HETEROCYCLES, Vol. 65, No. 6, 2005, pp. 1481 - 1490
Received, 16th March, 2005, Accepted, 14th April, 2005, Published online, 15th April, 2005

# RING TRANSFORMATION OF DIMETHOXYBENZENES TO HETEROCYCLES BY OZONOLYSIS

Yuki Yoshida,* Satoshi Ichikawa, Yuka Shinozuka, Mitsuru Satoh, Kunihiko Mohri, and Kimiaki Isobe

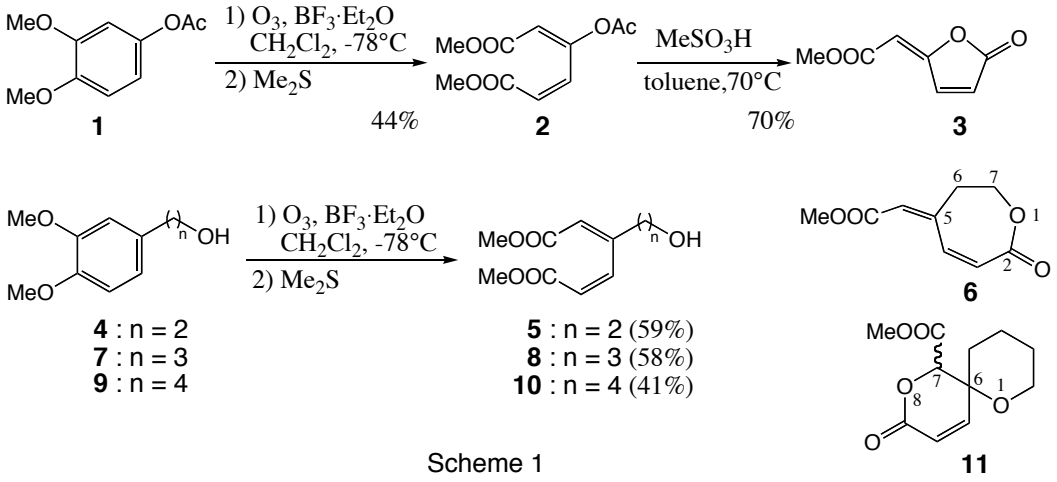
Showa Pharmaceutical University, 3-3165 Higashi-tamagawagakuen, Machida, Tokyo 194-8543, Japan

**Abstract** – Dimethoxybenzene derivatives, which have a hydroxyalkyl or an aminoalkyl side-chain, were oxidized with ozone and transformed to heterocycles by ring closure reaction of the oxidative products.

While ozone, a strong oxidant well known for cleaving carbon-carbon double bonds, has been used in structural determination and synthesis of organic compounds, reports on ozonolysis of aromatic rings are infrequent.[1-3] As described in a previous study, 3,4-dimethoxybenzyl alcohol was ozonized in the presence of $BF_3$-$Et_2O$ to obtain an unsaturated □-lactone.[4] Herein we wish to report the ozonolytic cleavage of *o*-dimethoxybenzenes having a hydroxyalkyl or an aminoalkyl side-chain, and their transformation to heterocycles such as unsaturated lactones or lactams.

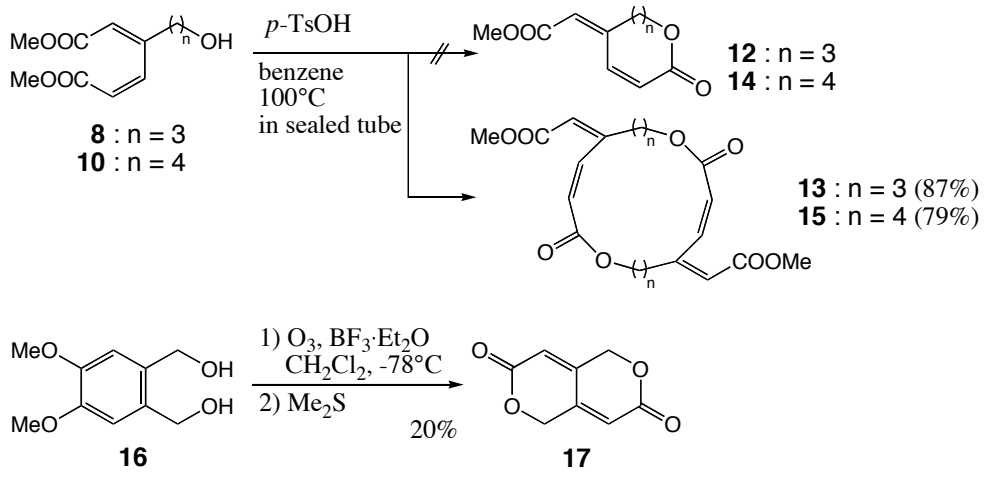
First, ozonolysis of 3,4-dimethoxyphenyl acetate (**1**) in $CH_2Cl_2$ at -78 °C in the presence of $BF_3$-$Et_2O$ gave the dimethyl muconate (**2**) in 32% yield. Heating of **2** with methanesulfonic acid in toluene at 70 °C for 5 h gave the unsaturated □-lactone (**3**)[5] in 70% yield. Ozonolysis of 3,4-dimethoxyphenethyl alcohol (**4**) gave the dimethyl muconate derivative (**5**) and the unsaturated □-lactone (**6**) in 59% and 15% yields,

