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Research article

Solvent-free synthesis, spectral correlations and antimicrobial activities of some 3,4-dimethoxy chalcones

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ABSTRACT

Background: The aim of this study was to synthesise some substituted styryl 3,4-dimethoxy phenyl ketones using solvent-free $SiO_2-H_2SO_4$ catalyzed aldol condensation between 3,4-dimethoxy acetophenone and substituted benzaldehydes under microwave irradiation. Then to characterize them by their analytical, physical and spectroscopic data, and also to study their the spectral correlation and antimicrobial activities.

Methods: Solvent free microwave assisted aldol condensation method was used for synthesising 3,4-dimethoxyphenyl chalcones. They were characterised by ultraviolet (UV), infrared (IR), nuclear magnetic resonance (NMR) and mass spectroscopic data. The UV, IR, NMR spectral data were correlated with substituent constants, F and R parameters, using Hammett equation, to study the effect of substituents. The Bauer-Kirby method was used for evaluation of antimicrobial activities of the synthesised chalcones.

Results: Yields of synthesised chalcones were more than 85%. The spectral data of these ketones had been correlated, using single and multi-linear regression analysis. These gave a satisfactory degree of correlations with some parameters and a fair degree of correlations with other parameters. Few chalcones gave excellent antimicrobial activities, whereas others gave poor antimicrobial activities.

Conclusion: Easy handling, non-hazardous and environmentally benign aldol condensation method had been adopted for synthesising chalcones with better yields. Some of the Hammett spectral correlations were found to be satisfactory with the observed spectroscopic data. Halo, methoxy, methyl and nitro substituted compounds had shown excellent antimicrobial activities based on their zone of inhibitions.

Keywords: Styryl 3,4-dimethoxyphenyl ketones, SiO_2-H_2SO_4, Crossed-Aldol condensation, Solvent free synthesis, Antimicrobial activities

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INTRODUCTION

Solvent-free[1,2] green synthetic methods have been applied for stereospecific, stereoselective and regioselective synthesis of organic compounds. These solvent free reactions involving the formation of carbon-carbon bond and carbon-heteroatom bond are important and interesting in green synthesis. Hence, the Aldol,[3] Crossed – aldol,[4] Knoevenagel,[5] Mannich,[6] Michae,[7] and Wittig[8] reactions had been applied for synthesizing isomeric biologically active compounds such as chalcones, alkenes and acyl compounds. Thermal condensation reactions had been found to be sluggish and time-consuming with poor yields. However in the microwave conditions, the reaction is faster, giving appreciable yield with an easier process of product isolation. Scientists and Chemists have used the microwave irradiation technique for solid phase green synthesis.[8,9] Numerous green catalysts such as fly-ash:sulphuric acid, silica-sulphuric acid[10,11] anhydrous zinc chloride,[12] grinding with sodium hydroxide,[13] aqueous alkali at lower temperatures,[14] solid sulphonic acid from bamboo,[15] barium hydroxide,[16] anhydrous sodium bicarbonate,[17] microwave irradiation,[18] fly-ash:water,[19] triphenylphosphite,[20] alkali earth metals,[21] KF/Al_2O_3,[22] sulfated titania[23] and silicotungstic acid[24] have been reported for the synthesis of a number of chalcones and their derivatives.

Spectral data is useful for the prediction of ground state equilibration of organic molecules, such as *s-cis* and *s-trans* isomers of alkenes, alkynes, benzoyl chlorides, styrenes and α, β-unsaturated ketones.[25,26] The quantitative structure-activity relationship (QSAR) and quantitative structure-property relationship (QSPR) were used for evaluating the structure, quantitative analysis and qualitative analysis of molecules.[27–29] Their use in structure parameter correlations becomes popular for studying biological activities,[30] normal co-ordinate analysis[31] and transition states of reaction mechanisms.[32] Infrared (IR) spectroscopy is a powerful tool and a very good technique for the qualitative and quantitative study of natural and synthetic molecules.[27] IR spectroscopy can provide information about the nature, concentration and structure of samples at the molecular level.[33] A great deal of work has been devoted to the reactivity of α,β-carbonyl compounds particularly, the theoretical study of substituent effects has been studied on long range interactions in the β-sheet structure[34] of oligopeptides and enone-dienol tautomerism.[35] Literature evidences QSAR studies of substituted benzo α-phenazines,[36] cancer agents, Diels-Alder reactions,[37] density functional theory,[38] gas phase reactivity of alkyl allyl sulphides[39] and rotational barriers in selenomides.[40] Santelli et.al[41] studied the quantitative structural relationships in α, β-unsaturated carbonyl compounds between the half wave reduction potential, the frontier orbital energy and the Hammett σ_p values. Dhami and Stothers[42] extensively studied the ^1H NMR spectra of a large number of acetophenones and styrenes with a view to establish the validity of the additivity of substituent effect in aromatic shielding first observed by Lauterber.[43] Savin and co-workers[44] studied the NMR data of unsaturated ketones, of the type RC_6H_4-CH = CH-$COCH_3$, and sought Hammett correlations for the ethylenic protons. Solcaniova[45] and co-workers measured ^1H and ^{13}C NMR spectra of substituted styrenes, styryl phenyls and obtained good Hammett correlations for the olefinic protons and carbons. At present, scientists[2,3,5,9,12,27] have shown more interest in correlating the spectral data with Hammett substituent constants to explain the substituent effects of organic compounds. Recently Thirunarayanan et.al.,[2,3,5,9,12,46–48] investigated the single and multi-regression analysis of substituent effects on alpha and beta hydrogens and carbons of some pyrrolyl, naphthyl and furyl chalcones.

Chalcones possess various multipronged properties, such as antimicrobial,[49] antidepressants,[50] antiplosmodial,[26] anti-aids,[51] insect antifeedant,[28] antibacterial, antifungal,[49] antiviral,[52] anticancerous,[53] antimalarial,[54] antituberculosis[55], antioxidant[56] and nematocidal[57] properties. These properties, present in different chalcones, are examined against respective microbes, bacteria's and fungi.

There is no information in the literature for the synthesis of 3,4-dimethoxyphenyl chalcones using green acidic catalyst $SiO_2 – H_2SO_4$ in Crossed-Aldol condensation reaction. Also there is no information in the literature regarding the correlation study of IR and NMR spectroscopic data with Hammett equation and antimicrobial properties.

Therefore the authors have synthesized some substituted styryl 3,4-dimethoxyphenyl ketones by condensation of 3,4-dimethoxy acetophenone with various substituted benzaldehydes, to study the quantitative structure property relationship from various spectral data and any antimicrobial properties.

EXPERIMENTAL

General

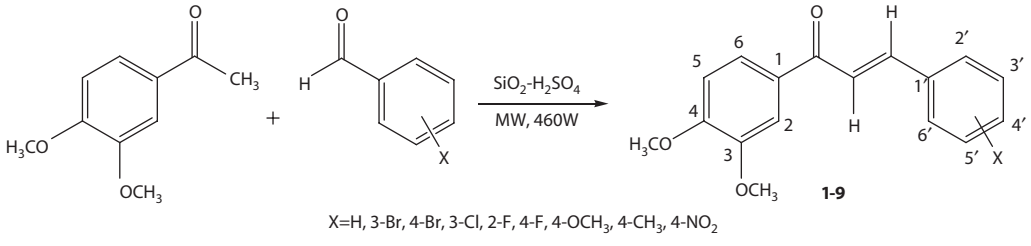
All chemicals used were purchased from Sigma-Aldrich and E-Merck and Himedia brands. Melting points of all chalcones were determined in open glass capillaries on SUNTEX melting point apparatus and are uncorrected. The reaction was carried out in LG395WA, Model LG Grill Intellowave Microwave oven, 230 V A/C, 16–800 W, 2450 MHz, at 460 W. The UV spectra of all synthesized chalcones was recorded with an ELICO-BL222 SPECTROMETER (λ_{max} nm) in spectral grade methanol. Infrared spectra (KBr, 4000–400 cm^{-1}) were recorded on AVATAR-300 Fourier transform spectrophotometer. Bruker AV400 NMR spectrometer operating at 400 MHz was used for recording ^1H NMR spectra and 100 MHz for ^{13}C spectra in $CDCl_3$ solvent using TMS as internal standard. Mass spectra were recorded on a SIMADZU GC-MS2010 Spectrometer using Electron Impact (EI) techniques.

