LFER parameters in substituted 5-benzylidenebarbituric acids.

**Key words:** 1H and13C NMR, substituted 5-benzylidenebarbituric acids, substituent effects.

**Introduction**

Correlation of the chemical shift with substituent constant has been widely used to investigate the nature of the effect of the substituent on the physical properties of compounds. Electron density around the nucleus of interest (H,C) is mostly affected by the electron-donating and electron-withdrawing ability of the substituent. Therefore, a correlation between the observed chemical shift and any parameter representing such ability seems to be well-founded, and there are numerous reports on the subject1.

The single substituent parameter (SSP) approach which is represented by equation (1) has been used to correlate the chemical shift of *m*- and *p*- substituted compound to unsubstituted compound using the Hammett *σm* and *σp* values. Values of 13C were reported for the system of *m-*and *p-*substituted cinnamic acids2. The dual substituent parameter (DSP) approach, on the other hand, divides the effect of substituent effect into inductive (*σI*) and resonance (*σR*) parameters as represented in Eq. (2).





Yukawa and Tsuno proposed Eq. (3) for dealing with enhanced resonance effects



The DSP analysis of sterically congested systems has been improved by TSP by using Charton’s steric parameter (ν) using Eq. (4).



The magnitude, as well as the sign of *ρ*, should have a profound meaning on the mechanism of the transmission of the substituent effect. For example, correlations of the chemical shift of carbonyl carbon with the Hammett *σ* for the system of benzanilides, X-C6H4-CO-NH-C6H4-Y show normal correlation when Y is varied, but the reverse correlation is observed when X is varied. π polarizations have been attributed for such observation.3,4 The magnitude of *ρx* (-2.838 ppm, r=0.940) is larger than that of *ρy* (0.853 ppm, r= 0.975) in DMSO -d6. The carbonyl carbon is directly bonded to the phenyl ring of X-C6H4, but it is separated by the nitrogen atom from C6H4-Y and therefore, the *ρx* should be larger than *ρy*. The estimation of sign and magnitude of the substituent chemical shift, however, seems to be complicated by many factors which affect the chemical shift.

Recently we reported the effect of substituents on the antimicrobial activities of substituted 2-benzylidene 1,3-indandiones5 and substituted 5-benzylidenebarbituric acids6.These above reports prompted us to undertake a detailed 13C NMR spectral and correlation study of substituted 5-benzylidenebarbituric acids.

**Materials and Methods**

All chemicals used were purchased from Sigma Aldrich. The purity of the compounds was checked by TLC on silica gel G plate.Substituted 5-benzylidenebarbituric acids (Figure-1) were prepared by reaction of the corresponding substituted benzaldehyde with barbituric acid as reported earlier7.



**Figure - 1**

**Spectra**

1H and 13C spectra of substituted 5-benzylidenebarbituric acids were obtained on a BRUKER AMX 400 MHz spectrometer. Chemical shifts of 1H were measured with the peak of DMSO at δ 2.51 as the internal reference, while those of 13C were recorded with the central peak of DMSO at δ 39.90 as the internal reference. The 1H and 13C chemical shifts of the substituted 5-benzylidenebarbituric acids are presented in Tables 1 and 2 respectively.

**Assignment of 1H and 13C chemical shifts**

Assignments of 1H chemical shifts were made using considerations of splitting patterns, spin decoupling and additivity of chemical shifts. The 13C chemical shifts were assigned by intensity and SCS considerations.

**Table 1: 1H NMR chemical shifts of substituted 5-benzylidenebarbituric Acids**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| S.No. | Substituent  (X) | H2,2’ | H3,3’ | H5 | H8 | H10 |
|  |  |  |  |  |  |  |
| 1. | -OCH3 | 7.065 | 8.369 | 8.252 | 11.175 | 11.302 |
|  |  |  |  |  |  |  |
| 2. | -OH | 6.878 | 8.32 | 8.213 | 11.117 | 11.249 |
|  |  |  |  |  |  |  |
| 3. | -CH3 | 7.304 | 8.094 | 8.255 | 11.218 | 11.365 |
|  |  |  |  |  |  |  |
| 4. | -H | 7.485 | 8.073 | 8.285 | 11.238 | 11.397 |
|  |  |  |  |  |  |  |
| 5. | -Cl | 7.518 | 8.069 | 8.243 | 11.275 | 11.425 |
|  |  |  |  |  |  |  |
| 6. | -Br | 7.670 | 7.979 | 8.223 | 11.272 | 11.421 |
|  |  |  |  |  |  |  |
| 7. | -NO2 | 8.245 | 8.017 | 8.324 | 11.329 | 11.504 |

**Table 2: 13C NMR chemical shifts of substituted 5-benzylidenebarbituric acid**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Substituent**  **X** | **C1** | **C2,2’** | **C3,3’** | **C4** | **C5** | **C6** | **C7** | **C9** | **C11** |
|  |  |  |  |  |  |  |  |  |  |  |
| 1. | -OCH3 | 162.64 | 114.41 | 137.96 | 125.62 | 155.46 | 116 | 163.92 | 150.67 | 164.39 |
|  |  |  |  |  |  |  |  |  |  |  |
| 2. | -OH | 163.48 | 115.97 | 138.77 | 124.24 | 156.05 | 114.61 | 162.75 | 150.7 | 164.59 |
|  |  |  |  |  |  |  |  |  |  |  |
| 3. | -CH3 | 143.96 | 129.33 | 134.43 | 130.31 | 155.46 | 118.3 | 162.26 | 150.68 | 164.08 |
|  |  |  |  |  |  |  |  |  |  |  |
| 4. | -H | 133.11 | 128.52 | 133.54 | 132.69 | 155.2 | 119.55 | 162.03 | 150.69 | 163.87 |
|  |  |  |  |  |  |  |  |  |  |  |
| 5. | -Cl | 137.21 | 128.55 | 135.15 | 132.01 | 153.52 | 120.09 | 162.04 | 150.65 | 163.67 |
|  |  |  |  |  |  |  |  |  |  |  |
| 6. | -Br | 126.29 | 131.51 | 135.15 | 132.4 | 153.56 | 120.24 | 162.04 | 150.65 | 163.67 |
|  |  |  |  |  |  |  |  |  |  |  |
| 7. | -NO2 | 148.49 | 132.69 | 123.37 | 140.48 | 151.63 | 123.15 | 161.62 | 150.68 | 163.13 |

