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Preparation and NMR properties of derivatives of arylamino-methylidene malonic acid and pentane-2,4-dione

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Abstract: A set of 22 anilinomethylidene derivatives (13 new ones) of di(m)ethyl malonate, malononitrile and pentane-2,4-dione with various substituents in position 4- and 3-, respectively were prepared to study the characteristic influence of these substituents and solvents on chemical shifts in 13C NMR spectra and like reference compounds for kinetic measurements.

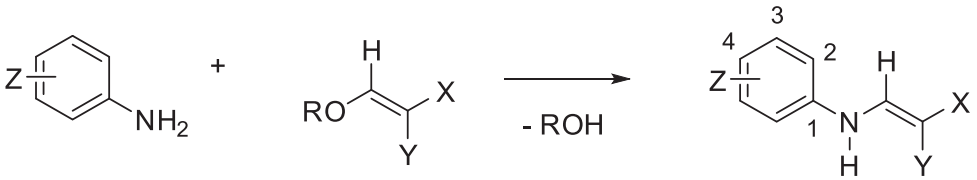
Keywords: NMR spectroscopy, substituent chemical shifts (SCS), arylaminomethylidene derivatives, enamines

Introduction

Arylaminomethylidene malonic acid derivatives are very useful intermediates used in organic synthesis of quinolone derivatives (Hermecz et al. 1992). Most frequently are used esters, less frequently are dinitriles or their formal hybrids — cyanoacetates (Bella et al. 2012, Milata et al. 1987). Derivatives of 2,4-pentanedione (acetylacetone) are used rarely (Wolfbeis et al. 1977), but they are interesting from a point of view of physical chemists (Couchouron et al. 1983). We need the target compounds like standards for kinetic measurement with differently substituted anilines. From various synthetic approaches to target compounds the first step of Gould — Jacobs reaction: reaction of aniline with activated enolether is the most advantageous (Hermecz et al. 1992) (Fig. 1.).

Materials and methods

Aniline and 3, 4-substituted anilines respectively were distilled before use, 4-nitroaniline was recrystallized from 2-propanol (Fig. 1). Enolethers — dimethyl and diethyl methoxymethylidene malonates were commercially available (Sigma Aldrich® and Acros Organics®). Commercially available ethoxymethylidene malononitrile was recrystallized from 2-propanol before use. Melting points were determined using Kofler hot plate without further corrections. Elemental analyses were determined using an automatic analysator Flash EA 1112 (fy Thermo Finnigan) and Fisons Instruments EA 1108 CHN.
IR spectra were taken on a FTIR Nicolet NEXUS 470 spectrophotometer using AT-R technique in region 3800—600 cm^{-1}. UV-VIS measurements were



I II III

Ia: Z = H;
Ib: Z = 3-Cl;
Ic: Z = 4-Br;
Id: Z = 4-Me;
Ie: Z = 4-OMe
If: Z = 4-NO_2

IIa, IIIa: X = Y = COOMe (R = Me for IIa)
IIb, IIIb: X = Y = COOEt (R = Et for IIb)
IIc, IIIc: X = Y = COMe (R = Et)
IId, IIId: X = Y = CN (R = Et)

Fig. 1. Reaction of anilines with enolethers.

recorded on UV-VIS NIR 3600 SHIMADZU spectrophotometer in region 250—700 nm. ^{1}H and ^{13}C NMR spectra were measured in $CDCl_3$ and DMSO-d_6 solution using spectrophotometers Varian VXR-300 (for ^{1}H 299,995 MHz, for ^{13}C 75,431 MHz) and Bruker Avance III 400 (for ^{1}H 400,23 MHz, for ^{13}C 100,65 MHz) at 25 °C. Chemical shifts (δ-scale) are quoted in parts per million and following abbreviations are used: s = singlet; d = doublet; t = triplet; q = quartet, m = multiplet.

Experimental

Preparation of the title compounds was realized according to Fig. 1.

General procedure for preparation of arylaminomethylidene derivatives III

Suitable substituted or nonsubstituted aniline **Ia-f** (5 mmol) dissolved in MeOH/EtOH (15—20 ml) was mixed with equimolar amount of enolether **IIa-d** (5 mmol) in MeOH/EtOH (15—20 ml). Reaction mixture was stirred at rt from 15 min up to 3 h at reflux. After end of the reaction solvent was evaporated through vacuum evaporator. Thus obtained raw products were purified by column chromatography or recrystallization. Purification and individual reaction conditions for all compounds are presented.

Dimethyl 2-[(phenylamino)methylidene]malonate (IIIa, Z = H)

There was used to a reaction aniline (**Ia, Z = H**) (0.47 g, 5 mmol) in 10 ml MeOH and enolether **IIa** (0.87 g, 5 mmol) in 15 ml MeOH. Reaction mixture was stirred 20 min at rt, then solvent was evaporated. Raw product was purified by column chromatography (EA (ethyl acetate):H(hexane) = 1:1, R_F = 0.24).

Yield: 1.02 g, 87 %, light yellow solid. Mp 46—48 °C (47 °C, Rappoport et al. 1972).