Preparation of $SiO_2-H_2SO_4$ catalyst

The Silica:H_2SO_4 catalyst had been prepared by the procedure published in literature.[61] In a 50 mL Borosil beaker, 1 g of Silica and 0.8 mL (0.5 mol) of sulphuric acid had been taken and mixed thoroughly with a glass rod. The mixture was heated in a hot air oven at 85°C for 1 h, cooled to room temperature, stored in a borosil bottle and tightly capped.

General procedure for synthesis of substituted styryl3,4-dimethoxyphenylketones

An appropriate mixture of 3,4-dimethoxyacetophenone (2 mmol), substituted benzaldehydes (2 mmol) and $SiO_2-H_2SO_4$(0.5 g) were taken in 50 mL borosil glass tubes. The reaction mixture was subjected to microwave irradiation for 8–10 min at 640watts, 140°C and atmospheric pressure in a microwave oven (Scheme 1) (LG LG395WA, model LG Grill, Intellowave, Microwave Oven, 230 V/AC, with 2450 MHz frequency, 160–800 W). Depending on the nature of the substituents present in the aldehydes, we assign various time intervals, 8.5 m, 9 m, 10 m for F, Br and NO_2 substituents, respectively. The completion of the reaction was monitored by thin layer chromatography. After completion, the reaction mixture was cooled to room temperature. After adding 10 mL of dichloromethane, the organic layer was separated which after evaporation yielded the solid product. The solid product was recrystallized with benzene-hexane mixture giving a glittering pale yellow solid. The spectroscopic data of selective compounds are summarized below. The real interest in adopting this method is to achieve lesser reaction timing, high yields and solvent-free technique. The other methods like conventional heating methods[3,62,63] with alkali gave lesser yield consuming more reaction time. Hence we adopt this method as a preferential one.



Scheme 1. Synthesis of substituted styryl 3,4-dimethoxyphenyl ketones using $SiO_2-H_2SO_4$ catalyzed aldol condensation between aryl ketones and benzaldehydes.

(E)-1-(3,4-dimethoxyphenyl)-3-phenylprop-2-en-1-one (1)

UV (λ_{max}nm) = 319.8; IR (KBr, cm^{-1}): ν = 1649 ($CO_{s\text{-}cis}$), 1604 ($CO_{s\text{-}trans}$), 1161 (CH_{ip}), 756(CH_{op}), 1020 (CH = CH_{op}), 561(C = C_{op}).^{1}H-NMR (400 MHz, $CDCl_3$, δ/ppm): = 7.57(1Hα, *d*, *J* = 15.6 Hz), 7.82(1Hβ, *d*, *J* = 15.6 Hz),7.42–7.71(8H, *m*, Ar-H).^{13}C-NMR (100 MHz, $CDCl_3$, δ/ppm): = 121.69 (C_α), 144.03 (C_β),188.66(CO), 131.33 (C_1), 110.79 (C_2) 144.03(C_3) 153.30 (C_4), 121.69 (C_5), 123.07 (C_6), 135.09 (C_1'), 128.41 (C_2',C_6'), 128.97 (C_3',C_5'), 128.97 (C_4').

(E)-3-(3-bromophenyl)-1-(3,4-dimethoxyphenyl)prop-2-en-1-one (2)

UV (λ_{max}nm) = 300.2, IR (KBr, cm^{-1}): ν = 1653 ($CO_{s\text{-}cis}$), 1596 ($CO_{s\text{-}trans}$), 1145 (CH_{ip}), 787(CH_{op}), 1020 (CH = CH_{op}), 561(C = C_{op}). ^{1}H NMR (400 $CDCl_3$, δ/ppm): = 7.59 (1Hα, *d*, *J* = 24.4 Hz), 7.77(1Hβ, *d*, *J* = 24.4 Hz),7.27–7.43(8H,*m*,Ar-H).^{13}C NMR (100 $CDCl_3$,δ/ppm): = 122.89 (C_α), 142.17 (C_β), 188.16(CO),

131.05 (C_1), 110.74 (C_2), 149.36(C_3), 153.51 (C_4), 110.74 (C_5), 123.21 (C_6), 133.09 (C_1'), 130.48 (C_2'), 123.21 (C_3'), 130.73 (C_4'), 131.67(C_5'),123.09 (C_6').

(E)-3-(4-bromophenyl)-1-(3,4-dimethoxyphenyl)prop-2-en-1-one (3)

UV (λ_{max}nm) = 308.5, IR (KBr, cm^{-1}): ν = 1655 ($CO_{s\text{-}cis}$), 1600 ($CO_{s\text{-}trans}$), 1145 (CH_{ip}), 758(CH_{op}), 1019 (CH = CH_{op}), 591(C = C_{op}). ^{1}H NMR (400 $CDCl_3$,δ/ppm): = 7.73 (1Hα, *d*, *J* = 15.6 Hz), 7.74(1Hβ, *d*, *J* = 15.6 Hz), 7.49−7.76(8H, *m*, Ar-H). ^{13}C NMR (100 $CDCl_3$, δ/ppm): = 122.16 (C_α), 142.57 (C_β),196.92(CO), 131.14 (C_1), 110.73 (C_2), 149.05(C_3), 153.39 (C_4), 122.16 (C_5), 123.12 (C_6), 134.01 (C_1'), 129.32, (C_2',C_6'), 129.77 (C_3',C_5'), 123.34 (C_4').

(E)-3-(3-chlorophenyl)-1-(3,4-dimethoxyphenyl)prop-2-en-1-one (4)

UV (λ_{max}nm) = 309.6, IR (KBr, cm^{-1}): ν = 1650 ($CO_{s\text{-}cis}$), 1577 ($CO_{s\text{-}trans}$), 1160 (CH_{ip}), 777(CH_{op}), 1021(CH = CH_{op}), 563(C = C_{op}). ^{1}H NMR ($CDCl_3$, δ/ppm): = 7.55 (1Hα, *d*, *J* = 16.8 Hz), 7.73(1Hβ, *d*, *J* = 16.8 Hz),7.37-7.76(8H, *m*, Ar-H).^{13}C NMR (100 $CDCl_3$, δ/ppm): = 124.85 (C_α), 142.26 (C_β), 188.18(CO), 131.05(C_1), 110.74(C_2), 149.35(C_3), 153.50 (C_4), 122.87 (C_5), 123.20 (C_6), 136.95(C_1'), 126.81(C_2'), 134.95(C_3'), 126.96(C_4'), 130.19(C_5'), 127.81(C_6').

(E)-3-(2-fluorophenyl)-1-(3,4-dimethoxyphenyl)prop-2-en-1-one (5)

UV (λ_{max}nm) = 312.2, IR (KBr, cm^{-1}): ν = 1651 ($CO_{s\text{-}cis}$), 1597 ($CO_{s\text{-}trans}$), 1164 (CH_{ip}), 768(CH_{op}), 1021(CH = CH_{op}), 585(C = C_{op}). ^{1}H NMR (400 $CDCl_3$,δ/ppm): = 7.67 (1Hα,*d*, J = 17.6 Hz), 7.89(1Hβ, *d*, J = 17.6 Hz),7.11−7.38(8H, *m*, Ar-H).^{13}C NMR (100 $CDCl_3$, δ/ppm): = 124.49 (C_α) 149.29 (C_β),188.64 (CO), 131.16 (C_1), 116.19 (C_2), 149.29(C_3), 153.39 (C_4), 116.41(C_5), 123.26(C_6), 123.21(C_1'), 160.47 (C_2'), 123.15 (C_3'), 124.49(C_5'), 129.84 (C_4'), 129.87(C_6').