**Results and Discussions**

**Correlations with Lynch-Equation**

The SCS of monosubstituted benzenes has been very useful in the signal assignment of polysubstituted compounds8-11. However, in many published studies summarized by Craik12 it has been apparent that the SCS values of X and Y at positions 4’ and 1’ in disubstituted benzenes Fig. (2) are non-additive. Lynch13 has proposed that the non-additivity of the chemical shifts of C-1’ and C-4’ is reflected in the relationship Eq. (5) where SCSX(Y) is the substituent chemical shift of the carbon *para-* to X in the series of 1’,4’-disubstituted benzenes (Fig. 2, X, Y ≠ H),



**Figure -2**



SCSX(H) is the corresponding substituent chemical shift of the carbon *para* to X in monosubstituted benzenes (Fig.2, Y=H), ‘b’ is the slope parameter and ‘a’ is the shift calculated for the parent spices with X=Y. A wide range of successful correlations (using Lynch equation) have been established for the SCS of carbons bearing Y in Fig. (2) with the value of ‘b’ ranging from 0.6 to 1.514. When the slope is close to unity, experimental results could be reproduced by additivity relationship and when b ≠ 1, the Lynch equation can be used to predict the SCS values through proportionality relationships. The slope b of the Lynch equation Eq. (5) is less than one, then the fixed substituent at C-1’ Fig. (2) diminishes the substituent effect. When slope b is larger than one, showing that the fixed substituent undergoes an amplification of the substituent effect.

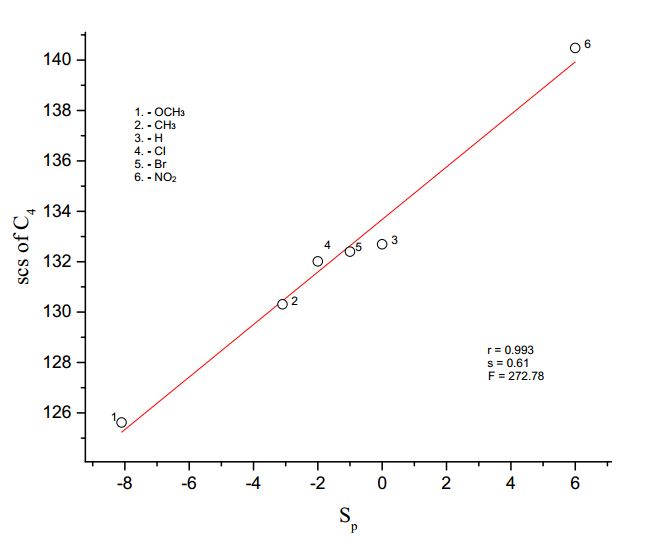
In case of C1, there is a good correlation with (r=0.988) appropriate SCS (Si) values, slope b is 0.97, which reveals that the fixed substituent Y=-CH-C-C3H2N2O3, has little effect on the additivity of this shifts14. A satisfactory correlation exists between SCS of C22’ and So with a correlation coefficient (r=0.828) and the slope value (b=0.84), indicating that the fixed substituent Y, significantly diminishes the substituent effect14. A poor correlation exists between SCS of C33’ and Sm with a correlation coefficient (r=0.113) and the slope value (b=0.71) which reveals that the fixed substituent Y diminishes the substituent effect14. The C4 carbon affords a good correlation with Sp with correlation coefficient r=0.993 and the slope value b=0.94 demonstrates that the fixed substituent Y has little effect on the additivity of these shifts14. The results of Lynch correlations are given in table (3) and the plots of Lynch correlations shown in fig. (3).

**Table (3): Results of Lynch correlationsa of 13C chemical shifts of substituted 5-benzylidenebarbituric acids Fig. (1) with SCS values for**

**monosubstituted benzenes.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Nucleus | Benzene  SCS | Slope  (b) | Intercept  (a) | rb | nc | sd |
| 1. | C1 | Si | 0.97 | 132.23 | 0.988 | 6 | 2.17 |
|  |  |  |  |  |  |  |  |
| 2. | C22’ | SO | 0.84 | 129.73 | 0.828 | 6 | 4.14 |
|  |  |  |  |  |  |  |  |
| 3. | C33’ | Sm | 0.71 | 132.69 | 0.113 | 6 | 5.63 |
|  |  |  |  |  |  |  |  |
| 4. | C4 | Sp | 0.94 | -126.43 | 0.993 | 6 | 0.61 |

Where, ‘a’ is SCSX (Y) = a + b SCSX (H); ‘b’ is Correlation coefficient; ‘c’ is Number of data points; ‘d’ is Standard deviations



**Fig. (3). Lynch plot of SCS of C4 vs Sp**

**Hammett and dual substituent parameter correlations**

The 13C chemical shifts of the carbon atoms of the 5-benzylidenebarbituric acid series afford several reasonable correlations using Hammett substituent parameters Eq.(1) and the data are given in Table (4).The results of the correlations of 13C SCS values of 5-benzylidenebarbituric acid series with *σI* and *σR* constants according to equation (2) are presented in Table (5). The results of multiple regression analysis of 13C chemical shifts with σp,( σp+- σp)  and σpo,(σp+- σpo) constants using Yukava – Tsuno equation (3) are presented in Table (6).