^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 11.01 (br d, 1H, ^{3}J = 13.1 Hz, —NH), 8.54 (d, 1H, ^{3}J = 13.8 Hz, —CH═), 7.41—7.36 (m, 2H), 7.20—7.14 (m, 3H), 3.87 (s, 3H, OMe), 3.78 (s, 3H, OMe)

UV VIS (DMSO, nm) λ_{max} 319

Elemental analysis for $C_{12}H_{13}NO_4$ — calculated (found) (%): C 61.27 (61.25), H 5.57 (5.52), N 5.95 (5.91)

Diethyl 2-[(phenylamino)methylidene]malonate (IIIb, Z = H)

There was used to a reaction aniline (**Ia, Z = H**) (0.47 g, 5 mmol) in 10 ml EtOH and enolether **IIb** (1.1 g, 5 mmol) in 15 ml EtOH. Reaction mixture was stirred 20 min at rt, then solvent was evaporated. Raw product was purified by column chromatography. (EA:H = 1:1, R_F = 0.29).

Yield: 1.25 g, 93 %, light yellow solid. Mp 51—53 °C (54—55 °C, Huppatz et al. 1981).

^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 11.01 (br d, 1H, ^{3}J = 13.5 Hz, —NH), 8.53 (d, 1H, ^{3}J = 13.7 Hz, —CH═), 7.38 (m, 2H), 7.16 (m, 3H), 4.32 (q, 2H, ^{3}J = 7.1 Hz, OCH_2), 4.25 (q, 2H, ^{3}J = 7.1 Hz, OCH_2), 1.39 (t, 3H, ^{3}J = 7.1 Hz, CH_3), 1.33 (t, 3H, ^{3}J = 7.1 Hz, CH_3)

UV VIS (DMSO, nm) λ_{max} 321

3-[(Phenylamino)methylidene]pentane-2,4-dione (IIIc, Z = H)

There was used to a reaction aniline (**Ia, Z = H**) (0.47 g, 5 mmol) in 10 ml EtOH and enolether **IIc** (0.78 g, 5 mmol) in 15 ml EtOH. Reaction mixture was stirred 15 min at rt and solvent was evaporated. Raw product was purified by column chromatography (EA:H = 1:1, R_F = 0.43).

Yield: 0.94 g, 94 %, yellow solid. Mp 85—87 °C (90 °C, Wolfbeis et al. 1979).

^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 12.70 (br s, 1H, —NH), 8.19 (d, 1H, ^{3}J = 12.8 Hz, —CH═), 7.38—7.33 (m, 2H), 7.19—7.11 (m, 3H), 2.50 (s, 3H, Me), 2.33 (s, 3H, Me)

UV VIS (DMSO, nm) λ_{max} 330

Elemental analysis for $C_{12}H_{13}NO_2$ — calculated (found) (%): C 70.92 (70.77), H 6.45 (6.33), N 6.89 (6.78)

2-[(Phenylamino)methylidene]malononitrile (IIId, Z = H)

There was used to a reaction aniline (**Ia, Z = H**) (0.47 g, 5 mmol) in 10 ml EtOH and enolether **IId** (0.61 g, 5 mmol) in 15 ml EtOH. Reaction mixture was stirred 20 min at rt and solvent was evaporated. Raw product was purified by column chromatography (EA:H = 1:1, R_F = 0.15).

Yield: 0.74 g, 88 %, yellow powder. Mp 248—249 °C (254—256 °C, Nasakin et al. 1992).

^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 11.1 (br d, 1H, —NH), 8.51 (s, 1H, —CH═), 7.46—7.36 (m, 4H), 7.20—7.16 (m, 1H)

UV VIS (DMSO, nm) λ_{max} 317

Elemental analysis for $C_{10}H_7N_3$ — calculated (measured) (%): C 70.99 (70.86), H 4.17 (4.06), N 24.84 (24.91)

Dimethyl 2-[(3-chlorophenylamino)methylidene]malonate (IIIa, Z = 3-Cl)

There was used to a reaction 3-chloroaniline (**Ib, Z = 3-Cl**) (0.64 g, 5 mmol) in 10 ml MeOH and enolether **IIa** (0.87 g, 5 mmol) in 20 ml MeOH. Reaction mixture was refluxed under regular stirring for 2 h. After its cooling solvent was evaporated and a raw

product was purified by column chromatography. (EA:H = 1:1, R_F = 0.35).
Yield: 1.21 g, 90 %, white powder. Mp 146—147 °C.
^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 11.01 (d, 1H, ^3J = 13.8 Hz, —NH), 8.47 (d, 1H, ^3J = 13.6 Hz, —CH═), 7.32—7.11 (m, 3H), 7.03—7.01 (m, 1H), 3.86 (s, 3H, OMe), 3.78 (s, 3H, OMe)
IR (ν, cm^{-1}) 2954, 1588, 1573, 1231, 769
UV VIS (DMSO, nm) λ_{max} 321
Elemental analysis for $C_{12}H_{12}ClNO_4$ calculated (found) (%): C 53.44 (53.24), H 4.49 (4.48), N 5.19 (4.96)

