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A SOLVENT-FREE METHOD FOR SUBSTITUTED IMIDAZOLIDIN-4-ONES SYNTHESIS

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Abstract – A new method of the solvent-free synthesis of substituted imidazolidin-4-ones is described. The method is developed for microwave-assisted solvent-free conditions and compared with classical thermally initiated solvent-free conditions. In both cases the reaction proceeds with good yields. However, the reaction under microwave conditions is accelerated six-times. Thermal effect of the microwaves is observed.

Application of syntheses under solvent-free conditions belongs to one of the fast growing application in organic synthesis.[1] Higher environmental safety of such reactions as well as improvement of economy are reflected in importance of these syntheses.

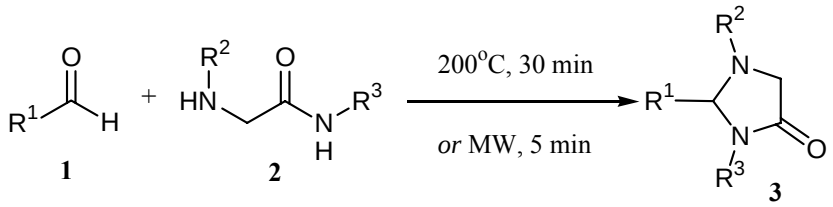
In our paper, we have focused on synthesis of substituted imidazolidin-4-ones (**3**). Such compounds are a versatile synthons for syntheses of α-amino acids[2] and di- or tripeptides.[3] The most known skeleton containing imidazolidin-4-one motive is Seebach's reagent.[4]

Already published reactions leading to imidazolidin-4-ones (**3**) are carried out in different solvents (generally CH_2Cl_2) and proceed usually within 1 and 11 h. The yields of the reactions vary from moderate to good.[5,6] Here, a new developed procedure of a simple, rapid and one-pot method for a conversion of *N*-substituted α-amino acid amides (**2**) and aldehyde (**1**) into corresponding imidazolidin-4-one (**3**) at solvent-free conditions is described (**Scheme 1**). The desired imidazolidin-4-ones (**3**) are under our reaction conditions formed in good yields (**Table**).

Two different procedures under solvent-free conditions are found and compared. In the case of a classical heating the yield of the reaction within 30 min always exceeded 90% .

Microwave irradiation was used as an alternative way of heating. Microwave irradiation (noted as MW) employing commercially available equipment (PROLABO 402 Synthewave oven) was used. Under these conditions the reactions with the comparable yields end in 5 min (reaction is six-time faster). The only

one exception was reaction with *p*-nitrobenzaldehyde. In that case the yield was only 68%. In this case the reaction product was accompanied with products of decomposition.



1 **2** **3**

Scheme 1

Compound	R^1	R^2	R^3	Yield (%)	
				Classical heating	Microwaves
3a	C_6H_5	$PhCH_2$	$CH_2=CHCH_2$	94	89
3b	*p*-Cl-C_6H_4	$PhCH_2$	$CH_2=CHCH_2$	96	90
3c	*p*-$(CH_3)_2N$-C_6H_4	$PhCH_2$	$CH_2=CHCH_2$	95	95
3d	*p*-NO_2-C_6H_4	$PhCH_2$	$CH_2=CHCH_2$	89	68
3e	*o*-$(CH_2=CHCH_2O)C_6H_4$	$PhCH_2$	$CH_2=CHCH_2$	□ [a]	85
3f	*p*-Cl-C_6H_4	$PhCH_2$	$PhCH_2$	92	90
3g	*p*-$(CH_3)_2N$-C_6H_4	$PhCH_2$	$PhCH_2$	□ [a]	94
3h	H	$PhCH_2$	$CH_2=CHCH_2$	92	90
3i	$(CH_3)_2CH$	$PhCH_2$	$CH_2=CHCH_2$	□ [a]	93
3j	*p*-Cl-C_6H_4	Me	cyclo-C_6H_{11}	□ [a]	89
3k	*p*-Cl-C_6H_4	Me	$(CH_3)_2CH$	93	93
3l	$(CH_3)_2CH$	Me	cyclo-C_6H_{11}	□ [a]	89
3m	Me	Me	$(CH_3)_2CH$	□ [a]	91
3n	Me	Me	cyclo-C_6H_{11}	91	86