**Table ( 4): Results of statistical treatment of 13C – Chemical shift with σp, σpo,σp+, σp+/ σp, σp+/ σp-,σp+/ σp/ σp- substituent constants using single**

**parameter equation (2)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Carbons** | **Scale** | ***ρ*** | **R** | **s** | **F** | **log δo** | **n** |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| 1 | C4 | *σp* | 0.043±0.006 | 0.949 | 0.006 | 43.33 | 2.115±0.002 | 7 |
|  | *σpO* | 0.038±0.010 | 0.882 | 0.008 | 13.99 | 2.114±0.004 | 6 |
|  | *σp+* | 0.029±0.002 | 0.986 | 0.003 | 179.37 | 2.121±0.001 | 7 |
|  | *σp+/ σp* | 0.033±0.006 | 0.924 | 0.007 | 29.11 | 2.117±0.003 | 7 |
|  | *σp+/ σp-* | 0.024±0.002 | 0.989 | 0.003 | 226.34 | 2.118±0.001 | 7 |
|  | *σp+/ σp/ σp-* | 0.026±0.004 | 0.938 | 0.006 | 37.12 | 2.115±0.002 | 7 |
|  |  |  |  |  |  |  |  |  |
| 2 | C5 | *σp* | -0.011±0.001 | 0.984 | 0.001 | 152.18 | 2.189±0.001 | 7 |
|  | *σpO* | -0.015±0.001 | 0.988 | 0.001 | 163.39 | 2.190±0.001 | 6 |
|  | *σp+* | -0.007±0.001 | 0.916 | 0.002 | 25.94 | 2.187±0.001 | 7 |
|  | *σp+/ σp* | -0.008±0.002 | 0.887 | 0.002 | 18.40 | 2.188±0.001 | 7 |
|  | *σp+/ σp-* | -0.006±0.001 | 0.938 | 0.002 | 36.47 | 2.188±0.001 | 7 |
|  | *σp+/ σp/ σp-* | -0.006±0.001 | 0.917 | 0.002 | 26.68 | 2.189±0.001 | 7 |
|  |  |  |  |  |  |  |  |  |
| 3 | C6 | *σp* | 0.025±0.004 | 0.950 | 0.004 | 45.95 | 2.073±0.001 | 7 |
|  | *σpO* | 0.021±0.005 | 0.900 | 0.004 | 17.16 | 2.073±0.002 | 6 |
|  | *σp+* | 0.018±0.001 | 0.995 | 0.001 | 508.52 | 2.077±0.001 | 7 |
|  | *σp+/ σp* | 0.019±0.003 | 0.917 | 0.005 | 26.46 | 2.075±0.002 | 7 |
|  | *σp+/ σp-* | 0.014±0.002 | 0.970 | 0.003 | 80.18 | 2.075±0.001 | 7 |
|  | *σp+/ σp/ σp-* | 0.015±0.003 | 0.902 | 0.005 | 21.75 | 2.075±0.002 | 7 |
|  |  |  |  |  |  |  |  |  |
| 4 | C7 | *σp* | -0.004±0.002 | 0.722 | 0.001 | 5.43 | 2.211±0.001 | 7 |
|  | *σpO* | -0.004±0.002 | 0.620 | 0.002 | 2.51 | 2.211±0.001 | 6 |
|  | *σp+* | -0.003±0.001 | 0.820 | 0.001 | 10.24 | 2.210±0.001 | 7 |
|  | *σp+/ σp* | -0.004±0.001 | 0.917 | 0.001 | 26.41 | 2.210±0.001 | 7 |
|  | *σp+/ σp-* | -0.002±0.001 | 0.775 | 0.001 | 7.51 | 2.210±0.001 | 7 |
|  | *σp+/ σp/ σp-* | -0.003±0.001 | 0.836 | 0.001 | 11.63 | 2.210±0.001 | 7 |
|  |  |  |  |  |  |  |  |  |
| 5 | C11 | *σp* | -0.003±0.001 | 0.979 | 0.0003 | 116.72 | 2.24±0.001 | 7 |
|  | *σpO* | -0.003±0.001 | 0.945 | 0.0004 | 33.30 | 2.215±0.001 | 6 |
|  | *σp+* | -0.002±0.001 | 0.996 | 0.0001 | 640.41 | 2.214±0.001 | 7 |
|  | *σp+/ σp* | -0.002±0.001 | 0.935 | 0.0005 | 34.80 | 2.214±0.001 | 7 |
|  | *σp+/ σp-* | -0.002±0.001 | 0.983 | 0.0003 | 145.26 | 2.214±.0001 | 7 |
|  | *σp+/ σp/ σp-* | -0.002±0.001 | 0.930 | 0.0005 | 32.23 | 2.215±0.001 | 7 |
|  |  |  |  |  |  |  |  |  |
| 6 | C22’ | *σo* | 0.044±0.024 | 0.632 | 0.020 | 3.33 | 2.094±0.008 | 7 |
|  | *σo\** | 0.038±0.020 | 0.691 | 0.020 | 3.66 | 2.095±0.009 | 6 |
|  | *Es* | -0.042±0.013 | 0.825 | 0.016 | 10.69 | 2.103±0.006 | 7 |