(E)-3-(4-fluorophenyl)-1-(3,4-dimethoxyphenyl)prop-2-en-1-one (6)

UV (λ_{max}nm) = 310.2,. IR (KBr, cm^{-1}): ν = 1651 ($CO_{s\text{-}cis}$), 1576 ($CO_{s\text{-}trans}$), 1161 (CH_{ip}), 805(CH_{op}), 1017 (CH = CH_{op}), 507(C = C_{op}). ^{1}H NMR (400 $CDCl_3$, δ/ppm): = 7.49(1Hα, *d*, J = 15.6 Hz), 7.78(1Hβ, *d*, J = 15.6 Hz), 7.47−7.69(8H, *m*, Ar-H).^{13}C NMR (100 $CDCl_3$, δ/ppm): = 123.03 (C_α), 142.7 (C_β), 188.4(CO), 131.25(C_1), 116.00(C_2), 149.31(C_3), 153.36 (C_4), 116.22 (C_5), 123.03 (C_6), 130.31(C_1'), 130.23 (C_2', C_6'), 110.78 (C_3',C_5'), 162.72 (C_4').

(E)-3-(3-mmethylphenyl)-1-(3,4-dimethoxyphenyl)prop-2-en-1-one (7)

UV (λ_{max}nm) = 335.2,IR (KBr, cm^{-1}): ν = 1654 ($CO_{s\text{-}cis}$), 1599 ($CO_{s\text{-}trans}$),1149 (CH_{ip}), 805(CH_{op}), 1020 (CH = CH_{op}), 500 (C = C_{op}). ^{1}H NMR (400 $CDCl_3$, δ /ppm): = 7.52 (1Hα, *d*, J = 16.4 Hz), 7.80(1Hβ, *d*, J = 16.4 Hz), 7.22−7.70(8H, *m*, Ar-H),2.40(s, 3H, CH_3).^{13}C NMR (100 $CDCl_3$, δ/ppm): = 122.98 (C_α) 144.13 (C_β),188.77(CO), 24.3(CH_3), 131.48 (C_1), 110.82 (C_2), 149.25(C_3), 153.20 (C_4), 120.70 (C_5), 122.98 (C_6), 132.36 (C_1'), 129.71 (C_2',C_6'), 109.97 (C_3').140.90 (C_4').110.82 (C_5').

(E)-1-(3,4-dimethoxyphenyl)-3-(4-methoxyphenyl)prop-2-en-1-one (8)

UV(λ_{max}nm) = 344.6, IR (KBr, cm^{-1}): ν = 1650 ($CO_{s\text{-}cis}$), 1594 ($CO_{s\text{-}trans}$), 1163 (CH_{ip}), 796(CH_{op}), 1026 (CH = CH_{op}), 555(C = C_{op}). ^{1}H NMR (400 $CDCl_3$,δ/ppm): = 7.45 (1Hα, *d*, J = 15.2 Hz), 7.79(1Hβ, *d*, J = 15.2 Hz), 7.42−7.81(8H, *m*, Ar-H) 3.85(3H, s, -OCH_3). ^{13}C NMR (100 $CDCl_3$, δ/ppm): = 122.86 (C_α) 143.86 (C_β), 188.66(CO), 55.4(− OCH_3), 131.59(C_1), 110.78 (C_2), 149.20(C_3), 153.10 (C_4), 119.34 (C_5), 122.86 (C_6), 130.16 (C_1'), 127.81 (C_2',C_6'), 114.41(C_3',C_5'), 161.55 (C_4').

(E)-1-(3,4-dimethoxyphenyl)-3-(4-Nitrophenyl)prop-2-en-1-one (9)

UV (λ_{max}nm) = 317.6, IR (KBr, cm^{-1}): ν = 1655 ($CO_{s\text{-}cis}$), 1597 ($CO_{s\text{-}trans}$), 1150 (CH_{ip}), 755(CH_{op}), 1018 (CH = CH_{op}), 594(C = C_{op}). ^{1}H NMR (400 $CDCl_3$, δ/ppm): = 7.51 (1Hα, *d*, J = 18.8 Hz), 7.66(1H β, *d*, J = 18.8 Hz), 7.48−7.84(8H, *m*, Ar-H).^{13}C NMR (100 $CDCl_3$, δ/ppm): = 123.37 (C_α) 140.74 (C_β),196.26 (CO), 130.75 (C_1), 110.12 (C_2), 149.51(C_3), 153.83 (C_4), 110.75 (C_5), 123.37 (C_6), 141.32 (C_1'), 128.55 (C_2',C_6'), 124.24 (C_3',C_5'), 147.96 (C_4').

ANTIBACTERIAL ACTIVITIES

Collection of Microorganisms

Microbes used were three gram positive pathogenic strains *Bacillus substilis*, *Micrococcus luteus*, *Staphylococcus aureus* and two gram negative strains *Escherichia coli* and *Pseudomonas aerogenosa*.

Innoculum preparation

The nutrient broth was prepared by weighing 1.3 g of the broth and dissolving it in 100 mL of sterile distilled water. The flask was swirled gently while adding the nutrient broth and the pH of the medium adjusted to 7.0. The Erlenmayer flask was plugged with non-adsorbent cotton and sterilized in an autoclave at 121°C and 15 lbs/inc^2 pressure for 15 min. After cooling inside a laminar flow, a loopful of

fresh bacterial sample was inoculated and incubated in an orbital shaker at 37° C for 24 h. The cultures were diluted 1:50 with sterile saline and 0.5 mL of the innoculum was used for the preparation of the spread plate. The same procedure had been adopted for all test bacterial samples.

Preparation of agar slants

Nutrients agar medium was prepared and sterilized in an autoclave at 121°C and 15 lbs/inc^2 pressure for 15 min. After sterilization the medium was dispensed into the test tubes. The test tubes were kept in the slanting position on a support. After complete solidification of the medium, streaking of the microorganism was done in the slant area using a sterile inoculation loop. The test tubes were incubated at 37°C for 24 h. After good growth the slants were stored at 2°C for further studies.

Preparation of Mueller Hinton agar plates

The Mueller Hinton agar weighing 38 g was dissolved in 1000 mL of sterile distilled water. The pH of the medium was adjusted to 7.0. The flask was plugged with cotton and sterilized at 121°C and 15 lbs/inc^2 pressure for 15 min. The medium was cooled to 45 – 47° C, 15 mL transferred into each sterile Petri-plate and allowed to solidify.

Preparation of test compound

The newly synthesized chalcone compounds, 15 mg of each was dissolved in 1 mL of DMSO solvent. Using 100μml solution, the discs were impregnated and placed on the Mueller Hinton solidified Agar medium to determine the antimicrobial activity of the compounds on each organism.

Antibacterial sensitivity assay

Antibacterial sensitivity assay was performed using Kirby-Bauer[60] disc diffusion technique. In each Petri plate 0.5 mL of the test bacterial sample was spread uniformly over the solidified Mueller Hinton agar using a sterile glass spreader. The discs with 5 mm diameter made up of Whatman No.1 filter paper, impregnated with the solution of the compound were placed on the medium using sterile forceps. The plates were incubated for 24 h at 37°C by keeping the plates upside down to prevent the collection of water droplets over the medium. After 24 h, the plates were visually examined and the diameter values of the zone of inhibition were measured. Triplicate results were recorded by repeating the same procedure.

Preparation of the Potato dextrose agar medium

PDA agar medium was prepared in a conical flask by dissolving 3.9 g of agar in 100 mL distilled water. Sterilized in the autoclave for 15 min at 121°C and 15 lbs/inch^2 pressure. The medium was allowed to solidify for 1 h. The fungal species were inoculated in the medium and kept for 5 – 7 days at room temperature.

Preparation of the fungal innoculum

After cooling 20 to 25 mL of sterile water was mixed with the medium. The water over the medium was swirled and decanted with the fungal species. Tween-80 (1 – 2 ml) was added to this solution for uniform growth.

Antifungal sensitivity assay

The antifungal sensitivity assay was performed using the Kirby-Bauer[60] disc diffusion technique. PDA medium was prepared and sterilized. It was poured (ear bearing heating condition) into Petri-plates already filled with 1 mL of the fungal species. The plate was rotated clockwise and counter clock-wise for uniform spreading of the species. The discs were impregnated with the test solution. The test solution was prepared by dissolving 15 mg of the chalcone in 1 mL of DMSO solvent. The medium was allowed to solidify and kept for 24 h. Then the plates were visually examined and the diameter values of zone of inhibition were measured. Triplicate results were recorded by repeating the same procedure.