Diethyl 2-[(3-chlorophenylamino)methylidene]malonate (IIIb, Z = 3-Cl)
There was used to a reaction 3-chloroaniline (**Ib, Z = 3-Cl**) (0.64 g, 5 mmol) in 15 ml EtOH and enolether **IIb** (1.1 g, 5 mmol) in 20 ml EtOH. Reaction mixture was refluxed under regular stirring for 2 h. After its cooling solvent was evaporated and a raw product was purified by column chromatography (EA:H = 1:1, R_F = 0.40).
Yield: 1.44 g, 95 %, colourless solid. Mp 41—44 °C (44—45 °C, Fodor et al. 1948).
^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 10.98 (d, 1H, ^3J = 13.3 Hz, —NH), 8.46 (d, 1H, ^3J = 13.5 Hz, —CH═), 7.33—7.28 (m, 1H), 7.15—7.11 (m, 2H), 7.03—7.00 (m, 1H), 4.32 (q, 2H, ^3J = 7.2 Hz, OCH_2), 4.26 (q, 2H, ^3J = 7.1 Hz, OCH_2), 1.39 (t, 3H, ^3J = 7.1 Hz, CH_3), 1.35 (t, 3H, ^3J = 7.1 Hz, CH_3)
UV VIS (DMSO, nm) λ_{max} 300

3-[(3-Chlorophenylamino)methylidene]pentane-2,4-dione (IIIc, Z = 3-Cl)
There was used to a reaction 3-chloroaniline (**Ib, Z = 3-Cl**) (0.64 g, 5 mmol) in 10 ml EtOH and enolether **IIc** (0.79 g, 5 mmol) in 20 ml EtOH. Reaction mixture was refluxed under regular stirring for 1 h. After its cooling solvent was evaporated and a raw product was purified by column chromatography (EA:H =1:1, R_F = 0.22).
Yield: 1.16 g, 98 %, light yellow solid. Mp 89—91 °C (92—94 °C, Snyder 1946).
^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 12.43 (d, 1H, ^3J = 12.7 Hz, —NH), 8.40 (d, 1H, ^3J = 12.7 Hz, —CH═), 7.73—7.40 (m, 3H), 7.25—7.21 (m, 1H), 2.39 (s, 6H, 2×Me)
UV VIS (DMSO, nm) λ_{max} 342
IR (ν, cm^{-1}) 3057, 1589, 1567, 1306, 778
Elemental analysis for $C_{12}H_{12}ClNO_2$ — calculated (found) (%): C 60.64 (60.70), H 5.09 (5.07), N 5.89 (5.71)

2-[(3-Chlorophenylamino)methylidene]malononitrile (IIId, Z = 3-Cl)
There was used to a reaction 3-chloroaniline (**Ib, Z = 3-Cl**) (0.64 g, 5 mmol) in 10 ml EtOH and enolether **IId** (0.61 g, 5 mmol) in 15 ml EtOH. Reaction mixture was refluxed under regular stirring for 1 h. After its cooling solvent was evaporated and a raw product was purified by column chromatography (EA:H =1:1, R_F = 0.28).
Yield: 0.96 g, 90 %, colourless solid. Mp 199—200 °C (200—201 °C, Santilli 1964).
^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 11.16 (br s, 1H, —NH), 8.57 (s, 1H, —CH═), 7.59 (s, 1H), 7.40—7.20 (m, 3H)
UV VIS (DMSO, nm) λ_{max} 325
IR (ν, cm^{-1}) 3203, 2227, 2216, 1662, 1338, 772
Elemental analysis for $C_{10}H_6ClN_3$ — calculated (found) (%): C 58.98 (58.84), H 2.97 (2.94), N 20.64 (20.51)

Dimethyl 2-[(4-bromophenylamino)methylidene]malonate (IIIa, Z = 4-Br)
There was used to a reaction 4-bromoaniline (**Ic, Z = 4-Br**) (0.86 g, 5 mmol) in 15 ml MeOH and enolether **IIa** (0.87 g, 5 mmol) in 20 ml MeOH. Reaction mixture was refluxed under regular stirring for 1.5 h. After its cooling raw product was collected by filtration and washed off with cold MeOH.
Yield: 1.15 g, 73 %, white powder. Mp 113—114 °C (116—117 °C, Rappoport et al. 1972).
^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 10.66 (s, 1H, —NH), 8.38 (br s, 1H, —CH═), 7.55 (d, 2H, ^3J = 8.9 Hz, H-3, H-5), 7.37 (d, 2H, ^3J = 8.9 Hz, H-2, H-6), 3.72 (s, 3H, OMe), 3.66 (s, 3H, OMe)
UV VIS (DMSO, nm) λ_{max} 328
Elemental analysis for $C_{12}H_{12}BrNO_4$ — calculated (found) (%): C 45.88 (45.94), H 3.85 (3.82), N 4.46 (4.28)

Diethyl 2-[(4-bromophenylamino)methylidene]malonate (IIIb, Z = 4-Br)
There was used to a reaction 4-bromoaniline (**Ic, Z = 4-Br**) (0.86 g, 5 mmol) in 15 ml EtOH and enolether **IIb** (1.1 g, 5 mmol) in 20 ml EtOH. Reaction mixture was refluxed under regular stirring for 1.5 h. After its cooling raw product was purified by column chromatography.
Yield: 1.60 g, 92 %, colourless solid. Mp 98—99 °C (100.5—101.7 °C, Lopez et al. 2010).
^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 10.65 (d, 1H, ^3J = 13.8 Hz, —NH), 8.34 (d, 1H, ^3J = 13.8 Hz, —CH═), 7.54 (d, 2H, ^3J = 8.8 Hz, H-3, H-5), 7.34 (d, 2H, ^3J = 8.9 Hz, H-2, H-6), 4.19 (q, 2H, ^3J = 7.1 Hz, OCH_2), 4.11 (q, 2H, ^3J = 7.1 Hz, OCH_2), 1.25 (t, 3H, ^3J = 7.1 Hz, CH_3), 1.21 (t, 3H, ^3J = 7.1 Hz, CH_3)
UV VIS (DMSO, nm) λ_{max} 323
Elemental analysis for $C_{14}H_{16}BrNO_4$ — calculated (found) (%): C 49.14 (49.20), H 4.71 (4.77), N 4.09 (3.91)

3-[(4-Bromophenylamino)methylidene]pentane-2,4-dione (IIIc, Z = 4-Br)

There was used to a reaction 4-bromoaniline (**Ic, Z = 4-Br)** (0.86 g, 5 mmol) in 10 ml EtOH and enolether **IIc** (0.79 g, 5 mmol) in 20 ml EtOH. Reaction mixture was stirred for 30 min at rt. Solvent was evaporated and a raw product was collected by filtration and finally washed off with cold EtOH.