[a] Reaction has not been carried out

Table 1

We suppose that the reaction acceleration is caused by the different transfer of the heat by microwaves. The reaction mixture is in that case heated up directly inside of the flask.[7] On the contrary, during the classical heating the heat is transferred from the outer medium (oil bath). Of course, the second type of heating must be slower. It was found during our experiments carried out at oil bath. It takes from 5 to 6 min before the internal temperature of the sample reaches 200°C. However, in the case of microwave assisted reactions it takes from 1 to 1.5 min only. We assume that this observed acceleration of the reaction is due to a microwave action and formation of hot spots in the reaction mixture.

We have found that the method is suitable for all alkyl as well as aryl aldehydes (**1**). Moreover, desired substituents R^2 and R^3 on compounds (**2**) could be easily introduced by the reaction of α-bromoacetyl bromide in two steps.[8]

In conclusion, a new procedure leading to 1,2,3-trisubstituted imidazolidin-4-ones (**3**) under solvent-free conditions in good yields was discovered. It was found that this method can be carried out under both classical and microwave heating. In case of the microwave irradiation acceleration of the reaction was observed. A rapid internal heating of the sample and hot spots are probably a motor of the acceleration of the reaction carried out under microwave conditions.

EXPERIMENTAL

Melting points were measured on a Kofler hot stage VEB Wägetechnik Rapido 79/2106. IR spectra were recorded on a FTIR ATI MATTSON spectrophotometer in NaCl cell or KBr pallets. Microwave irradiation was carried out in PROLABO 402 Synthewave oven (power 300W, frequency 2450 MHz). NMR spectra were recorded on Bruker Avance 300 apparatus with working frequency 300 MHz for ^1H and 75 MHz for ^{13}C in $CDCl_3$ with TMS as an internal standard. Chemical shifts are given in ppm, coupling constants *J* in Hz. MS were recorded on a FISONS INSTRUMENTS TRIO 1000 spectrometer in positive mode with electron-ionization (70eV). Flash column chromatography was carried out on Merck silica (63-100 μm) using petroleum ether:ethyl acetate mixture (ratio is given in procedure).

General procedure for preparation of compounds (2)[8]

Primary amine (4.0 mmol) was dissolved in dry acetonitrile (2 mL) and the solution was cooled to 0°C. 2-Bromoacetic acid amide (1.0 mmol) was slowly added to vigorously stirred reaction mixture. The temperature was kept bellow 10°C during the addition. Then reaction mixture was allowed to warm up to rt and stirred for additional 4 h. The solvent was removed under vacuum and the residue was dissolved in 2M NaOH (2 mL). Aqueous solution was extracted with Et_2O (3x3 mL). Organic layer was dried over $MgSO_4$ and the solvent together with an excess of primary amine was evaporated under vacuum. Final product was usually sufficiently pure for following synthesis.

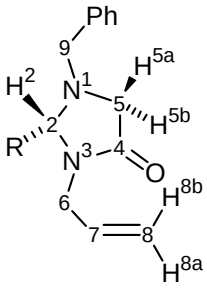
General procedure for preparation of compounds (3)

A mixture of aldehyde (**1**) (1.0 mmol) and amine (**2**) (1.0 mmol) was irradiated by microwaves for 5 minutes. Temperature of the reaction mixture was maintained at 200 °C. Then the reaction mixture was allowed to cool down to rt and crude reaction mixture was purified by flash column chromatography.

For a comparison the reaction mixture of the same composition was placed into preheated oil bath. Temperature of the oil bath was maintained at 200°C. Temperature of the reaction mixture reached 200°C

in 5 minutes after the reaction started (measured by optical fiber directly inside the reaction mixture). After 30 minutes the reaction mixture was allowed to cool down to rt and crude reaction mixture was separated by flash column chromatography.