respectively. Treatment of **5** with trifluoroacetic acid at room temperature afforded **6** in 82% yield.[6] The NOESY spectrum of **6** showed a correlation between exo olefinic proton and H-6. Therefore the configuration of double bond must be the *Z*-form; other two-dimensional NMR spectral data also support this structure.




Scheme 1

Dimethyl muconates (**8**, **10**) were also obtained by ozonolysis of corresponding alcohols (**7**, **9**) under the same conditions in moderate yields. In the reaction of **9**, a small amount of spirolactone (**11**), a higher oxidized product than **10**, was formed as by-product. The configuration of ester group in **11** could not be clarified. Dimethyl muconate derivatives (**8** and **10**) were expected to give the eight-membered ring compound (**12**) and nine-membered ring compound (**14**), respectively. Heating of **8** with *p*-toluenesulfonic acid in benzene at 100 °C (in a sealed tube) gave a colorless oily product. Its structure

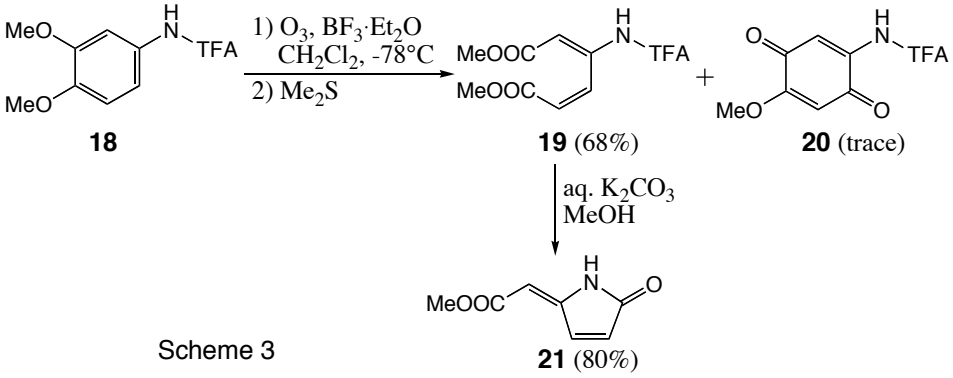



Scheme 2

was identified as dilactone (**13**) from the MS and other spectral data. Similar treatment of **10** gave dilactone (**15**) in 79% yield. The structure of dilactones (**13**, **15**) was determined in a similar way where exo olefinic proton also exhibited a NOESY correlation with adjacent methylene protons showing that the configuration of double bond is *Z*. Also, ozonolysis of a dimethoxybenzene having two hydroxymethyl groups (**16**)[7] gave bicyclic lactone (**17**) in a low yield.

Next, ozonolysis of 3,4-dimethoxybenzene derivatives having an aminoalkyl group was carried out. Ozonolysis of *N*-(3,4-dimethoxyphenyl)-2,2,2-trifluoroacetamide (**18**) afforded dimethyl muconate derivative (**19**) in 68% yield accompanied by a small amount of *p*-quinone (**20**). Treatment of **19** with aqueous potassium carbonate in MeOH at room temperature afforded the expected □-lactam **(21)** in 80% yield. Similarly, *N*-[(3,4-dimethoxyphenyl)methyl]-2,2,2-trifluoroacetamide (**22**) gave the corresponding muconate (**23**) in 51% yield, which was then transformed into a lactam by esterification with HCl gas-MeOH after hydrolysis of the protecting group with aqueous potassium carbonate. In this case, isomerization of the double bond occurred and afforded 2-pyridone (**24**) in 55% yield.