Yield: 1.30 g, 91 %, colourless crystals. Mp 139—140 °C.

^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 12.72 (br s, 1H, —NH), 8.16 (d, 1H, ^3J = 12.6 Hz, —CH═), 7.50 (d, 2H, ^3J = 8.7 Hz, H-3, H-5), 7.05 (d, 2H, ^3J = 8.7 Hz, H-2, H-6), 2.54 (s, 3H, Me), 2.38 (s, 3H, Me)

UV VIS (DMSO, nm) λ_{max} 338

Elemental analysis for $C_{12}H_{12}BrNO_2$ — calculated (found) (%): C 51.09 (51.00), H 4.29 (4.18), N 4.96 (4.89)

2-[(4-Bromophenylamino)methylidene]malononitrile (IIId, Z = 4-Br)

There was used to a reaction 4-bromoaniline (**Ic, Z = 4-Br**) (0.86g, 5 mmol) in 15 ml EtOH and enolether **IId** (0.61 g, 5 mmol) in 20 ml MeOH. Reaction mixture was stirred for 30 min at rt. Solvent was evaporated and a raw product was collected by filtration and finally washed with cold EtOH.

Yield: 0.69 g, 56 %, colourless solid. Mp 251—253 °C.

^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 11.17 (br s, 1H, —NH), 8.50 (s, 1H, —CH═), 7.55 (d, 2H, ^3J = 8.8 Hz, H-3, H-5), 7.39 (d, 2H, ^3J = 8.8 Hz, H-2, H-6)

IR (ν, cm^{-1}) 3217, 2225, 2209, 1668, 811

UV VIS (DMSO, nm) λ_{max} 330

Elemental analysis for $C_{10}H_6BrN_3$ — calculated (found) (%): C 48.41 (48.35), H 2.44 (2.43), N 16.94 (16.81)

Dimethyl 2-[(p-tolylamino)methylidene]malonate (IIIa, Z = 4-Me)

There was used to a reaction 4-methylaniline (**Id, Z = 4-Me**) (0.54 g, 5 mmol) in 8—10 ml MeOH and enolether **IIa** (0.87 g, 5 mmol) in 8—10 ml MeOH. Reaction mixture was refluxed under regular stirring for 3 h. After its cooling raw product was recrystallized from petrolether.

Yield: 0.67 g, 54 %, colourless solid. Mp 104—106 °C (108—110 °C, Rappoport et al. 1972).

^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 11.01 (br s, 1H, —NH), 8.52 (d, 1H, ^3J = 13.6 Hz, —CH═), 7.55 (d, 2H, ^3J = 8.9 Hz, H-2, H-6), 7.17 (d, 2H, ^3J = 8.4 Hz, H-3, H-5), 3.86 (s, 3H, OMe), 3.78 (s, 3H, OMe), 2.34 (s, 3H, Me)

UV VIS (DMSO, nm) λ_{max} 330

Elemental analysis for $C_{13}H_{15}NO_4$ — calculated (found) (%): C 62.64 (62.69), H 6.07 (5.96), N 5.62 (5.44)

Diethyl 2-[(p-tolylamino)methylidene]malonate (IIIb, Z = 4-Me)

There was used to a reaction 4-methylaniline (**Id, Z = 4-Me**) (0.54 g, 5 mmol) in 8-10 ml EtOH and enolether **IIb** (1.1 g, 5 mmol) in 8-10 ml EtOH. Reaction mixture was refluxed under regular stirring for 3 h. After its cooling solvent was evaporated and a raw product was purified by column chromatography (EA:H =1:1, R_F = 0.20).

Yield: 1.31 g, 93 %, colourless solid. Mp 46—48 °C (45—46 °C, Mao et al. 2009).

^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 11.00 (d, 1H, ^3J = 13.6 Hz, —NH), 8.52 (d, 1H, ^3J = 13.8 Hz, —CH═), 7.18 (d, 2H, ^3J = 8.3 Hz, H-2, H-6), 7.05 (d, 2H, ^3J = 8.4 Hz, H-3, H-5), 4.32 (q, 2H, ^3J = 7.1 Hz, OCH_2), 4.26 (q, 2H, ^3J = 7.1 Hz, OCH_2), 1.40 (t, 3H, ^3J = 7.1 Hz, CH_3), 1.35 (t, 3H, ^3J = 7.1 Hz, CH_3)

UV VIS (DMSO, nm) λ_{max} 334

3-[(p-Tolylamino)methylidene]pentane-2,4-dione (IIIc, Z = 4-Me)

There was used to a reaction 4-methylaniline (**Id, Z = 4-Me)** (0.54 g, 5 mmol) in 10 ml EtOH and enolether **IIc** (0.78 g, 5 mmol) in 20 ml EtOH. Reaction mixture was stirred for 1 h at rt. Solvent was evaporated and a raw product was collected by filtration and washed off with hexane.