RESULTS AND DISCUSSION

We attempted to synthesize aryl chalcone derivatives by crossed-aldol condensation of aryl methyl ketones, containing electron withdrawing as well as electron donating substituents, with various

substituted benzaldehydes in the presence of acidic catalyst $SiO_2-H_2SO_4$ under microwave irradiation. At present the authors have synthesised the 3,4-dimethoxyphenyl chalcone derivatives by the reaction between 2 mmol of 3,4-dimethoxyacetophenone and 2 mmol of substituted benzaldehydes in microwave irradiation with 0.5 g of $SiO_2-H_2SO_4$ catalyst (Scheme 1). During the course of this reaction $SiO_2-H_2SO_4$ catalyses aldol condensation between aryl ketone and aldehydes and elimination of water to give the chalcones. Chalcone yields in this reaction are more than 85%. The catalyst was repeatedly reused for the aldol condensation between 3,4-dimethoxy acetophenone and benzaldehyde. The first two runs gave 87% product. The third, fourth and fifth runs of the reactions produced yields of 86.5%, 86.5% and 86% of chalcones, respectively. It was observed that there is no appreciable loss in the effect of catalytic activity up to the fifth run. The physical constants, yields and mass fragments of the synthesised chalcones are presented in Table 1.

Spectral linearity

The spectral linearity of chalcones was studied by evaluating the substituent effects[2,3,5,9,12,27–29,46–48] with respect to various spectral data. The assigned spectral data of all chalcones such as UV λ_{max} (nm), infrared carbonyl stretches νCO*s-cis* and νCO*s-trans*, the deformation modes of vinyl part $CH_{outofplane,\ in\text{-}plane}$, CH = CH and $>C=C<_{outofplanes}$ (cm^{-1}), NMR chemical shifts δ(ppm) of H_α, H_β, C_α, C_β and CO are correlated with various Hammett substituent constants.

UV-Vis spectral study

The measured absorption maxima (λ_{max} nm) of the chalcones are presented in Table 2. These values are correlated with Hammett substituent constants and F and R parameters using single and multi-linear regression analysis.[11,12,26,31,32] The form of the Hammett equation employed for the correlation involving the absorption maxima, is

$$\lambda = \rho\sigma + \lambda_o \tag{1}$$

where λ_o is the frequency for the parent member of the series.

The results of statistical analysis,[2,3,5,9,12,27–29,46–48] of these measured absorption maxima values with Hammett substituent constants, F and R parameters, show that the Hammett σ constants only give satisfactory correlation, with r = 0.969. The remaining parameters are failing in correlation. This is due to the weak polar, filed, resonance and inductive effects of the substituents for predicting the reactivity on absorption. This is associated with the resonance conjugative structure shown in Figure 1. The multiregression analysis of these frequencies of all ketones with inductive, resonance and Swain – Lupton's[58] constants produce satisfactory correlations, as evidenced in Equations (2 and 3).

$$\lambda max^{(nm)} = 328.59(\pm 8.72) - 35.81(\pm 10.93)\sigma_I - 10.70(\pm 2.96)\sigma_R$$

$$(R = 0.961, n = 9, P > 90\%) \tag{2}$$

$$\lambda max^{(nm)} = 326.27(\pm 8.13) - 34.09(\pm 7.29)F - 20.19(\pm 8.30)R$$

$$(R = 0.963, n = 9, P > 90\%) \tag{3}$$

IR spectral study

The carbonyl stretching frequencies (cm^{-1}) of *s-cis* and *s-trans* isomers are presented in Table 2 and the corresponding conformers are shown in Figure 2. The stretching frequencies for carbonyl absorption are assigned based on the work done by Hays and Timmons[59] for *s-cis* and *s-trans* conformers as 1690 and 1670 cm^{-1}, respectively.

This data has been correlated with Hammett substituent constants and Swain-Lupton constants.[58] In this correlation the structure parameter Hammett equation employed is shown in the following equation:

$$\nu = \rho\sigma + \nu_o \tag{4}$$

where ν is the carbonyl frequencies of substituted system and ν_o is the corresponding quantity of unsubstitued system; σ is a Hammett substituent constant, which in principle is characteristics of the substituent and ρ is a reaction constant which is depend upon the nature of the reaction.

Table 1. Analytical and mass spectral data of chalcones synthesized by $SiO_2 - H_2SO_4$ catalyzed aryl 3,4-dimethoxy ketones and substituted benzaldehydes under microwave irradiation.

Entry	Ketone	Aldehyde	Product	M.W.	Yield (%)	M.p. (°C)	Mass (m/z)
1	3,4-$(OCH_3)_2C_6H_3$	C_6H_5	3,4-$(OCH_3)_2C_6H_3COCH = CHC_6H_5$	268	95	74 −75 (74−75)[58]	268[M^+], 237,175, 162,149,131,121, 103, 77.
2	3,4-$(OCH_3)_2C_6H_3$	3-Br C_6H_4	3,4-$(OCH_3)_2COCH = CHC_6H_4$Br-3	347	96	94 −95	347[M^+], 349[M^{2+}], 267, 208,191,178,167, 154, 137, 77
3	3,4-$(OCH_3)_2C_6H_3$	4-BrC_6H_4	3,4-$(OCH_3)_2COCH = CHC_6H_4$Br-4	347	90	92 −93	347[M^+], 349[M^{2+}], 267, 208,191,178,167, 154, 137,77
4	3,4-$(OCH_3)_2C_6H_3$	3-ClC_6H_4	3,4-$(OCH_3)_2COCH = CHC_6H_4$Cl-3	303	85	62−63	303[M^+], 305[M^{2+}], 267,191,178,165, 137,124,
5	3,4-$(OCH_3)_2C_6H_3$	2-FC_6H_4	3,4-$(OCH_3)_2COCH = CHC_6H_4$F-2	286	90	75−76	286[M^+], 288[M^{2+}], 267,191,178,149,137, 108, 95.
6	3,4-$(OCH_3)_2C_6H_3$	4-FC_6H_4	3,4-$(OCH_3)_2COCH = CHC_6H_4$F-4	286	94	92−93	286[M^+],288[M^{2+}], 267,191,178,149,137, 108, 95.
7	3,4-$(OCH_3)_2C_6H_3$	4-$CH_3C_6H_4$	3,4-$(OCH_3)_2COCH = CHC_6H_4CH_3$-4	282	95	76−77	282[M^+],191,178, 145, 131, 104, 91.
8	3,4-$(OCH_3)_2C_6H_3$	4-$OCH_3C_6H_4$	3,4-$(OCH_3)_2COCH = CHC6H4OCH_3$-4	298	88	68−69	298[M^+],191,178, 161,137,120,107.
9	3,4-$(OCH_3)_2C_6H_3$	4-$NO_2C_6H_4$	3,4-$(OCH_3)_2COCH = CHC_6H_4NO_2$-4	313	90	122−123	313[M^+],267,191, 137,45.

Table 2. The UV and IR spectroscopic data of substituted styryl 3,4-dimethoxyphenyl ketones.