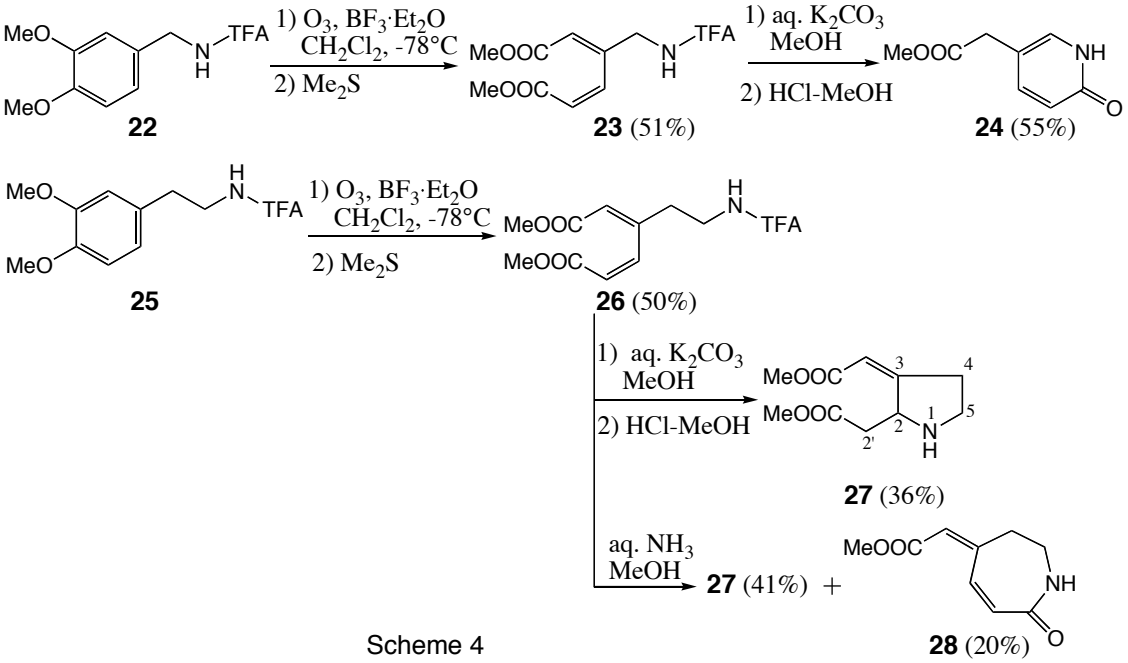
Dimethyl muconate (**26**) was also obtained by ozonolysis of phenylethylamine derivative (**25**) by the same procedure. On deprotection of the trifluoroacetyl group in **26** in the same way, a Michael-type reaction proceeded to give **27**. While **27** was the main product when the deprotection reaction was done in 10%$NH_3$-MeOH, the expected seven-membered lactam (**28**) was also obtained in 20% yield. Compounds **27** and **28** were also analyzed by the NOESY spectrum and other two-dimensional NMR spectral data.




**18** **19** (68%) **20** (trace)

**21** (80%)

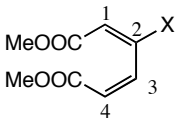
Scheme 3




Scheme 4

In conclusion, we were able to obtain some heterocycles such as unsaturated lactones and lactams, and dilactones from dimethoxybenzene derivatives that have a hydroxyalkyl or an aminoalkyl group on a side-chain, by ozonolysis followed by ring closure reaction of the muconates.

Table 1. $^{13}$C-NMR Spectral Data for Muconate Derivatives (in $CDCl_3$)