“n=6 means calculated without -OH group”

**Table 5: DSP analysis of chemical shift data with dual parameter equation (3 )**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No** | **Carbons** | **Scale** | ***ρI*** | ***ρR*** | **R** | **SE** | **F** | **log δo** | **n** | **λ=*ρR*/*ρI*** |
|
| 1 | C4 | *σI ,σR* | 0.024±0.003 | 0.051±0.003 | 0.995 | 0.002 | 154.44 | 2.122±0.001 | 6 | 0.25 |
|  |  | *σI ,σRo* | 0.032±0.017 | 0.036±0.017 | 0.849 | 0.01 | 3.89 | 2.118±0.007 | 6 | 1.33 |
|  |  | *σI ,σR+* | 0.010±0.030 | 0.018±0.016 | 0.640 | 0.016 | 1.39 | 2.122±0.015 | 7 | 1.80 |
|  |  | *σI ,σR-* | 0.019±0.011 | 0.037±0.009 | 0.943 | 0.007 | 12.10 | 2.120±0.005 | 6 | 2.00 |
|  |  | *F,R* | 0.025±0.003 | 0.054±0.002 | 0.996 | 0.002 | 279.61 | 2.123±0.001 | 7 | 2.00 |
|  |  |  |  |  |  |  |  |  |  |  |
| 2 | C5 | *σI ,σR* | -0.013±0.001 | -0.007±0.001 | 0.998 | 0.0003 | 349.25 | 2.191±0.001 | 6 | 0.70 |
|  |  | *σI ,σRo* | -0.014±0.003 | -0.005±0.002 | 0.956 | 0.002 | 16.09 | 2.191±0.001 | 6 | 0.36 |
|  |  | *σI ,σR+* | -0.011±0.006 | -0.002±0.001 | 0.838 | 0.003 | 4.74 | 2.191±0.003 | 7 | 0.20 |
|  |  | *σI ,σR-* | -0.012±0.002 | -0.005±0.001 | 0.980 | 0.001 | 36.20 | 2.191±0.001 | 6 | 0.42 |
|  |  | *F,R* | -0.014±0.001 | -0.009±0.001 | 0.993 | 0.001 | 146.55 | 2.191±0.001 | 7 | 0.71 |
|  |  |  |  |  |  |  |  |  |  |  |
| 3 | C6 | *σI ,σR* | 0.016±0.002 | 0.026±0.002 | 0.996 | 0.001 | 176.46 | 2.077±0.001 | 6 | 1.63 |
|  |  | *σI ,σRo* | 0.019±0.010 | 0.016±0.010 | 0.810 | 0.006 | 2.86 | 2.074±0.004 | 6 | 0.80 |
|  |  | *σI ,σR+* | 0.008±0.019 | 0.010±0.009 | 0.636 | 0.01 | 1.36 | 2.076±0.009 | 7 | 1.25 |
|  |  | *σI ,σR-* | 0.014±0.008 | 0.017±0.007 | 0.885 | 0.005 | 5.43 | 2.075±0.003 | 6 | 1.21 |
|  |  | *F,R* | 0.015±0.003 | 0.032±0.002 | 0.990 | 0.002 | 105.40 | 2.078±0.001 | 7 | 2.13 |
|  |  |  |  |  |  |  |  |  |  |  |
| 4 | C7 | *σI ,σR* | -0.001±0.001 | -0.008±0.002 | 0.928 | 0.001 | 9.34 | 2.209±0.001 | 6 | 2.00 |
|  |  | *σI ,σRo* | -0.002±0.003 | -0.004±0.003 | 0.550 | 0.002 | 0.649 | 2.210±0.002 | 6 | 2.00 |
|  |  | *σI ,σR+* | 0.001±0.002 | -0.003±0.002 | 0.669 | 0.002 | 1.618 | 2.208±0.002 | 7 | 0.21 |
|  |  | *σI ,σR-* | -0.001±0.001 | -0.004±0.003 | 0.648 | 0.002 | 1.087 | 2.210±0.001 | 6 | 4.00 |
|  |  | *F,R* | -0.001±0.002 | -0.005±0.002 | 0.806 | 0.001 | 3.719 | 2.209±0.001 | 7 | 5.00 |
|  |  |  |  |  |  |  |  |  |  |  |
| 5 | C11 | *σI ,σR* | -0.003±0.001 | -0.003±0.001 | 0.998 | 0.0001 | 341.86 | 2.214±0.001 | 6 | 1.50 |
|  |  | *σI ,σRo* | -0.003±0.001 | -0.002±0.001 | 0.859 | 0.0007 | 4.22 | 2.214±0.001 | 6 | 0.66 |
|  |  | *F,R* | -0.002±0.001 | -0.004±0.001 | 0.993 | 0.002 | 152.18 | 2.214±0.001 | 7 | 2.00 |
|  |  |  |  |  |  |  |  |  |  |  |
| 6 | C22’ | *σI ,σR* | 0.010±0.022 | 0.079±0.020 | 0.891 | 0.01 | 5.81 | 2.115±0.010 | 6 | 8.00 |
|  |  | *σI ,σRo* | 0.020±0.001 | 0.031±0.042 | 0.438 | 0.03 | 0.35 | 2.104±0.018 | 6 | 1.50 |
|  |  | *F,R* | 0.006±0.019 | 0.081±0.024 | 0.903 | 0.01 | 8.85 | 2.117±0.010 | 7 | 1.33 |

“n=6 means calculated without -OH group”