Yield: 0.84 g, 77 %, light yellow cotton. Mp 136—138 °C (139—140 °C, Claisen 1893).

^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 12.75 (br s, 1H, —NH), 8.22 (d, 1H, ^3J = 12.8 Hz, —CH═), 7.19 (d, 2H, ^3J = 8.2 Hz, H-2, H-6), 7.08 (d, 2H, ^3J = 8.4 Hz, H-3, H-5), 2.57 (s, 3H, 4-Me), 2.39 (s, 3H, Me), 2.37 (s, 3H, Me)

UV VIS (DMSO, nm) λ_{max} 345

IR (ν, cm^{-1}) 2926, 1595, 1570, 1308, 814

Elemental analysis for $C_{13}H_{15}NO_2$ — calculated (found) (%): C 71.87 (71.85), H 6.96 (6.91), N 6.45 (6.32)

2-[(p-Tolylamino)methylidene]malononitrile (IIId, Z = 4-Me)

There was used to a reaction 4-methylaniline (**Id, Z = 4-Me**) (0.54 g, 5 mmol) in 10 ml EtOH and enolether **IId** (0.61 g, 5 mmol) in 20 ml EtOH. Reaction mixture was stirred for 40 min at rt. Solvent was evaporated and a raw product was washed off with cold EtOH.

Yield: 0.71 g, 76 %, yellow crystalls. Mp 289—290 °C (297 °C, Rappoport et al. 1972).

^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 11.06 (br s, 1H, —NH), 8.40 (s, 1H, —CH═), 7.27 (d, 2H,

^3J = 8.4 Hz, H-2, H-6), 7.14 (d, 2H, ^3J = 8.4 Hz, H-3, H-5), 2.24 (s, 3H, Me)
UV VIS (DMSO, nm) λ_{max} 320
Elemental analysis for $C_{11}H_9N_3$ — calculated (found) (%): 72.11 (72.02), H 4.95 (4.88), N 22.94 (22.89)

Dimethyl 2-[(4-methoxyphenylamino)methylidene] malonate (IIIa, Z = 4-OMe)
There was used to a reaction 4-methoxyaniline (**Ie, Z = 4-OMe**) (0.62 g, 5 mmol) in 15 ml MeOH and enolether **IIa** (0.87 g, 5 mmol) in 15—20 ml MeOH. Reaction mixture was refluxed under regular stirring for 3 h. After its cooling raw product was recrystallized from petrolether.
Yield: 0.64 g, 48 %, colourless solid. Mp 86—89 °C (89—91 °C, Zewge et al. 2007).
^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 11.02 (br s, 1H, —NH), 8.45 (d, 1H, ^3J = 8.7 Hz, —CH═), 7.11—6.89 (m, 4H), 3.86 (s, 3H, OMe), 3.81 (s, 3H, OMe), 3.78 (s, 3H, 4-OMe)
IR (ν, cm^{-1}) 2946, 1683, 1645, 1449, 1266, 1241, 797
UV VIS (DMSO, nm) λ_{max} 324
Elemental analysis for $C_{13}H_{15}NO_5$ — calculated (found) (%): C 58.86 (58.74), H 5.70 (5.65), N 5.28 (5.12)

Diethyl 2-[(4-methoxyphenylamino)methylidene]malonate (IIIb, Z = 4-OMe)
There was used to a reaction 4-methoxyaniline (**Ie, Z = 4-OMe**) (0.62 g, 5 mmol) in 10 ml MeOH and enolether **IIb** (1.1 g, 5 mmol) in 20 ml EtOH. Reaction mixture was refluxed under regular stirring for 3 h. After its cooling raw product was purified by column chromatography (EA:H =10:1, R_F = 0.20).
Yield: 1.22 g, 82 %, orange solid. Mp < 35 °C (38—39 °C, Deshmukh et al. 1999).
^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 10.95 (br s, 1H, —NH), 8.40 (d, 1H, ^3J = 13.8 Hz, —CH═), 7.04 (d, 2H, ^3J = 8.7 Hz, H-2, H-6), 6.86 (d, 2H, ^3J = 8.7 Hz, H-3, H-5), 4.31-4.17 (m, 4H, OCH_2), 3.76 (s, 3H, OMe), 1.37-1.27 (m, 6H, CH_3)
UV VIS (DMSO, nm) λ_{max} 321

2-[(4-Methoxyphenylamino)methylidene]pentane-2,4-dione (IIIc, Z = 4-OMe)
There was used to a reaction 4-methoxyaniline (**Ie, Z = 4-OMe)** (0.62 g, 5 mmol) in 10 ml EtOH and enolether **IIc** (0.78 g, 5 mmol) in 20 ml EtOH. Reaction mixture was stirred for 1 h at rt. Solvent was evaporated and a raw product was purified by column chromatography (EA:H =1:1, R_F = 0.31).
Yield: 1.09 g, 95 %, light yellow solid. Mp 85—87 °C.
^{1}H NMR (300 MHz, $CDCl_3$) δ (ppm) 12.79 (br s, 1H, —NH), 8.15 (d, 1H, ^3J = 12.8 Hz, —CH═), 7.12 (d, 2H, ^3J = 8.9 Hz, H-2, H-6), 6.93 (d, 2H, ^3J = 8.9 Hz, H-3, H-5), 3.83 (s, 3H, OMe), 2.55 (s, 3H, Me), 2.37 (s, 3H, Me)
IR (ν, cm^{-1}) 2990, 1616, 1594, 1318, 1249, 979, 828
UV VIS (DMSO, nm) λ_{max} 342
Elemental analysis for $C_{13}H_{15}NO_3$ — calculated (found) (%): C 66.94 (66.78), H 6.48 (6.37), N 6.00 (5.92)