| Carbon | **2** | **5** | **8** | **10** | **19** | **23** | **26** |
|---|---|---|---|---|---|---|---|
| 1 | 113.2 | 118.9 | 116.2 | 116.3 | 113.8 | 119.6 | 118.0 |
| 2 | 155.6 | 152.8 | 156.9 | 157.3 | 141.4 | 150.2 | 151.7 |
| 3 | 130.6 | 144.2 | 146.0 | 145.7 | 135.7 | 142.6 | 144.0 |
| 4 | 124.4 | 120.9 | 119.5 | 119.5 | 122.1 | 121.7 | 120.7 |
| CO | 167.6 | 166.6 | 166.2 | 166.3 | 168.4 | 166.7 | 166.1 |
| | 166.0 | 165.8 | 165.9 | 165.8 | 166.6 | 165.4 | 165.4 |
| | 165.3 | | | | | | |
| N-<u>C</u>O-$CF_3$ | | | | | 156.0 [a] | 157.3 [a] | 157.3 [a] |
| N-CO-<u>C</u>$F_3$ | | | | | 115.4 [b] | 115.8 [b] | 115.6 [b] |
| OMe | 51.8 | 51.8 | 51.5 | 51.4 | 53.0 | 51.9 | 51.3 |
| | 51.7 | 51.3 | 51.2 | 51.1 | 51.8 | 51.6 | 50.9 |
| <u>C</u>$H_2$OH | | 59.6 | 61.6 | 62.4 | | | |
| $CH_2$ | | 40.8 | 33.6 | 37.3 | | 44.2 | 36.9 |
| | | | 30.3 | 32.1 | | | 35.8 |
| | | | | 24.2 | | | |
| $CH_3$ | 20.6 | | | | | | |

a) $J_{CCF}$ =37-39 Hz b) $J_{CF}$ =287-289 Hz

## EXPERIMENTAL

Unless otherwise stated, the following procedure was adopted. Melting points were determined on a

Yanaco micro-melting point apparatus and are uncorrected. IR spectra were recorded on a JASCO IR-810 spectrophotometer and data are given in $cm^{-1}$. $^1H$- and $^{13}C$-NMR spectra were obtained with a JEOL JNM-EX90, a JEOL JNM-AL300 or a JNM-□500 spectrometer in $CDCl_3$ solutions with TMS as an internal standard and the chemical shifts are given in □ values. MS and HRMS were obtained with a JEOL JMS D-300 and JEOL JMS-HX110A spectrometers. NCIMS were obtained with a SHIMADZU GCMS-QP5050A spectrometer. Elemental analyses were performed with a Thermo Quest FlashEA 1112 microanalyzer.

**Ozonolysis of *o*-Dimethoxybenzene Derivatives. General Procedure** --- Ozone was generated with an ozone generator ("ON-1-2 Type", Nihon Ozone Co., Ltd.), using commercial-grade oxygen as a source. The flow rate of oxygen was 50 mL/min, and the voltage was adjusted to 80 V. Ozonized oxygen was passed into a solution of the dimethoxybenzene derivatives (1.0 mmol) and $BF_3$-$Et_2O$ (170 mg, 1.2 mmol) in $CH_2Cl_2$ (20 mL) at -78 °C until the starting material disappeared on TLC. After the excess ozone was removed by suction with an aspirator, methyl sulfide (1 mL) was added to the solution and the temperature was raised to rt gradually. The reaction mixture was diluted with $CH_2Cl_2$ (20 mL), washed with brine, dried over anhydrous $Na_2SO_4$ or $MgSO_4$, and concentrated *in vacuo*. The residue was purified by silica gel chromatography (AcOEt) and/or by crystallization.

**2**: Yellow oil. IR ($CHCl_3$): 1715, 1713, 1710. $^1H$-NMR: 7.37 (1H, d, *J*=12.6 Hz, olefinic H), 6.03 (1H, d, *J*=12.6 Hz, olefinic H), 5.84 (1H, s, olefinic H), 3.75 (3H, s, OMe), 3.74 (3H, s, OMe), 2.17 (3H, s, $OCOCH_3$). LR-EIMS *m*/*z*: 228 ($M^+$).

**5**: Yellow oil. IR ($CHCl_3$): 3500, 1720, 1718. $^1H$-NMR: 6.85 (1H, d, *J*=11.8 Hz, olefinic H), 6.00 (1H, d, *J*=11.8 Hz, olefinic H), 5.88 (1H, s, olefinic H), 3.87 (2H, m, $CH_2OH$), 3.71 (3H, s, OMe), 3.66 (3H, s, OMe), 2.57 (2H, t, *J*=5.8 Hz, $CH_2$). LR-EIMS *m*/*z*: 214 ($M^+$).