Entry	Subtt.	λ_{max} (nm)	νCO_{cis}	νCO_{trans}	νCH_{ip}	νCH_{op}	$\nu CH = CH_{op}$	$\nu C = C_{op}$
1	H	319.8	1649	1604	1161	756	1020	561
2	3-Br	300.2	1653	1596	1145	787	1020	561
3	4-Br	308.5	1655	1600	1145	758	1019	591
4	3-Cl	309.6	1650	1577	1160	777	1021	563
5	2-F	312.2	1651	1597	1164	768	1021	585
6	4-F	310.2	1651	1576	1161	805	1017	507
7	4-CH_3	335.2	1654	1599	1149	805	1020	500
8	4-OCH_3	344.6	1650	1594	1163	796	1026	555
9	4-NO_2	317.6	1655	1597	1150	755	1018	594

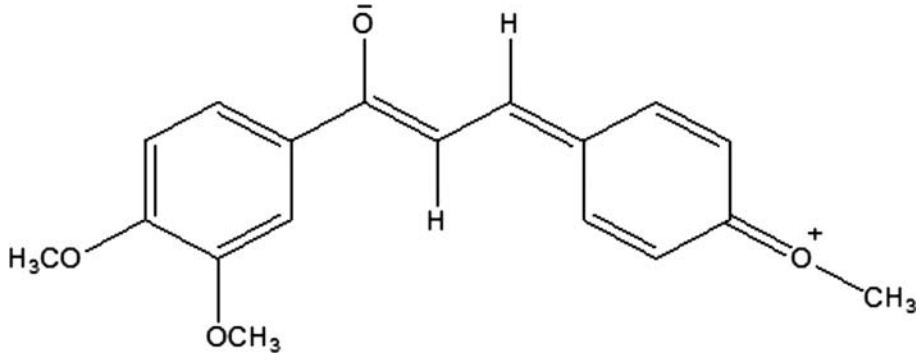


Figure 1. The resonance – conjugative structure.

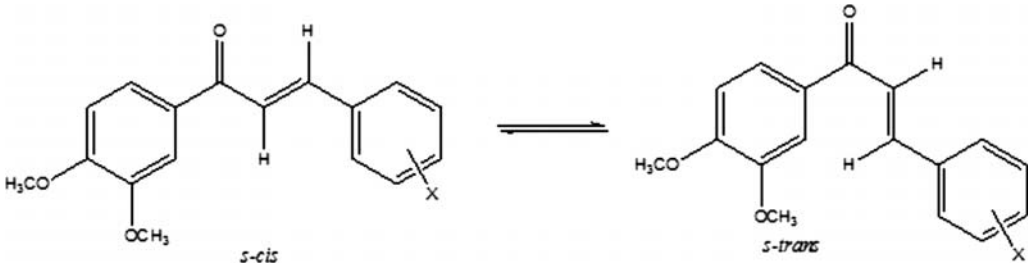


Figure 2. The *s-cis* and *s-trans* conformers of substituted styryl 3,4-dimethoxyphenyl ketones.

The results of single parameter statistical analysis of carbonyl frequencies with Hammett substituent constants, F and R parameters are presented in Table 3. From the Table 3, the Hammett σ_I constant correlates satisfactorily with r = 0.928. Also, a satisfactory correlation is observed for *s-trans* conformers with σ_R (r = 0.944) and R (r = 0.939) parameters. The remaining parameters fail in correlation. The failure in correlation is due the conjugation between the substituent and the carbonyl group in chalcones as shown in Figure 1.

The correlation of CH $_{in\text{-}plane}$ *and* $_{outofplane}$ modes with Hammett σ constants and R parameters give poor correlations. A satisfactory correlation is obtained for CH = CH $_{outofplane}$ with Hammett σ_R constant with (r = 0.933) except for halo and methoxy substituents. A satisfactory correlation is obtained for the $C = C_{outofplane}$ modes with Hammett σ, σ_I constants and F parameters, with r values 0.960, 0.948, 0.932, respectively. The remaining Hammett substituent constants and R parameters give poor correlations due to the conjugation between the substituent and the vinyl group in chalcones, shown in Figure 1.

In view of the inability of some of the σ constants to produce individually satisfactory correlations, it is attempted to seek multiple correlations involving σ_I and σ_R constants and Swain-Lupton's,[58] F and R

Table 3. Results of statistical analysis of infrared $\nu(cm^{-1})$ $CO_{s\text{-}cis}$, $CO_{s\text{-}trans}$, CH_{ip}, CH_{op}, $CH = CH_{op}$ and $C = C_{op}$ substituted styryl 3,4-dimethoxyphenyl ketones with Hammett σ, σ^+, σ_I, σ_R constants and F and R parameters.

Frequency	Constants	r	I	ρ	s	n	Correlated derivatives
$CO_{s\text{-}cis}$	σ	0.743	1651.44	3.18	2.21	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.739	1651.72	1.90	2.25	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.744	1652.95	4.69	2.19	7	3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-NO_2.
	σ_R	0.817	1651.42	1.40	2.41	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3 4-NO_2.
	F	0.738	1652.90	3.34	2.26	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.855	1643.88	−26.12	12.16	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$CO_{s\text{-}trans}$	σ	0.708	1593.81	−2.73	10.59	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.702	1593.26	0.46	10.63	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.843	1599.89	−17.79	9.59	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.944	1597.44	20.32	9.52	7	H, 3-Br, 4-Br, 2-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.745	1600.13	−16.33	9.46	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.939	1597.41	15.03	9.76	7	H, 3-Br, 4-Br, 2-F, 4-OCH_3, 4-CH_3, 4-NO_2.
CH_{ip}	σ	0.836	1156.97	−9.39	7.87	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.733	1156.14	−5.54	7.98	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.708	1156.37	−2.82	8.44	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.757	1151.11	−20.84	6.93	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.711	1154.02	3.16	8.42	9	CH_{op}
	R	0.852	1151.04	−15.85	7.19	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
CH_{op}	σ	0.757	785.25	−38.37	17.89	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.766	782.33	−28.48	16.43	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.722	785.71	−19.39	21.37	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.853	768.32	−50.63	18.50	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.709	781.46	−6.89	21.85	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.755	766.34	−43.59	18.21	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$CH = CH_{op}$	σ	0.852	1020.96	−4.27	2.31	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.758	1020.68	−3.11	2.19	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.731	1021.44	−3.31	2.57	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.933	1019.43	−3.89	2.56	7	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-CH_3, 4-NO_2.
	F	0.733	1021.49	−3.06	2.55	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.734	1019.32	−3.33	2.55	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$C = C_{op}$	σ	0.960	545.68	67.39	28.36	7	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-OCH_3, 4-NO_2.
	σ^+	0.763	550.86	44.88	27.89	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.948	532.23	68.33	31.50	7	3-Br, 4-Br, 3-Cl, 2-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.729	566.59	45.25	34.53	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.932	540.95	39.58	34.13	7	3-Br, 4-Br, 3-Cl, 2-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.829	567.70	37.84	34.50	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.

r = correlation coefficient; ρ = slope; I = intercept; s = standard deviation; n = number of substituents.

parameters. This gives satisfactory correlations with respect to all parameters. The correlation equations for *s-cis*, *s-trans* and deformation modes are given in Equations 5–16.

$$\nu CO_{s-cis}^{(cm-1)} = 1651.81(\pm 1.48) + 3.39(\pm 1.22)\sigma_I + 5.26(\pm 2.56)\,\sigma_R$$

$$(R = 0.956, n = 9, P > 95\%) \quad (5)$$

$$\nu CO_{s-cis}^{(cm-1)} = 1651.96(\pm 1.47) + 3.10(\pm 1.12)F + 4.62(\pm 3.30)R$$

$$(R = 0.951, n = 9, P > 95\%) \quad (6)$$

$$\nu CO_{s-trans}^{(cm-1)} = 1602.61(\pm 6.38) - 15.39(\pm 3.85)\sigma_I + 17.77(\pm 5.34)\sigma_R$$

$$(R = 0.957, n = 9, P > 95\%) \quad (7)$$

$$\nu CO_{s-trans}^{(cm-1)} = 1601.28(\pm 6.38) - 12.73(\pm 3.57)F + 9.78(\pm 4.36)R$$

$$(R = 0.951, n = 9, P > 90\%) \quad (8)$$

$$\nu CH_{ip}^{(cm-1)} = 1153.05(\pm 4.98) - 5.76(\pm 1.82)\sigma_I - 21.79(\pm 1.98)\sigma_R$$

$$(R = 0.959, n = 9, P > 90\%) \quad (9)$$

$$\nu CH_{ip}^{(cm-1)} = 1152.00(\pm 5.00) - 3.17(\pm 1.64)F - 17.16(\pm 1.26)R$$

$$(R = 0.953, n = 9, P > 90\%) \quad (10)$$

$$\nu CH_{op}^{(cm-1)} = 777.32(\pm 12.65) - 26.83(\pm 7.47)\sigma_I - 55.07(\pm 3.41)\sigma_R$$