2-[(4-metoxyphenylamino)methylidene]malononitrile (IIId, Z = 4-OMe)
There was used to a reaction 4-methoxyaniline (**Ie, Z = 4-OMe**) (0.62 g, 5 mmol) in 10 ml EtOH and enolether **IId** (0.61 g, 5 mmol) in 15 ml EtOH. Reaction mixture was stirred for 30 min at rt. Raw product was collected by filtration and washed off with hexane.
Yield: 0.70 g, 70 %, light yellow powder. Mp 266—267 °C (245 °C, Rappoport et al. 1972).
^{1}H NMR (300 MHz, DMSO-d_6) δ (ppm) 11.03 (br s, 1H, —NH), 8.37 (s, 1H, —CH═), 7.35 (d, 2H, ^3J = 9.0 Hz, H-2, H-6), 6.93 (d, 2H, ^3J = 9.0 Hz, H-3, H-5), 3.74 (s, 3H, OMe)
UV VIS (DMSO, nm) λ_{max} 335
Elemental analysis for $C_{11}H_9N_3O$ — calculated (found) (%): C 66.32 (66.41), H 4.55 (4.49), N 21.09 (21.06)

Dimethyl 2-[(4-nitrophenylamino)methylidene]malonate (IIIa, Z = 4-NO_2)
There was used to a reaction 4-nitroaniline (**If, Z = 4- NO_2**) (0.69 g, 5 mmol) in 10 ml MeOH and enolether **IIa** (0.87 g, 5 mmol) in 20 ml MeOH. Reaction mixture was refluxed under regular stirring for 3 h. After its cooling raw product was collected by filtration and washed off with cold MeOH.
Yield: 0.91 g, 65 %, yellow crystalline product. Mp 156—157 °C.
^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 11.23 (br s, 1H, —NH), 8.54 (br s, 1H, —CH═), 8.25 (d, 2H, ^3J = 9.1 Hz, H-3, H-5), 7.62 (d, 2H, ^3J = 9.1 Hz, H-2, H-6), 3.88 (s, 3H, OMe), 3.82 (s, 3H, OMe)
UV VIS (DMSO, nm) λ_{max} 367
Elemental analysis for $C_{12}H_{12}N_2O_6$ — calculated (found) (%): C 51.43 (51.35), H 4.32 (4.28), N 10.00 (9.90)

Diethyl 2-[(4-nitrophenylamino)methylidene]malonate (IIIb, Z = 4-NO_2)
There was used to a reaction 4-nitroaniline (**If, Z = 4- NO_2**) (0.69 g, 5 mmol) in 10 ml EtOH and enolether **IIb** (1.1 g, 5 mmol) in 20 ml EtOH. Reaction mixture was refluxed under regular stirring for 3 h. After its cooling raw product was collected by filtration and washed off with cold EtOH.

Yield: 1.13 g, 72 %, yellow solid. Mp 136–138 °C (142 °C, Darque et al. 2009).
^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 11.20 (br s, 1H, —NH), 8.51 (s, 1H, —CH═), 8.20 (d, 2H, ^3J = 9.2 Hz, H-3, H-5), 7.60 (d, 2H, ^3J = 9.2 Hz, H-2, H-6), 4.23 (q, 2H, ^3J = 7.1 Hz, OCH_2), 4.15 (q, 2H, ^3J = 7.1 Hz, OCH_2), 1.28 (t, 3H, ^3J = 7.0 Hz, CH_3), 1.24 (t, 3H, ^3J = 7.0 Hz, CH_3)
UV VIS (DMSO, nm) λ_{max} 373

Results and discussion

To avoid geometrical isomerism on the double bond of the products of the nucleophilic vinylic substitution (Saloň et al. 2005) and therefore thus influence the kinetics of this reaction, we decided to prepare only compounds with the same substituents on the β – position of the double bond, e.g. on the opposite side to arylamino substituent. Therefore, reaction of the dimethyl methoxymethylidene malonate (IIa), diethyl ethoxymethylidene malonate (IIb), ethoxymethylidene pentane-2,4-dione (IIc) and ethoxymethylidene malononitrile (IId) respectively, with the appropriate substituted aniline in the same alcohol like alkoxy and/or ester group was used for the preparation of target compounds.

NMR spectra and the substituent chemical shifts (SCS) of the analogous anilinomethylidene (nonsubstituted) compounds

In 1989 Goljer and co-workers published carbon spectra of the appropriate anilinomethylidene (nonsubstituted) compounds IV (equal to III: Z = H) (Tab. 1, 2).

NMR spectra and the substituent chemical shifts (SCS) of the studied compounds

Applying of the published substituent chemical shifts (Ewing 1979) of the substituents of the benzene ring regarding the position of the substituent it is possible to calculate the chemical shifts of the studied compounds and compare them with measured ones to assign them. Of course, there exist some other methods like the use of plugins of the drawing programs like ISIS Draw®, ChemDraw® etc., but the used algoritm is not clear. Another alternative is the calculation using semiempirical/*ab initio* calculation methods.