**8**: Colorless oil. IR ($CHCl_3$): 3523, 1720. $^1H$-NMR: 7.09 (1H, dd, *J*=12.3, 0.9 Hz, olefinic H), 5.91 (1H, d, *J*=12.3 Hz, olefinic H), 5.79 (1H, d, *J*=0.9 Hz, olefinic H), 3.69 (2H, t, *J*=6.9 Hz, $CH_2OH$), 3.69 (3H, s,

OMe), 3.67 (3H, s, OMe), 2.50 (2H, t, *J*=7.5 Hz, $CH_2$), 1.82-1.73 (2H, m, $CH_2$). HR-EIMS *m/z*: Calcd for $C_{11}H_{16}O_5$: 228.0998; Found 228.0969.

**10**: Colorless oil. IR ($CHCl_3$): 3460, 1718. $^1$H-NMR: 7.01 (1H, dd, *J*=12.4 Hz, olefinic H), 5.90 (1H, d, *J*=12.4 Hz, olefinic H), 5.77 (1H, s, olefinic H), 3.69 (3H, s, OMe), 3.67 (3H, s, OMe), 3.65-3.62 (2H, m, $CH_2OH$), 2.43 (2H, t, *J*=6.4 Hz, $CH_2$), 1.72 (1H, br s, OH), 1.60-1.56 (4H, m, $CH_2$). LR-EIMS *m/z*: 242 ($M^+$).

**11**: Light yellow oil. IR (KBr): 1705. $^1$H-NMR: 6.90 (1H, dd, *J*=10.1, 0.9 Hz, olefinic H), 6.19 (1H, d, *J*=10.1 Hz, olefinic H), 5.06 (1H, s, H-7), 3.83-3.62 (2H, m, $CH_2O$), 3.77 (3H, s, OMe), 1.90-1.48 (6H, m, $CH_2$). $^{13}$C-NMR: 167.8, 161.3 (s, C=O), 142.7, 123.4 (d, olefinic C), 81.9 (d, C-7), 68.2(s, C-6), 62.7 (t, $CH_2O$), 52.8 (q, OMe), 30.0, 24.9, 18.3 (t, $CH_2$). HR-EIMS *m/z*: Calcd for $C_{11}H_{14}O_5$: 226.0841; Found 226.0876.

**17**: Colorless needles. mp 120-124 °C (AcOEt-MeOH). IR (KBr): 1710. $^1$H-NMR: 6.10 (2H, t, *J*=1.5 Hz, olefinic H), 5.25 (4H, d, *J*=1.5 Hz, $CH_2O$). $^{13}$C-NMR: 160.5 (s, C=O), 141.2 (s, $\underline{C}$=CH), 116.8 (d, olefinic C), 67.2 (t, $CH_2O$). NCIMS *m/z*: 166 ($M^+$). *Anal. Calcd* for $C_8H_6O_4$: C, 57.83; H, 3.64. Found: C, 58.09; H, 3.66.

**19**: Yellow oil. IR ($CHCl_3$): 1720, 1710. $^1$H-NMR: 12.45 (1H, br s, NH), 8.09 (1H, d, *J*=13.8 Hz, olefinic H), 7.36 (1H, s, olefinic H), 6.08 (1H, d, *J*=13.8 Hz, olefinic H), 3.85 (3H, s, OMe), 3.76 (3H, s, OMe). NCIMS *m/z*: 281 ($M^+$).

**20**: Yellow needles. mp 130-133 °C (AcOEt-hexane). IR (KBr): 3340, 1750, 1675, 1658. $^1$H-NMR: 8.97 (1H, br s, NH), 7.51 (1H, s, olefinic H), 6.02 (1H, s, olefinic H), 3.91 (3H, s, OMe). $^{13}$C-NMR: 181.3, 181.1 (s, C=O), 160.1(s), 155.5 (q, $^2J_{C,F}$=39 Hz, $\underline{C}OCF_3$), 136.9 (s), 115.4, 104.5 (d, olefinic C), 114.8 (q, $^1J_{C,F}$=288 Hz, $CO\underline{C}F_3$), 56.9 (q, OMe). NCIMS *m/z*: 249 ($M^+$).

**23**: Yellow oil. IR ($CHCl_3$): 3430, 1720. $^1$H-NMR: 7.45 (1H, br s, NH), 7.08 (1H, d, *J*=12.0 Hz, olefinic H), 6.04 (1H, d, *J*=12.0 Hz, olefinic H), 5.39 (1H, s, olefinic H), 4.21 (2H, d, *J*=6.0 Hz, $CH_2$), 3.74 (3H, s,

OMe), 3.70 (3H, s, OMe). NCIMS *m/z*: 295 ($M^+$).