3-Allyl-1-benzyl-2-phenylimidazolidin-4-one (3a): Flash chromatography (1:3) – Slightly yellow crystals, mp 62-63°C (petroleum ether/ethyl acetate). IR (KBr): ν^{-1} = 3081 (w), 3064 (w), 3029 (w), 2921 (w), 2850 (w), 2800 (w), 1708 (s), 1432 (m), 1414 (m), 1371 (w), 1103 (w), 1025 (w), 700 (m). ^{1}H NMR (300 MHz): δ 3.05 (dd, 1H, $^2J_{6,6}$=15.3, $^3J_{6,7}$=7.3 Hz, one of H-6), 3.18 (dd, 1H, $^2J_{5a,5b}$=14.6, $^5J_{5a,6}$=2.0 Hz, H-5a), 3.45 (d, 1H, $^2J_{9,9}$=13.2 Hz, one of H-9), 3.60 (d, 1H, $^2J_{5b,5a}$=14.5 Hz, H-5b), 3.83 (d, 1H, $^2J_{9,9}$=13.2 Hz, the other of H-9), 4.23 (ddd, 1H, $^2J_{6,6}$=15.4, $^3J_{6,7}$=4.6, $^5J_{6,5a}$=1.9 Hz, the other of H-6), 4.96 (dd, 1H, $^3J_{8b,7}$=17.2, $^2J_{8b,8a}$=1.3 Hz, H-8b), 5.01 (s, 1H, H-2), 5.10 (dd, 1H, $^3J_{8a,7}$=10.2, $^2J_{8a,8b}$=1.3 Hz, H-8a), 5.60 (m, 1H, H-7), 7.21–7.48 (m, 10H, arom. CH). ^{13}C NMR (75 MHz): δ 42.8 (C-6), 54.9 (C-5), 56.4 (C-9), 81.6 (C-2), 118.4 (C-8), 127.7–146.2 (arom. CH and C_q), 132.1 (C-7), 170.8 (C-4, C=O). EI-MS; *m/z* (%): 293.5 (1) [M^++1], 292.5 (8) [M^+], 291.3 (19), 216.5 (7), 215.2 (74), 201.1 (12), 117.6 (18), 117.6 (18), 91.0 (100), 64.9 (10), 40.8 (9). Anal. Calcd for $C_{19}H_{20}N_2O$: C 78.05 H 6.89 N 9.58. Found C 78.01 H 6.93 N 9.52.



3-Allyl-1-benzyl-2-(4-chlorophenyl)imidazolidin-4-one (3b): Flash chromatography (1:1) – Slightly red crystals, mp 71-72° C (petroleum ether/ethyl acetate). IR (KBr): ν^{-1} = 3064 (w), 3027 (w), 2923 (w), 2848 (w), 2807 (w), 1708 (s), 1419 (w), 1292 (m), 1082 (m), 644 (m), 584 (m). ^{1}H NMR (300 MHz): δ 2.91 (dd, 1H, $^2J_{6,6}$=15.5, $^3J_{6,7}$=7.6 Hz, one of H-6), 3.04 (dd, 1H, $^2J_{5a,5b}$=14.4, $^5J_{5a,6}$=2.0 Hz, H-5a), 3.43 (d, 1H, $^2J_{9,9}$=13.2 Hz, one of H-9), 3.47 (d, 1H, $^2J_{5b,5a}$=14.5 Hz, H-5b), 3.68 (d, 1H, $^2J_{9,9}$=13.2 Hz, the other of H-9), 4.10 (ddd, 1H, $^2J_{6,6}$=15.5, $^3J_{6,7}$=4.6, $^5J_{6,5a}$=1.7 Hz, the other of H-6), 4.83 (s, 1H, H-2), 4.84 (dd, 1H, $^3J_{8b,7}$=16.2, $^2J_{8b,8a}$=0.9 Hz, H-8b), 4.99 (dd, 1H, $^3J_{8a,7}$=10.2, $^2J_{8a,8b}$=0.7 Hz, H-8a), 5.47 (m, 1H, H-7), 7.05–7.38 (m, 9H, arom. CH). ^{13}C NMR (75 MHz): δ 42.7 (C-6), 54.9 (C-5), 56.4 (C-9), 80.9 (C-2), 118.5 (C-8), 127.7–137.2 (arom. CH and C_q), 132.0 (C-7), 170.7 (C-4, C=O). EI-MS; *m/z* (%): 328.4 (4) [M^++1], 326.5 (12) [M^+], 325.5 (17), 235.1 (18), 215.2 (61), 178.2 (12), 124.9 (19), 92.0 (11), 90.9 (100), 88.9 (12), 64.9 (8), 40.9 (15). Anal. Calcd for $C_{19}H_{19}N_2OCl$: C 69.83 H 5.86 N 10.85. Found C 69.78 H 5.88 N 10.84.