In the Table 3 there are presented all our recorded ^{13}C NMR spectra in first row for each compound. In next row(s) there are presented calculated values obtained using appropriate values for aminoethylidene substituent in deuterochloroform (Table 3)/hexadeuterodimethyl sulfoxide (Table 1) and for the appropriate substituent in right position and solvent. In all cases we used also data for neat liquid (NL). In the column Reference, there are references for the work, where the spectra of the corresponding compounds were appeared first.

Substituent chemical shifts are frequently used in proton and carbon spectra for founding of the unknown values of the chemical shifts of the new synthesized substances to confirm their structure. Some of them are used like sole, some should be combined. We selected the second approach, e.g. combine SCS for monosubstituted benzenes to obtain set of datas for disubstituted benzenes. Data for proton spectra are more sensitive for solvents, for example dimethyl sulfoxide (Rao et al. 1974). Carbon data reflecting well electron distribution in the molecule and therefore SCS are in relation with electron properties of the substituents.

β,β-Disubstituted aminoethylidene substituent with two electron withdrawing groups displayed an interesting influence on benzene ring: on ipso carbon it has practically the same values like on ortho car-

Tab. 1. ^{13}C chemical shifts of the studied compounds IV in DMSO-d_6.

Compound	C – 1	C – 2	C – 3	C – 4	C – 7	C – 8	Others
IVa	139.3	117.6	129.6	124.7	151.4	92.6	165.2, 167.5, 51.0, 50.9
IVb	139.3	117.3	129.6	124.6	150.9	93.6	165.0, 167.4
IVc	139.0	118.1	129.3	125.3	155.5	52.0	116. 3, 113.9
IVd	139.0	118.2	129.5	125.2	152.6	112.4	195.1, 199.4, 27.4, 31.4

Tab. 2. Substituent chemical shifts of the studied compounds IV in DMSO-d_6.

Compound	C – 1	C – 2	C – 3	C – 4
IVa	+10.5	–10.3	+1.0	–3.3
IVb	+10.5	–10.4	+0.8	–3.2
IVc	+10.8	–10.9	+1.1	–3.8
IVd	+10.8	–11.2	+1.1	–3.9

Tab. 3. ^{13}C NMR spectra of arylaminomethylidene derivatives III.

Compound No.	Z	Solvent	C-1	C-2	C-3	C-4	C-5	C-6	Other signals	Reference
IIIa	H	$CDCl_3$	139.0	117.2	129.0	125.1	129.0	117.2	51.4, 51.6, 92.8, 152.2, 166.0, 169.3	Mohri et al. 1999
IIIb	H	$CDCl_3$	139.2	117.2	129.7	124.9	129.7	117.2	14.3, 14.5, 60.1, 60.4, 93.3, 152.2, 165.9, 169.2	Loupy et al. 2005
IIIc	H	$CDCl_3$	138.5	117.3	129.5	125.3	129.5	117.3	26.9, 31.6, 112.7, 151.4, 194.4, 200.5	Hansen et al. 1995
IIId	H	DMSO-d_6	139.7	118.5	129.9	125.6	129.9	118.5	52.2, 114.7, 117.0, 156.3	Goljer et al. 1989
	3-Cl	$CDCl_3$	140.3	117.2	135.7	125.0	130.9	115.4		
IIIa	Calc.	$CDCl_3$	140.4	117.6	135.3	125.5	130.4	117.3	51.6, 51.7, 93.9, 151.7, 165.7, 169.2	This work
	Calc.	NL	140.0	117.4	135.4	125.3	130.0	117.2		
	3-Cl	$CDCl_3$	140.0	116.7	135.2	124.3	130.4	114.8		
IIIb	Calc.	$CDCl_3$	140.6	117.6	136.0	125.3	131.1	115.3	13.8, 13.9, 59.8, 60.1, 94.2, 150.8, 165.0, 168.4	This work
	Calc.	NL	140.2	117.4	136.1	125.1	130.7	115.2		
	3-Cl	DMSO-d_6	140.7	118.0	134.1	124.8	131.1	117.3		
IIIc	Calc.	DMSO-d_6	141.0	118.2	134.2	125.4	131.3	116.9	27.6, 31.6, 113.0, 152.5, 195.5, 199.7	This work
	Calc.	NL	140.0	118.3	135.7	125.5	130.3	116.1		
	3-Cl	DMSO-d_6	141.0	118.1	134.4	125.2	131.4	117.2		
IIId	Calc.	DMSO-d_6	141.0	118.3	134.4	125.3	131.5	117.0	53.4, 114.3, 116.6, 156.4	This work
	Calc.	NL	140.0	118.4	135.9	125.4	130.5	116.2		
IIIa	4-Br	DMSO-d_6	139.4	120.4	132.7	117.1	132.7	120.4	51.6, 93.7, 151.6, 160.0	This work
	Calc.	NL	138.3	119.8	132.9	119.3	132.9	119.8		
IIIb	4-Br	DMSO-d_6	139.4	120.2	132.7	116.9	132.7	120.2	14.6, 14.7, 60.0, 60.2, 94.4, 151.2, 165.3, 167.6	Lager et al. 2006
	Calc.	NL	138.3	119.5	132.9	119.2	132.9	119.5		
	4-Br	$CDCl_3$	138.2	118.6	133.0	119.3	133.0	118.6		
IIIc	Calc.	$CDCl_3$	136.9	118.9	132.7	119.5	132.7	118.9	27.4, 32.1, 113.7, 151.3, 194.8, 201.3	This work
	Calc.	NL	137.5	119.5	132.8	119.9	132.8	119.5		
IIId	4-Br	DMSO-d_6	138.8	120.1	132.2	117.2	132.2	120.1	52.4, 114.1, 116.4, 155.8	This work
	Calc.	NL	138.0	120.4	132.8	119.8	132.8	120.4		
	4-Me	$CDCl_3$	136.7	117.3	130.3	135.0	130.3	117.3		
IIIa	Calc.	$CDCl_3$	136.0	117.1	129.7	134.3	129.7	117.1	20.8, 51.4, 51.5, 92.2, 152.5, 166.1, 169.4	This work
	Calc.	NL	136.1	117.3	129.8	134.2	129.8	117.3		
	4-Me	$CDCl_3$	136.9	117.2	130.3	134.8	130.3	117.2		
IIIb	Calc.	$CDCl_3$	136.2	117.1	130.4	134.1	130.4	117.1	14.3, 14.5, 20.8, 60.0, 60.3, 92.9, 152.2, 165.9, 169.2	Matta et al. 1996
	Calc.	NL	136.3	117.3	130.3	134.0	130.3	117.3		
	4-Me	$CDCl_3$	138.0	119.3	131.9	137.2	131.9	119.3		
IIIc	Calc.	$CDCl_3$	135.5	117.2	130.2	134.5	130.2	117.2	22.3, 28.8, 33.5, 114.4, 153.5, 196.2, 202.4	This work
	Calc.	NL	135.6	117.4	130.1	134.4	130.1	117.4		