**Table (6): Results of multiple regression analysis of 13C chemical shifts with σp,( σp+- σp)  and σpo, (σp+- σpo) constants using Yukava – Tsuno equation (3).**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Carbon** | **scale** | **ρ** | **r** | **R** | **SE** | **F** | **n** |
| 1. | C4 | *σp,( σp+- σp)* | 0.028±0.006 | 0.032±0.009 | 0.986 | 0.003 | 72.76 | 7 |
|  |  | *σpo,( σp+- σpo)* | 0.027±0.009 | 0.020±0.009 | 0.954 | 0.006 | 15.15 | 6 |
|  |  |  |  |  |  |  |  |  |
| 2. | C5 | *σp,( σp+- σp)* | -0.013±0.001 | 0.004±0.002 | 0.994 | 0.001 | 167.30 | 7 |
|  |  | *σpo,( σp+- σpo)* | -0.012±0.001 | -0.001±0.001 | 0.988 | 0.001 | 61.27 | 6 |
|  |  |  |  |  |  |  |  |  |
| 3. | C6 | *σp,( σp+- σp)* | 0.016±0.002 | 0.021±0.003 | 0.996 | 0.001 | 274.61 | 7 |
|  |  | *σpo,( σp+- σpo)* | 0.014±0.002 | 0.012±0.003 | 0.989 | 0.002 | 65.94 | 6 |
|  |  |  |  |  |  |  |  |  |
| 4. | C7 | *σp,( σp+- σp)* | -0.007±0.002 | -0.006±0.003 | 0.866 | 0.001 | 6.01 | 7 |
|  |  | *σpo,( σp+- σpo)* | -0.001±0.001 | -0.005±0.001 | 0.937 | 0.001 | 10.76 | 6 |
|  |  |  |  |  |  |  |  |  |
| 5. | C11 | *σp,( σp+- σp)* | -0.003±0.001 | -0.002±0.001 | 0.998 | 0.001 | 518.04 | 7 |
|  |  | *σpo,( σp+- σpo)* | -0.002±0.001 | -0.001±0.001 | 0.994 | 0.001 | 133.10 | 6 |

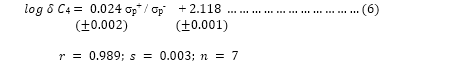
“n=6 means calculated without -OH group”

**Substituent effects on the 13C NMR chemical shifts of the substituted 5-benzylidenebarbituric acids**

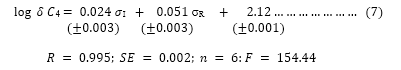
The use of 13C NMR SCS is to monitor the transmission of electronic effects in the molecular frame works in general and to understand the mode of transmission of long-range substituent effects in extended π-electron systems, in particular, are topics of current interest. Thus long-range 13C SCS have been reported for N-benzylideneanilines15, N-benzylidenebensylamines16,chalcones17, benzophenones18, phenylacetylenes19,β-nitrostyrenes20,21, cinnamic acids22,23, cinnamates24, benzonitrile25, cyanopyridine26, (E)-1-benzylidene-2-(diphenyl methylene) hydrazines27, aryl hydrazides28,(E)-1-benzylidene-2-(4-bromophenyl) hydrazines29, N-(substituted phenyl)-2-cyano acetamides30, 4-bromo-1-naphthyl chalcones31and symmetrical diimines32. The 13C chemical shift data of several carbon atoms of substituted 5-benzylidenebarbituric acids has been correlated with SSP equation (Eq.1.), DSP equations (Eq.2.) and Yukawa-Tsuno equation (Eq.3.).

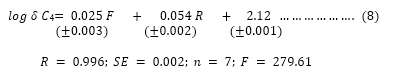
**C4 - Carbon atom**

The Chemical shift of C4 carbon appeared over a relatively narrow range of 16.24 ppm. The result of SSP analysis shown in the table (4), an excellent correlation affords by σp+ / σp- constant given in equation (6), and the plot of log δ C4 vs σp+ / σp- as shown in Fig. (4).



The result of DSP analysis in the table (5), afford an excellent correlation are shown in equations (7 ) and (8)





.

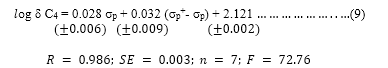
The sign of *ρ*I and *ρ*R are positive reveals that the normal substituent effect operates on C4 carbon atom, i.e., an electron withdrawing substituent decrease the C4 carbon atom shielding and an electron releasing substituent increase it. Examination of chemical shift of data in table (2), electron-withdrawing substituent causes downfield shift



log

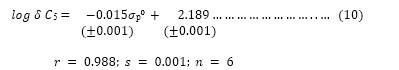
**Fig. 4. The plot of log δ C4 vs σp+ / σp-**

and electron releasing substituent causes up field. The magnitude of *ρR*is greater than *ρI* indicate that the predominance of resonance effect over inductive effect in the chemical shift of C4 carbon atom.This result is also shown from Yukawa-Tsuno equation (3) is given in table (6). The result of best fit eq. (3) is given in equation (9)



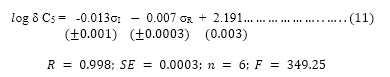
**C5 - Carbon atom**

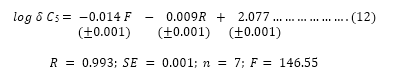
The chemical shift of C5 carbon appeared over a relatively narrow range of 4.42 ppm. The SSP analysis with various σ parameters, σpo gave satisfactory correlation, results shown in the table (4). It gave negative correlation (Eq.10) and negative slope indicates that a reverse substituent effect operates on the carbonyl carbon. The Hammett plot of log δ C5 vs *σpo* gives,



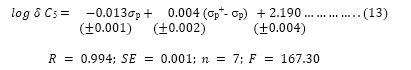
Examination of chemical shift data (table 2) of C5 carbon, electron releasing group cause downfield shift by increasing the shielding and electron withdrawing group cause upfield shift by decreasing the shielding.