$$(R = 0.962, n = 9, P > 95\%) \quad (11)$$

$$\nu CH_{op}^{(cm-1)} = 775.02(\pm 11.63) - 27.19(\pm 4.73)F - 54.82(\pm 6.17)R$$

$$(R = 0.965, n = 9, P > 95\%) \quad (12)$$

$$\nu CH = CH_{op}^{(cm-1)} = 1020.75(\pm 1.73) - 3.92(\pm 3.76)\sigma_I - 4.54(\pm 4.16)\sigma_R$$

$$(R = 0.959, n = 9, P > 90\%) \quad (13)$$

$$\nu CH = CH_{op}^{(cm-1)} = 1020.86(\pm 1.49) - 5.06(\pm 3.18)F - 5.42(\pm 3.36)R$$

$$(R = 0.961, n = 9, P > 90\%) \quad (14)$$

$$\nu C = C_{op}^{(cm-1)} = 541.05(\pm 21.00) + 76.15(\pm 5.59)\sigma_I + 57.86(\pm 5.48)\sigma_R$$

$$(R = 0.961, n = 9, P > 95\%) \quad (15)$$

$$\nu C = C_{op}^{(cm-1)} = 548.46(\pm 20.89) + 63.14(\pm 4.44)F + 63.90(\pm 47.02)R$$

$$(R = 0.956, n = 9, P > 90\%) \quad (16)$$

^{1}H NMR spectral study

The ^{1}H NMR spectra of synthesized chalcones were recorded in deuteriochloroform solutions employing tetramethylsilane (TMS) as the internal standard. The signals of the ethylenic protons are assigned from their spectra. The lower chemical shifts (ppm) are obtained for Hα and higher chemical shifts (ppm) are obtained for Hβ in this series of ketones. The β-proton doublets are well separated from the signals of the aromatic protons. The assigned vinyl proton chemical shifts δ(ppm) of all ketones are presented in Table 4.

In NMR spectra, the proton or the ^{13}C chemical shifts (δ) depend on the electronic environment of the nuclei concerned. The assigned vinyl proton chemical shifts (ppm) have been correlated with reactivity

Table 4. The ^{1}H and ^{13}C NMR chemical shifts (δ, ppm) of substituted styryl 3,4-dimethoxyphenyl ketones.

Entry	Substt.	δH_α	δH_β	Substt.	δC_α	δC_β	δCO	Substt.
1	H	7.566 ($J = 15.6$ Hz)	7.817($J = 15.2$ Hz)	–	121.69	144.03	188.66	
2	3-Br	7.596($J = 24.4$ Hz)	7.773($J = 24.4$ Hz)	–	122.89	142.17	188.16	–
3	4-Br	7.735($J = 22.0$ Hz)	7.742($J = 22.0$ Hz)	–	122.16	142.57	196.92	–
4	3-Cl	7.554($J = 16.8$ Hz)	7.735($J = 16.8$ Hz)	–	124.85	142.26	188.18	–
5	2-F	7.672($J = 17.6$ Hz)	7.893($J = 17.6$ Hz)	–	124.49	149.29	188.64	–
6	4-F	7.490($J = 15.6$ Hz)	7.779($J = 15.6$ Hz)	–	123.03	142.70	188.40	–
7	4-CH_3	7.524($J = 15.2$ Hz)	7.801($J = 15.2$ Hz)	2.40	122.98	144.13	188.77	24.3
8	4-OCH_3	7.446($J = 15.2$ Hz)	7.792($J = 15.2$ Hz)	3.85	122.86	143.86	188.66	55.4
9	4-NO_2	7.510($J = 18.8$ Hz)	7.665($J = 18.8$ Hz)	–	123.37	140.74	196.26	–

parameters using Hammett equation as shown below:

$$\text{Log}\delta = \text{Log}\delta_o + \rho\sigma \quad (17)$$

whereδ_o is the chemical shift of unsubstitued ketones.

The assigned chemical shifts (ppm) of H_α and H_β proton are correlated with various Hammett sigma constants. The results of statistical analysis[2,3,5,9,12,27–29,46–48] are presented in Table 5. The obtained correlations of H_α are satisfactory with Hammett σ^+ constant. A fair degree of correlation is obtained for H_β proton chemical shifts (ppm) with Hammett sigma σ constant. All correlations give negative ρ values. The remaining substituent constants fail in correlation for both the proton chemical shifts due to reasons stated earlier and is associated with the conjugative structure shown in Figure 1.

Application of Swain-Lupton[58] treatment to the relative chemical shifts of H_α and H_β, with F and R values, is successful with resonance and inductive, but fails with F and R parameters, as per the multi regression Equations 18–21.

$$\delta_{H\alpha}^{(ppm)} = 7.59(\pm0.05) + 0.15(\pm0.08)\sigma_I - 0.12(\pm0.15)\sigma_R \quad (R = 0.963, n = 9, P > 95\%) \quad (18)$$

$$\delta_{H\alpha}^{(ppm)} = 7.54(\pm0.06) + 0.07(\pm0.04)F + 0.04(\pm0.05)R \quad (R = 0.921, n = 9, P > 90\%) \quad (19)$$

$$\delta_{H\beta}^{(ppm)} = 7.79(\pm0.03) - 0.13(\pm0.06)\sigma_I - 0.20(\pm0.07)\sigma_R \quad (R = 0.980, n = 9, P > 95\%) \quad (20)$$

$$d_{H\beta}^{(ppm)} = 7.77(\pm0.03) + 0.09(\pm0.07)F - 0.18(\pm0.07)R \quad (R = 0.972, n = 9, P > 90\%) \quad (21)$$

^{13}C NMR spectral study

Spectral analysts, organic chemists and scientists[2,3,5,9,12,27–29,46–48] have done extensive study on ^{13}C NMR spectra for a large number of different ketones and styrenes. The assigned vinyl C_α, C_β and carbonyl carbon chemical shifts are presented in Table 4. The results of statistical analysis are given in Table 5. The correlations of C_α chemical shifts (δ, ppm) with Hammett σ constants, F and R parameters are poor. The correlations of chemical shifts (ppm) of C_β carbon with Hammett σ, σ^+ constants and F parameters are satisfactory. Remaining Hammett σ constants and R parameter are failing in correlation. This is due to the reasons stated earlier and is associated with the resonance conjugative structure, shown in Figure 1. The carbonyl carbon chemical shifts (ppm) of all ketones give satisfactory correlation with Hammett σ, σ^+, σ_I constants and F parameters, except for halo and nitro substituents.

The correlations of Swain Lupton's[58] parameter are satisfactory and their regression equations are given in 22–27.

$$\delta_{C\alpha}^{(ppm)} = 122.27(\pm0.67) + 1.73(\pm1.47)\sigma_I - 1.12(\pm1.02)\sigma_R \quad (R = 0.951, n = 9, P > 95\%) \quad (22)$$

$$\delta_{C\alpha}^{(ppm)} = 122.35(\pm0.64) + 2.69(\pm1.37)F - 2.32(\pm1.45)R \quad (R = 0.950, n = 9, P > 95\%) \quad (23)$$

Table 5. Results of statistical analysis of infrared δ(ppm) of ethylenic protons, carbons and carbonyl carbons of substituted styryl 3,4-dimethoxyphenyl ketones with Hammett σ, σ^+, σ_I, σ_R constants and F and R parameters.