**26**: Yellow oil. IR ($CHCl_3$): 1715, 1713, 1710. $^1$H-NMR: 8.10 (1H, t, *J*=6.1 Hz, NH), 6.96 (1H, dd, *J*=12.3, 1.2 Hz, olefinic H), 6.02 (1H, d, *J*=12.3 Hz, olefinic H), 5.80 (1H, d, *J*=1.2 Hz, olefinic H), 3.72 (3H, s, OMe), 3.70 (3H, s, OMe), 3.55 (2H, q, *J*=6.1 Hz, $CH_2$), 2.64 (2H, t, *J*=6.1 Hz, $CH_2$). NCIMS *m/z*: 309 ($M^+$).

**Reaction of dimethyl muconate (2) with methanesulfonic acid** --- A solution of **2** (10 mg, 0.04 mmol) and methanesulfonic acid (1 drop) in toluene (1 mL) was heated at 70 °C for 5 h. After cooling, the reaction mixture was purified by silica gel (CC-7) column chromatography with AcOEt-hexane (1:4) to give **3** (5 mg, 70%).

**3**: Light yellow gum (lit.,[5] mp 81.5-82 °C). IR ($CHCl_3$): 1719, 1710. $^1$H-NMR: 8.38 (1H, d, *J*=5.5 Hz, olefinic H), 6.47 (1H, d, *J*=5.5 Hz, olefinic H), 5.94 (1H, m, olefinic H), 3.81 (3H, s, OMe). $^{13}$C-NMR: 167.6, 165.2 (s, C=O), 160.4 (s, C=CH), 141.9, 124.4, 102.1 (d, olefinic C), 52.0 (q, OMe). HR-EIMS *m/z*: Calcd for $C_7H_6O_4$: 154.0266; Found 154.0263.

**Reaction of dimethyl muconate (5) with methanesulfonic acid** --- A solution of **5** (10 mg, 0.05 mmol) and trifluoroacetic acid (1 drop) in toluene (1 mL) was stirred at rt for 14 h. The reaction mixture was purified by silica gel column chromatography with AcOEt-hexane (1:2) to give **6** (7 mg, 82%).

**6**: Colorless needles. mp 122-125 °C (AcOEt-hexane). IR (KBr): 1705, 1685, 1631 $^1$H-NMR: 8.09 (1H, d, *J*=12.6 Hz, olefinic H), 6.14 (1H, d, *J*=12.6 Hz, olefinic H), 5.88 (1H, s, olefinic H), 4.37 (2H, m, $CH_2O$), 3.75 (3H, s, OMe), 2.94 (2H, m, $CH_2$). $^{13}$C-NMR: 167.4, 165.3 (s, C=O), 148.8 (s, C=CH), 134.8, 124.2, 123.1 (d, olefinic C), 65.6 (t, $CH_2O$), 51.8 (q, OMe), 37.3 (t, $CH_2$). HR-EIMS *m/z*: Calcd for $C_9H_{10}O_4$: 182.0578; Found 182.0568. *Anal. Calcd* for $C_9H_{10}O_4$: C, 59.33; H, 5.53. Found: C, 59.39; H, 5.54.

**Reaction of dimethyl muconate (8) with *p*-toluenesulfonic acid** --- A solution of **8** (35 mg, 0.15 mmol) and *p*-toluenesulfonic acid monohydrate (10 mg) in benzene (10 mL) was heated at 100 °C in a sealed tube for 10 h. The reaction mixture was washed with brine, dried over anhydrous $Na_2SO_4$, and

concentrated *in vacuo*. The residue was purified by silica gel chromatography with AcOEt-hexane (1:1) to give **13** (26 mg, 87%).

**13**: Colorless oil. IR ($CHCl_3$): 1712. $^1$H-NMR: 8.08 (2H, d, *J*=13.0 Hz, olefinic H), 5.93 (2H, dd, *J*=13.0, 1.4 Hz, olefinic H), 5.89-5.88 (2H, m, olefinic H), 4.36 (4H, t, *J*=5.9 Hz, $CH_2O$), 3.75 (6H, s, OMe), 2.48 (4H, t, *J*=6.3 Hz, $CH_2$), 1.99-1.91 (4H, m, $CH_2$). $^{13}$C-NMR: 169.3, 165.6 (s, C=O), 149.8 (s, C=CH), 133.8, 123.5, 120.8 (d, olefinic C), 66.5 (t, $CH_2O$), 51.6 (q, OMe), 30.4, 29.8 (t, $CH_2$). NCIMS *m*/*z*: 392 ($M^+$).