The DSP analysis of C5 carbon with various σR scale is given in table (8),the best fit is given in equations (11) and (12).



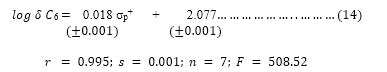


The sign of slopes *ρI* and *ρR* are negative, reveals that the reverse substituent effect operates on C5 carbon atom. The results of Yukawa-Tsuno equation (13), also indicate that the magnitude of ‘r’ is very low (< 1).

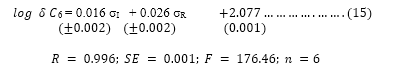


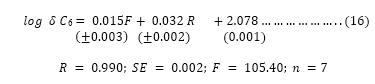
**C6 – Carbon atom**

The chemical shift of C6 carbon atom appeared over a relatively narrow range of 7.15 ppm. The results of SSP analysis shown in table (4), excellent correlation afford by σp+ constant given in equation (14).



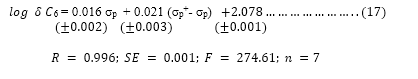
The results of DSP analysis in table (5), afford an excellent correlation are shown in equations (15) and (16).





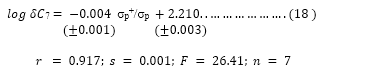
The sign of *ρI* and *ρR* are positive reveals that the normal substituent effect operates on C6 carbon atom, i.e., an electron withdrawing substituent decrease the C7 carbon atom shielding and an electron releasing substituent increase it. Examination of chemical shift data in table (2), electron withdrawing substituent causes downfield shift and electron releasing substituent causes upfield. The magnitude of *ρR* greater than *ρI* indicate that the predominance of resonance effect over inductive effect in the chemical shift of C6 carbon atom.

The results of Yukawa-Tsuno equation (17), also indicate that the magnitude of ‘r’ is very low (<1).

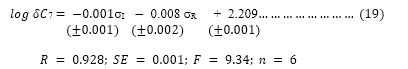


**C7 – Carbon atom**

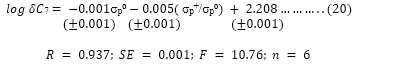
The chemical shift of C7 carbon atom appeared over a range of about 2.3 ppm. The result of SSP analysis shown in table (4), fairly well correlation afford by σ*p+/σp* constant is given in equation (18), and the plot of log δC7 vs σp+/σp is shown in Fig. (31). The result is shown in equation (18).



The examination of chemical shift data (table 2) of C7 carbon electron-releasing group causes downfield shift by increasing the shielding and electron withdrawing group cause up field shift by decreasing the shielding. The DSP analysis of C7 carbon with various *σR* scale is shown in table (5), the best fit is given in Eq. (19).

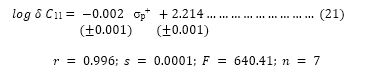


The result of Yukawa-Tsuno equation (3), is given in table (6). The result of best fit of Eq. (3) is given in Eq. (20).

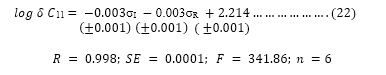


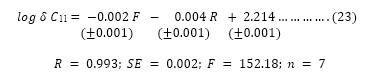
**C11 – Carbon atom**

The chemical shift of C11 carbon appeared over a relatively narrow range of 1.46 ppm. The SSP analysis with various σ parameters, *σp+* gave excellent correlation, results shown in table (4). It gave negative correlation (Eq. 21) and negative slope indicates that a reverse substituent effect operates on the C11 carbon.

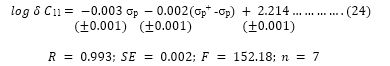


Examination of chemical shift data in table (2) shows that the electron-releasing substituent causes downfield shift while electron-withdrawing substituent causes upfield shift. The DSP analysis of C11 carbon with various *σR* scale is given in table (5), the best fit is given in equations (22) and (23).



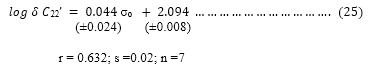


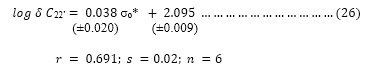
The result of Yukawa-Tsuno equation (3), is given in table (6) also indicate that the magnitude of ‘r’ is very low (<1).



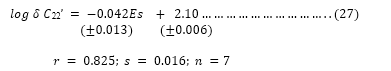
**C22’-Carbon atoms**

The chemical shift of C22’carbon atom appeared over a relatively narrow range of about 2.116 ppm. In the SSP analysis of C22 ’*σo,* and *σo*\* gave poor correlation coefficients (r) 0.632 and 0.691 respectively. The results of SSP analysis are given in Eqs. (25) and (26).

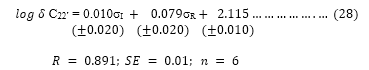


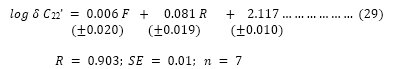


But the same parameter for *Es,* gave satisfactory correlation, given in Eq. (27).



The best fit of DSP analysis is given in Eqs. (28) and (29).





The sign of slopes *ρI* and *ρR* are positive reveals that the normal substituent effects operate on C22’ carbon atom. The magnitude of *ρR* is higher than the magnitude of *ρI* indicate that the resonance effect is predominant over resonance effect on C22’ carbon atom.