Frequency	Constants	R	I	ρ	s	n	Correlated derivatives
$\delta_{H\alpha}^{(ppm)}$	σ	0.729	7.55	0.08	0.09	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.958	7.55	0.11	0.07	7	H,3-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3.
	σ_I	0.718	7.54	0.07	0.09	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.702	7.57	0.01	0.09	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.717	7.54	0.06	0.09	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.804	7.57	0.01	0.09	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$\delta_{H\beta}^{(ppm)}$	σ	0.956	7.79	−0.11	0.06	8	H,3-Br, 4-Br, 3-Cl, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.829	7.78	−0.04	0.06	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.741	7.82	−0.10	0.06	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.862	7.74	−0.18	0.05	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.714	7.79	−0.03	0.07	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.862	7.74	−0.14	0.05	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$\delta_{C\alpha}^{(ppm)}$	σ	0.835	122.94	1.16	1.00	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.832	123.03	0.74	1.00	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.845	122.45	1.89	0.95	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.830	122.86	−1.41	1.02	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
.	F	0.850	122.39	1.81	0.93	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.726	122.87	−1.02	1.03	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$\delta_{C\beta}^{(ppm)}$	σ	0.934	144.00	−2.75	2.42	8	H,3-Br, 4-Br, 3-Cl, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.908	143.59	−0.41	2.57	8	H,3-Br, 4-Br, 3-Cl, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.821	144.30	−2.11	2.52	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.857	142.24	−6.34	2.12	9	NO_2.
	F	0.906	143.28	0.59	2.58	8	H,3-Br, 4-Br, 3-Cl, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.856	142.12	−5.17	2.13	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
$\delta_{CO}^{(ppm)}$	σ	0.850	189.28	5.80	3.30	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ^+	0.846	189.79	3.45	3.39	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_I	0.840	188.09	5.96	3.50	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	σ_R	0.850	191.97	8.29	3.30	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	F	0.823	189.02	3.05	3.72	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.
	R	0.846	192.01	6.32	3.39	9	H, 3-Br, 4-Br, 3-Cl, 2-F, 4-F, 4-OCH_3, 4-CH_3, 4-NO_2.

r = correlation coefficient; ρ = slope; I = intercept; s = standard deviation; n = number of substituents.

$$\delta_{C\beta}^{(ppm)} = 143.26(\pm 1.45) - 3.03(\pm 1.15)\sigma_I - 6.84(\pm 3.49)\sigma_R \ (R = 0.962, n = 9, P > 95\%) \quad (24)$$

$$\delta_{C\beta}^{(ppm)} = 142.59(\pm 1.46) - 1.55(\pm 1.11)F - 5.81(\pm 3.29)R \quad (R = 0.958, n = 9, P > 95\%) \quad (25)$$

$$\delta_{CO}^{(ppm)} = 189.45(\pm 2.01) + 7.24(\pm 4.37)\sigma_I + 9.48(\pm 4.03)\sigma_R \ (R = 0.906, n = 9, P > 90\%) \quad (26)$$

$$\delta_{CO}^{(ppm)} = 190.07(\pm 2.03) + 6.35(\pm 2.32)F + 8.95(\pm 2.57)R \quad (R = 0.906, n = 9, P > 90\%) \quad (27)$$

ANTIMICROBIAL ACTIVITIES

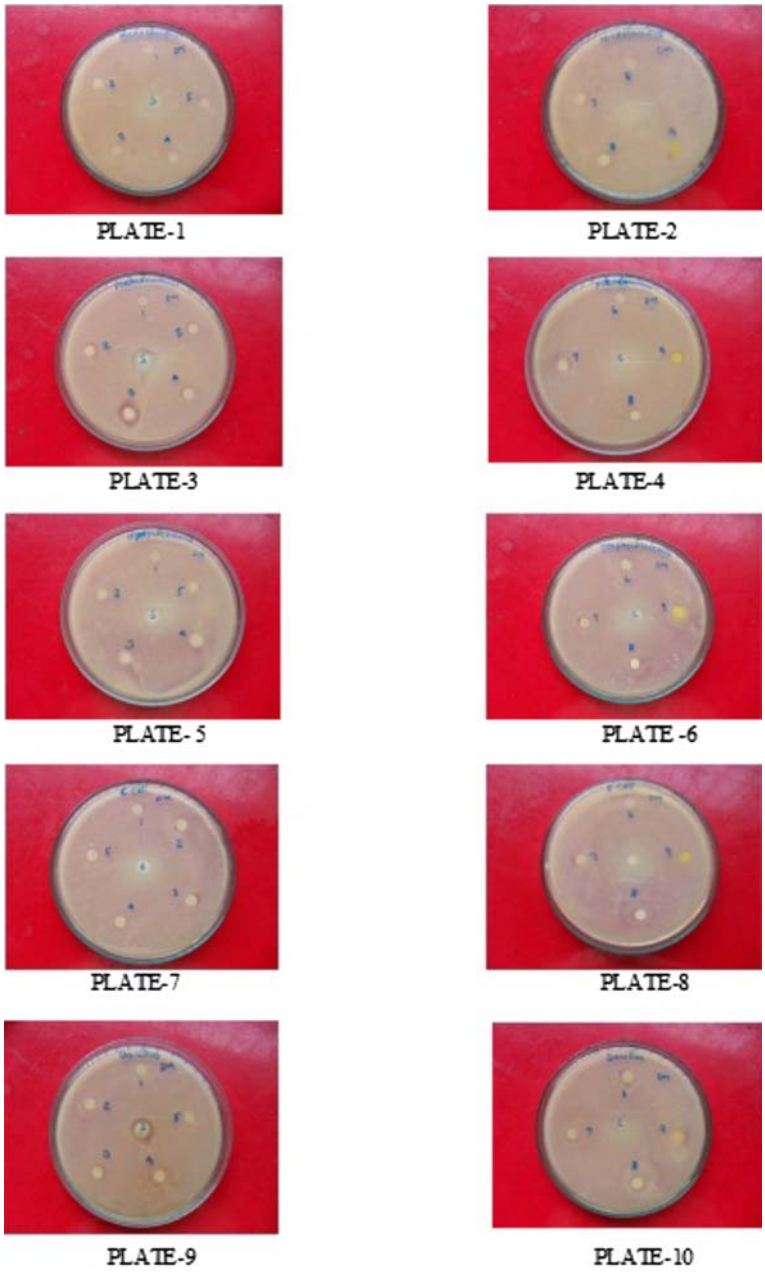


Figure 3. Antibacterial activity of styryl 3,4-dimethoxyphenyl ketones-petri dishes.

Antibacterial sensitivity assay

The antibacterial screening effect of synthesized chalcones is shown in Figure 3 (Plates 1–10). The antibacterial activities of all the synthesized chalcones have been studied against three gram positive pathogenic strains *Micrococcus luteus*, *Bacillus substilis*, *Staphylococcus aureus* and two gram negative strains *Escherichia coli* and *Pseudomonas aerogenosa*. The disc diffusion technique was followed using the Kirby–Bauer[60] method, at a concentration of 250 mg/mL with Ampicillin taken as the standard drug.

The measured zone of inhibitions is shown in Table 6 and the clustered column chart in Figure 4. All the compounds show a weak to moderate activity against, *E. coli* and *S. aureus*. and moderate to high activity against *M. luteus*, *Pseudomonas* and *B. substilis*. Compounds with substituents, H and 4-Br, show good activity against *M. luteus*. Compounds with substituents H, 3-Br, 2-F and 4-CH_3 show good activity against *Pseudomonas* and the compound with substituent 4-Br shows excellent activity

Table 6. The antibacterial activities of substituted styryl 3, 4–dimethoxyphenyl ketones.