**Reaction of dimethyl muconate (10) with *p*-toluenesulfonic acid** --- A solution of **10** (35 mg, 0.14 mmol) and *p*-toluenesulfonic acid monohydrate (10 mg) in benzene (10 mL) was heated at 100 °C in a sealed tube for 10 h. The reaction mixture was worked up as described above to give **15** (24 mg, 79%).

**15**: Colorless oil. IR ($CHCl_3$): 1790, 1718. $^1$H-NMR: 7.49 (2H, dd, *J*=11.4, 2.0 Hz, olefinic H), 5.99 (2H, dd, *J*=11.4, 0.8 Hz, olefinic H), 5.78-5.77 (2H, m, olefinic H), 4.36 (4H, t, *J*=5.7 Hz, $CH_2O$), 3.72 (6H, s, OMe), 2.32-2.28 (4H, m, $CH_2$), 1.90-1.72 (8H, m, $CH_2$). $^{13}$C-NMR: 167.0, 166.6 (s, C=O), 158.3 (s, C=CH), 146.9, 122.1, 117.0 (d, olefinic C), 65.8 (t, $CH_2O$), 51.3 (q, OMe), 39.3, 27.3, 27.2 (t, $CH_2$). NCIMS *m*/*z*: 420 ($M^+$).

**Reaction of dimethyl muconate (19) with aqueous potassium carbonate** --- A solution of **19** (281 mg, 1 mmol) and 17% $K_2CO_3$ aq (2 mL) in MeOH (20 mL) was stirred at rt for 1 h. The mixture was concentrated, and the residue was extracted with $CH_2Cl_2$ and the extract was washed with brine, dried over anhydrous $Na_2SO_4$, and concentrated *in vacuo*. The residue was purified by short silica gel chromatography with AcOEt and recrystallization to give **21** (122 mg, 80%).

**21**: Colorless needles. mp 151-152 °C (AcOEt-hexane). IR (KBr): 3310, 1708, 1700, 1650. $^1$H-NMR: 12.45 (1H, br s, NH), 8.09 (1H, d, *J*=13.8 Hz, olefinic H), 7.36 (1H, s, olefinic H), 6.08 (1H, d, *J*=13.8 Hz, olefinic H), 3.85 (3H, s, OMe), 3.76 (3H, s, OMe). $^{13}$C-NMR: 172.4 (s, C=O), 166.6 (s), 166.1 (s, C=O), 112.1 (d, olefinic C), 57.5 (d), 51.7 (q, OMe), 51.2 (q, OMe), 43.7 (t), 38.0 (t), 35.3 (t). NCIMS *m*/*z*: 153

($M^+$). *Anal. Calcd* for $C_7H_7NO_3$: C, 54.90; H, 4.61; N, 9.15. Found: C, 55.05; H, 4.69; N, 9.02.

**Reaction of dimethyl muconate (23) with aqueous potassium carbonate** --- A solution of **23** (60 mg, 0.2 mmol) and 17% $K_2CO_3$ (1 mL) in MeOH (5 mL) was stirred at 40 °C for 20 h. The mixture was acidified with 10% HCl and concentrated to dryness, the residue was purified by ODS chromatography. MeOH eluate was concentrated *in vacuo* and the residue was treated with HCl gas-MeOH at rt. The mixture was concentrated, and purified by ODS chromatography again to give **24** (38 mg, 55%).

**24**: Colorless needles. mp 103-106 °C (AcOEt-hexane). IR (KBr): 1740, 1670. $^1$H-NMR: 7.46 (1H, d, *J*=9.2 Hz, olefinic H), 7.31 (1H, s, olefinic H), 6.60 (1H, d, *J*=9.2 Hz, olefinic H), 3.71 (3H, s, OMe), 3.41 (2H, s, $CH_2$). $^{13}$C-NMR: 171.2, 164.7 (s, C=O), 143.6, 133.9, 120.0 (d, olefinic C), 113.2 (s), 52.2 (q, OMe), 36.6 (t, $CH_2$). HR-EIMS *m/z*: Calcd for $C_8H_9NO_3$: 167.0580; Found 167.0574. *Anal. Calcd* for $C_8H_9NO_3$: C, 57.48; H, 5.43; N, 8.38. Found: C, 57.67; H, 5.54; N, 8.22.