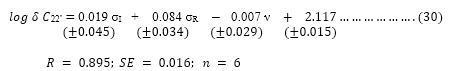
The TSP analysis of Charton steric parameter (ν) gave poor correlations that are given in table (7).

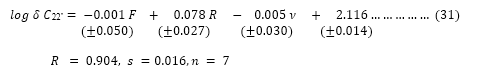
**Table (7): TSP analysis of SCS data of C22’ carbon atom of substituted 5-benzylidenebarbituric acids employing equation (4).**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |
| S.No. | Scale | α | β | φ | R | s | F | PR | PS | n |
|  |  |  |  |  |  |  |  |  |  |  |
| 1. | *σI ,σR,ν* | 0.019  (±0.045) | 0.084  (±0.034) | -0.007  (±0.029) | 0.895 | 0.016 | 2.68 | 76.4 | 6.4 | 6 |
|  |  |  |  |  |  |  |  |  |  |  |
| 2. | *σI ,σRo,ν* | -0.008  (±0.092) | 0.019  (±0.060) | 0.022  (±0.058) | 0.492 | 0.03 | 0.21 | 39.0 | 43.8 | 6 |
|  |  |  |  |  |  |  |  |  |  |  |
| 3. | *σI ,σR+,ν* | -0.093  (±0.071) | 0.035  (±0.023) | 0.057  (±0.035) | 0.760 | 0.155 | 1.37 | 19.2 | 31.3 | 7 |
|  |  |  |  |  |  |  |  |  |  |  |
| 4. | *σI ,σR-,ν* | 0.006  (±0.085) | 0.039  (±0.058) | 0.001  (±0.063) | 0.595 | 0.03 | 0.36 | 84.7 | 2.17 | 6 |
|  |  |  |  |  |  |  |  |  |  |  |
| 5. | *F, R, ν* | -0.001  (±0.050) | 0.078  (±0.027) | 0.005  (±0.030) | 0.904 | 0.016 | 4.47 | 92.0 | 5.95 | 7 |
|  |  |  |  |  |  |  |  |  |  |  |

“n=6 means calculated without -OH group”

The best fit of TSP analysis is taken from high correlation coefficient (R) and least standard error (SE) of the regression equation and the results are given in Eqs. (30) and (31).





A better description of the composition of the electrical effect33 is given by the equation,

PR =

PR is the percentage of delocalized effect. The result of TSP analysis is given in table (10) shows that the delocalized effect is predominant over the localized effect. The magnitude (%) of the steric factor33 is given by the equation,

PS =

The results of table (7) shows that steric effect is also operating to some extent.

**Conclusions**

A series of seven numbers of substituted 5-benzylidenebarbituric acids have been synthesized by condensation of barbituric acid with substituted benzaldehydes. These synthesized substituted 5-benzylidenebarbituric acids have been characterized by the1H and13C spectral data. The 13C NMR spectral data of these substituted 5-benzylidenebarbituric acids have been correlated with Hammett substituent constants and F and R parameters. From the results of statistical analysis, the effects of the substituent on the spectral data have been studied. The 13C NMR spectral correlations produced the most number of satisfactory correlations.

**Acknowledgements**

One of the authors (P.Mohandass) is grateful to the University Grants Commission (UGC), Hyderabad for the award of Faculty Development Programme. Authors are also thankful to the Principal and Managing Board of Saraswathi Narayanan College, Madurai for providing research facilities.

**Conflict of interest statement**

We declare that we have no conflict of interest.

**References**

1. Craik DJ.and. Brownlee RTC. Substituent effects on chemical shifts in the side chains of aromatic systems, Progress in Physical Organic Chemistry . John Wiley &sons Inc., New York, 1983; pp 1-74.

2.Slater CD, Robinson CN, Bies R, BryanDW, Chang K, Hill AW,Moore WH.Jr.Otey TG, Popperireiter ML, Reisser JR, Stablein GE, WaddyVP, III Wilkinson WO, Wray WA. A comparison of single- and dual- parameter equations in the correlation of carbon-13 shifts in substituted styrene. Journal of Organic Chemistry.1985; 50(21): 4125-4130.

3. Suezawa H, Yuzuri T, Hirota M, Ito Y. Hanada.Substituent effects on the 1H and 13C and 15N NMR spectra of substituted benzanilides.Bulletin of the Chemical Society of Japan.1990; 60(2):328-334.

4. Yuzuri T, Suezawa H, Hirota M.Further investigations on polar substituent effects on the NMR chemical shifts of N-Acylanilines and related compounds. Correlation analytical approach and solvent effects. Bulletin of the Chemical Society of Japan.1994; 67(6):1664-1673.

5. Radhakrishnan K, Mohandass P, Sankaralingam S, Chandramohan S. Synthesis and antimicrobial activity of 2-benzylidene-1,3-indandiones: A structure reactivity study. Der Chemica Sinica*,*2016**; 7**(4): 1-7.

6. Radhakrishnan K, Mohandass P, Sankaralingam S, Chandramohan S. Synthesis and antibacterial activity of 5-benzylidenebarbituric acids: A structure -reactivity study. International Journal of Chemtech Research*.* 2017;10(7):1019-1027.

7. Branko S. Jursic A simple method for knoevenagal condensation of α,β-conjugated and aromatic aldehydes with barbituric acid. Journal of Heterocyclic Chemistry. 2001; 38(3): 655-657.