		Zone of Inhibition (mm) Gram positive Bacteria			Gram negative Bacteria	
S Entry	**Substt.**	*B.subtilis*	*M.luteus*	*S.aureus*	*E.Coli*	*P.aeruginosa*
1	H	7	8	7	–	8
2	3-Br	8	7	7	–	8
3	4-Br	8	8	–	–	13
4	3-Cl	–	6	–	7	–
5	2-F	7	7	8	6	8
6	4-F	10	6	8	–	7
7	4-Me	8	6	7	7	8
8	4-OMe	9	7	7	7	6
9	4-NO_2	6	7		6	7
	AMPICILLIN	16	19	14	17	13
	DMSO	–	–	–	–	–

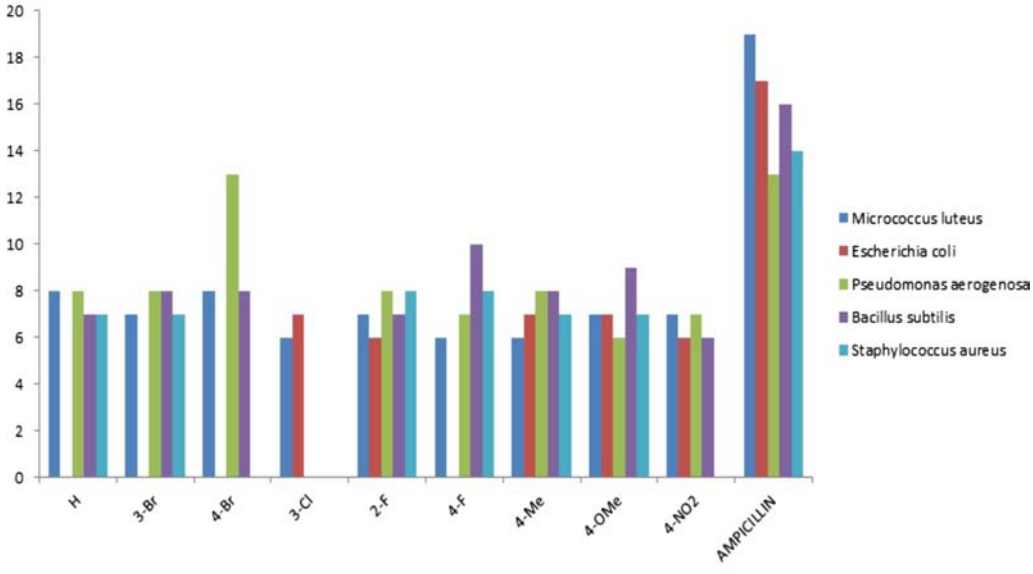


Figure 4. Antibacterial activity of styryl 3,4-dimethoxyphenyl ketones-clustered column chart.

against *Pseudomonas*. Compounds with substituents 3-Br, 4-Br and 4-OMe show good activity against *B. substilis*. Compounds with substituents 4-F show very good activity against *B.substilis*. Chalcones containing substituents 2-F and 4-F show good activity against *S. aureus*. The rest of the compounds are found to have weak activity against all the microorganisms.

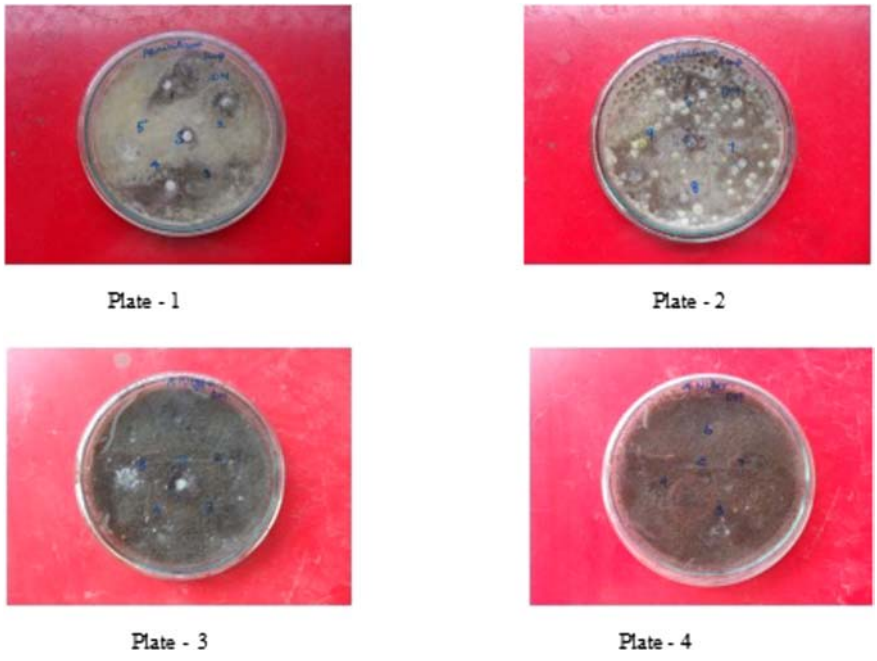


Figure 5. Antifungal activity of styryl 3,4 –dimethoxyphenyl ketones-petri dishes.

Table 7. Antifungal activity of styryl 3,4 –dimethoxyphenyl ketones.

Entry	Substt	Zone of Inhibition (mm)	
		A.niger	*Pen.Scup*
1	H	7	10
2	3-Br	7	9
3	4-Br	–	–
4	3-Cl	8	10
5	2-F	7	–
6	4-F	–	–
7	4-Me	–	7
8	4-Ome	8	–
9	4-NO_2	–	9
	MICONAZOLE	14	13
	DMSO	–	–

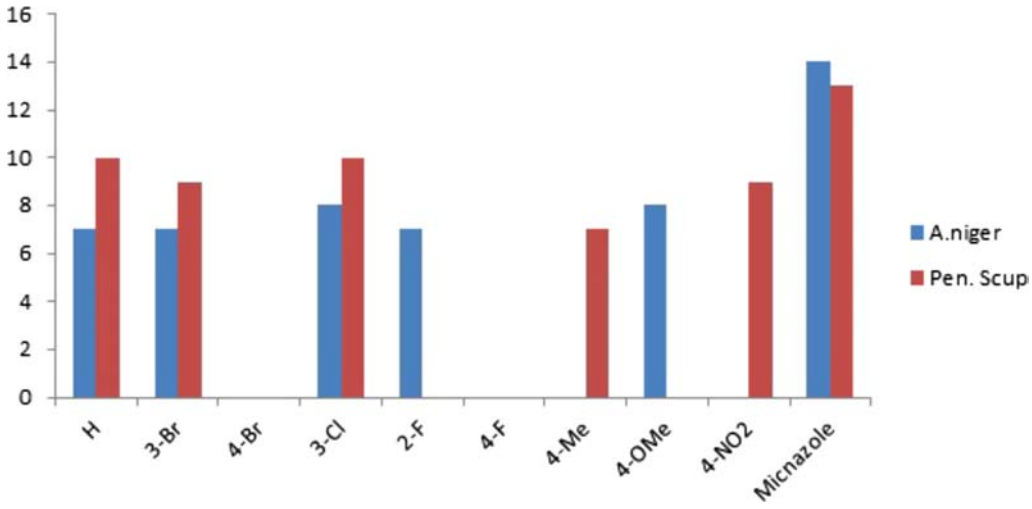


Figure 6. Antifungal activity of styryl 3,4 –dimethoxyphenyl ketones-clustered column chart.

Antifungal sensitivity assay

The antifungal activities of substituted chalcones synthesized in the present study are shown in Figure 5 for Plates (1–4) and the zone of inhibition values of the effect is given in Table 7. The clustered column chart, shown in Figure 6 reveals that all the compounds have excellent antifungal activity against the two fungal species, *A.niger*, and *Pen.Scup*. Chalcones with substituents H, 3-Br, 3-Cl, 4-CH_3 and 4-NO_2 show greater antifungal activity against *Pen.Scup*. Chalcones with substituents 3-Br, 4-Cl, 2-F, and 4-OCH_3 show good activity against *A.niger*.

CONCLUSIONS

We have synthesised a series of 3,4-dimethoxyphenyl chalcones by solvent free, solid $SiO_2-H_2SO_4$ acid catalysed crossed aldol condensation between 3,4-dimethoxyacetopheneone and substituted benzaldehydes. The yields of the chalcones were found to be more than 85%. The effect of substituents with respect to the UV-vis absorption maxima (λmax, nm) gives satisfactory correlation with Hammett σ constants. The correlations of infrared spectral frequencies are satisfactory for νCO $_{s\text{-}trans}$ with σ_R and R, νCH = CH_{op} with σ_R, C = C_{op} with σ_I and F parameters. The vinyl protons and carbon chemical shifts (δ, ppm) of Hα, Hβ, Cα and Cβ, show satisfactory correlation with σ and $\sigma+$ constants. The chalcones with halo, methyl and methoxy substituents show good antibacterial activities against the bacterial strains. Similarly the chalcones with halo, methyl, methoxy and nitro substituents show good antifungal activity against the fungi strains.

The authors of this work have no competing interests.

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