Tab. 3 continue. ^{13}C NMR spectra of arylaminomethylidene derivatives III.

Compound No.	Z	Solvent	C-1	C-2	C-3	C-4	C-5	C-6	Other signals	Reference
	4-Me	DMSO-d_6	137.3	118.5	130.3	135.0	130.3	118.5		
IIId	Calc.	DMSO-d_6	136.0	118.1	130.1	134.2	130.1	118.1	20.8, 51.4, 114.8, 117.1, 156.1	This work
	Calc.	NL	136.1	118.3	130.1	134.3	130.1	118.3		
	4-OMe	$CDCl_3$	132.6	115.0	118.9	153.0	118.9	115.0		
IIIa	Calc.	$CDCl_3$	131.3	118.2	114.6	156.5	114.6	118.2	51.4, 51.5, 55.6, 91.8, 157.3, 166.1, 169.5	Zewge et al. 2007
	Calc.	NL	130.9	118.1	114.3	155.3	114.3	118.1		
	4-OMe	$CDCl_3$	132.7	114.9	118.8	152.6	118.8	114.9		
IIIb	Calc.	$CDCl_3$	131.5	118.2	115.3	156.6	115.3	118.2	14.3, 14.4, 55.5, 59.9, 60.2, 92.4, 157.1, 165.8, 169.2	This work
	Calc.	NL	131.1	118.1	115.0	155.1	115.0	118.1		
	4-OMe	$CDCl_3$	133.8	120.9	116.5	159.2	116.5	120.9		
IIIc	Calc.	$CDCl_3$	130.8	118.3	115.1	156.7	115.1	118.3	28.8, 33.4, 57.0, 114.2, 153.9, 196.1, 202.3	This work
	Calc.	NL	130.4	118.2	114.8	155.5	114.8	118.2		
	4-OMe	DMSO-d_6	132.5	119.6	116.8	155.7	116.8	119.6		
IIId	Calc.	DMSO-d_6	131.1	119.4	115.1	156.2	115.1	119.4	50.3, 55.3, 114.5, 156.9	Mukhopadhyaya et al. 2000
	Calc.	NL	130.9	119.1	114.8	155.4	114.8	119.1		
	4-NO_2	$CDCl_3$	144.3	116.5	126.0	144.0	126.0	116.5		
IIIa	Calc.	$CDCl_3$	145.1	118.1	124.1	145.0	124.1	118.1	51.9, 52.0, 96.5, 150.2, 165.2, 168.9	This work
	Calc.	NL	144.8	118.1	123.8	144.7	123.8	118.1		
	4-NO_2	$CDCl_3$	144.5	116.3	126.0	143.8	126.0	116.3		
IIIb	Calc.	$CDCl_3$	145.3	118.1	124.8	144.8	124.8	118.1	14.2, 14.3, 60.6, 61.0, 97.3, 149.7 165.0, 168.5	Kim et al. 2010
	Calc.	NL	145.4	118.1	124.5	144.5	124.5	118.1		

$CDCl_3$ — deuterochloroform, DMSO-d_6 — hexadeuterodimethylsulfoxide, NL — neat liquid data from Ewing 1979.

bons, but reversal sign. It is not so strong effect like the amino group, but slighly similar to aminoacetyl group, thus similar to aminogroup substituted with polarized double bond. The obtained data are in good agreement with calculated ones within small range of deviations what is confirming the accuracy of the used method. On the other hand, meta- and para-substitution does not twisting the aminoethylidene substituent off of the plane of the benzene ring. In Table 3 are presented ^{13}C NMR data of the products III obtained from nucleophilic vinylic substitution of substituted anilines I and activated enolethers II.

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