8. Gronowitz S, Johnso A. Maholanyinov,S .Tomo and Sokaniova.Org.Magn.Reson*.*1975**;7**:732.

9. Dana G. Convert JP. Girault and Mathoz E. Effect of nuclear magnetic resonance of 13C. Study of derivatives of 2-phenanthyl furan and 2- phenylpyrrole. Canadian Journal ofChemistry.1976; 54(11):1827-1836.

10. Ray GJ, Kurland RJ, Colter AK. Magnetic resonance studies of triphenyl carbonium ions -II; Carbon-13 magnetic resonance studies of charge delocalization in *para*-substituted triphenyl carbonium ions.Tetrahedron.1971; 27(4):735-752.

11. Hinton JF, Layton B. Natural abundance of 13C NMR investigation of substituted bromobenzene using noise decoupling of proton resonances. Organic Magnetic Resonance.1972; 4: 353-360.

12. Craik DJ. Annual Reports on NMR spectroscopy. Edited by Webb GA. Academic Press. London. 1983; 15:1.

13. Lynch BM. Proportionality relationships in the carbon-13 nuclear magnetic resonance spectra of *para-*disubstituted benzenes; a new interpretation of non-additive behavior. Canadian Journal of Chemistry.1977; 55:541-547.

14. Perumal S, Chandrasekaran R, Vijayabaskar V, David A. Wilson.1H and 13C NMR study of substituted effects in 2- and 3- substituted diphenyl sulphides and sulphones and 4-substituted 2’6’-Dimethyldiphenyl sulphides. Magnetic Resonance in Chemistry. 1995; 33:779-790.

15. Inamoto N, Kushida K, Masuda H, Ohta S, Satoh Y, Tamwa.K, Tokomara K, Tori M Yoshida . Novel substituent effects in 1H and 13C NMR spectra of 4- and 4’-substituted N-benzylideneanilines. Tetrahedron Letters. 1974;15(41):3617-3620.

16. Arrowsmith JE, Cook MJ, Hardstone DJ. Long range substituent-induced chemical shifts in the 13C NMR spectra of N-Benzylidenebenzylamines. Organic Magnetic Resonance.1978;11(3):160-161.

17. Solcaniova E, Toma, Gronowitz. Investigation of substituted effects of chalcones by 13C nmr spectroscopy. Organic Magnetic Resonance.1976;8: 439-443.

18. Shapiro MJ .Carbon-13 NMR substituted effects in *para*-substituted benzophenones.Tetrahedron. 1977; 33(10):1091-1094.

19. Dawson DA. and Reynolds WF.Canadian Journal of Chemistry.1975; 53(3): 373-382.

20. Happer DAR. Australian Journal of Chemistry. 1976; 53: 373.

21. Happer,D.A.R.; McKerrow, S.M. and Wilkinson, A.L Australian Journal of Chemistry.1977; 2:1479.

22. Gunthor H, Prestein J, Watan PJ. Carbon-13 NMR spectra of coumarin and methoxy coumarin-A reinvestigation of charge density/chemical shift relations. Organic Magnetic resonance.1975; 7: 339-344.

23. Modro TA, Renolds WF, Kovupowa ES. Journal of the Chemical Society Perkin Transaction 2. 1977; 11:479-1483.

24. Happer DAR*.* and SteensonBE. The determination of inductive effects by 13C nuclear magnetic resonance spectrometry. Journal of the Chemical Society Perkin Transaction 2.1983;6:843-848.

25. Fadhil GF, Essa AH*.* Substituent effectsin the 13C NMR chemical shifts of para-(*para*-substituted benzylidene amino) benzonitrile and para-(*ortho*- substituted benzylidene amino)benzonitrile. Journal of the Iranian Chemical Society. 2009; 6(4): 808-811.

26. Arulkumaran R, ManikandanV, Thirunarayanan G. Synthesis and Hammett spectral correlation studies of some substituted cyanopyridine compounds. World scientific news. 2017; 80: 239-255.

27. Arulkumaran R, Manikandan V, Christhuraj P, Thirunarayanan G. Synthesis and spectral correlation studies of some substituted (E)-1- benzylidene-2-(diphenylmethylene) hydrazines. World scientific news. 2017; 62: 93-110.

28. Thirunarayanan G. Sekar KG. and Lakshmi narayanan R. infrared and 13C NMR spectral studies of some Aryl hydrazides; assessment substituent effects. International Letters of Chemistry, Physics and Astronomy. 2014; 32: 88-94.

29. Rajarajan M, Senbagam R, Vijayakumar V, ManikandanV, Balaji S, Vanangamudi G, Thirukumaran G. Synthesis, spectral studies and antimicrobial aactivities of some substituted (E)-1-benzylidene-2-(4-bromophenyl)-hydrazines. World scientific news.2015; 9:155-171.

30. Marinkovic AD, Brkic D, Jelena MS, Mijin DZ. Milcic M, Petrovic SD.Influence of substituents on IR, 1H- and 13C- NMR spectral data of N-(substituted phenyl)-2-cyanoacetamide-correlation analysis. Chemical Industry and Chemical Engineering Quarterly. 2013;19(1):67-78.

31. Thirunarayanan G, Gopalakrishnan M. and Vanangamudi G. IR and NMR spectral studies of 4-bromo-1-naphthyl chalcones-assessment of substituent effects. Spectra Chimica Acta.Part A. 2007; 67(3-4):1106-1112.

32. Thirunarayanan G. Synthesis, IR and NMR spectral correlations in some symmetrical diimines. Bulletin of Chemical Society of Ethiopia.2014;28(1):73-79.

33. Charton M. Nature of the ortho effect. Reaction rates of carboxylic acids with diazodiphenylmethane. Journal of Organic Chemistry. 1975; 40(4): 407-411.