**Reaction of dimethyl muconate (26) with aqueous potassium carbonate** --- A solution of **26** (100 mg, 0.32 mmol) and 17% $K_2CO_3$ (6 mL) in MeOH (8 mL) was stirred at 40 °C for 30 h. The mixture was acidified with 10% HCl and concentrated to dryness. The mixture was diluted with $CHCl_3$ and filtered. The filtrate was concentrated to dryness; the resulted residue was treated with HCl gas-MeOH at rt. The mixture was concentrated, and purified by silica gel chromatography with AcOEt-hexane (1:1) to give **27** (25 mg, 36%).

**27**: Brown gum. IR ($CHCl_3$): 1720. $^1$H-NMR: 5.86 (1H, m, olefinic H), 4.79 (1H, dd, *J*=5.9, 0.8 Hz, H-2), 3.71(3H, s, OMe), 3.69 (3H, s, OMe), 3.09-3.00 (2H, m, H-5), 2.92-2.88, 2.49-2.44 (each 1H, m, H-2'), 2.74-2.53 (2H, m, H-4), 2.27 (1H, br s, NH). $^{13}$C-NMR: 172.4, 166.1 (s, C=O), 166.6 (s), 112.1 (d, olefinic C), 57.5 (d, C-2), 51.7 (q, OMe), 51.2 (q, OMe), 43.7 (t, C-5), 38.0 (t, C-2'), 35.3 (t, C-4). HR-EIMS *m/z*: Calcd for $C_{10}H_{15}NO_4$: 213.1001; Found 213.1031.

**Reaction of dimethyl muconate (26) with ammonia water** --- A solution of **26** (100 mg, 0.32 mmol) and 28% $NH_3$ (6 mL) in MeOH (10 mL) was stirred at rt for 14 h. The mixture was concentrated to

dryness and extracted with $CHCl_3$. The extracts was washed with brine, dried over anhydrous $Na_2SO_4$, and concentrated *in vacuo*. The residue was purified by silica gel (CC-7) chromatography with AcOEt-hexane (1:1) to give **27** (28 mg, 41%) and **28** (12 mg, 20%).

**28**: Yellow gum. IR ($CHCl_3$): 1735, 1710. $^1$H-NMR ($CDCl_3$): 7.92 (1H, dd, *J*=12.9, 0.6 Hz, olefinic H), 7.17 (1H, br s, NH), 6.04-5.98 (1H, m, olefinic H), 5.73 (1H, br s, olefinic H), 3.67 (3H, s, OMe), 3.33-3.27 (2H, m, $CH_2$), 2.73-2.69 (2H, m, $CH_2$). $^{13}$C-NMR: 169.5,165.6 (s, C=O), 150.6 (s), 132.5, 128.6, 123.0 (d, olefinic C), 51.6 (q, OMe), 39.6, 38.8 (t, $CH_2$). NCIMS *m/z*: 181 ($M^+$).

## REFERENCES AND NOTES

1. H. Rapoport and G. B. Payne, *J. Org. Chem.*, 1950, **15**, 1093.
2. R. B. Woodward, M. P. Cava, W. D. Ollis, A. Hunger, H. U. Daeniker, and K. Schenker, *Tetrahedron*, 1963, **19**, 247.
3. P. R. R. Costa, S. Pinheiro, and C. C. Lopes, *Tetrahedron Lett.*, 1985, **26** (35), 4155.
4. K. Isobe, K. Mohri, K. Tokoro, C. Fukushima, F. Higuchi, J. Taga, and Y. Tsuda, *Chem. Pharm. Bull.*, 1988, **36** (4), 1275.
5. E. Vilen, D. W. Reeve, and A. B. McKague, *Holzforschung*, 1996, **50**, 575; K. Nagai, K, Akiyama, and N. Kuramoto, *J. Polym. Sci.*, 1986, **24**, 197.
6. The yield of **6** was low when methanesulfonic acid was used.
7. M. A. A. Meziane, S. Royer, and J. P. Bazureau, *Tetrahedron Lett.*, 2001, **42**, 1017.