3-Allyl-1-benzyl-2-[4-(*N*,*N*-dimethylamino)phenyl]imidazolidin-4-one (3c): Flash chromatography (1:3) – White crystals, mp 84-86° C (petroleum ether/ethyl acetate). IR (KBr): ν^{-1} = 3079 (w), 3027 (w), 2922 (m), 2852 (w), 2802 (w), 1707 (s), 1612 (m), 1434 (m), 1415 (m), 1164 (m), 1120 (m), 808 (w), 700

(w). ^{1}H NMR (300 MHz): δ 3.00 (s, 6H, $N(CH_3)_2$), 3.09 (dd, 1H, $^{2}J_{6,6}$=15.5, $^{3}J_{6,7}$=7.3 Hz, one of H-6), 3.11 (dd, 1H, $^{2}J_{5a,5b}$=14.5, $^{5}J_{5a,6}$=2.1 Hz, H-5a), 3.37 (d, 1H, $^{2}J_{9,9}$=13.2 Hz, one of H-9), 3.54 (d, 1H, $^{2}J_{5b,5a}$=14.5 Hz, H-5b), 3.86 (d, 1H, $^{2}J_{9,9}$=13.2 Hz, the other of H-9), 4.20 (ddd, 1H, $^{2}J_{6,6}$=15.5, $^{3}J_{6,7}$=4.7, $^{5}J_{6,5a}$=1.9 Hz, the other of H-6), 4.90 (s, 1H, H-2), 5.00 (dd, 1H, $^{3}J_{8b,7}$=16.8, $^{2}J_{8b,8a}$=0.9 Hz, H-8b), 5.10 (dd, 1H, $^{3}J_{8a,7}$=9.9, $^{2}J_{8a,8b}$=0.7 Hz, H-8a), 5.63 (m, 1H, H-7), 6.72–7.36 (m, 9H, arom. CH). ^{13}C NMR (75 MHz): δ 40.6 ($N(CH_3)_2$), 42.6 (C-6), 55.1 (C-5), 56.1 (C-9), 81.6 (C-2), 112.2–137.2 (arom. CH and C_q), 118.0 (C-8), 132.4 (C-7), 170.8 (C-4, C=O). EI-MS; *m/z* (%): 335.5 (1) [M^+], 293.5 (3), 292.5 (8), 291.3 (17), 216.5 (11), 215.2 (88), 201.0 (17), 117.6 (13), 92.1 (6), 90.9 (100), 64.8 (8), 40.8 (9). Anal. Calcd for $C_{21}H_{25}N_3O$: C 75.19 H 7.51 N 12.53. Found C 75.11 H 7.48 N 12.50.

3-Allyl-1-benzyl-2-(4-nitrophenyl)imidazolidin-4-one (3d): Flash chromatography (1:1) – White crystals, mp 93-94^{o} C (petroleum ether/ethyl acetate). IR (KBr): ν^{-1} = 3080 (w), 3064 (w), 3029 (w), 2924 (w), 2811 (w), 1711 (s), 1524 (s), 1434 (m), 1348 (s), 1315 (m), 801 (m), 701 (m). ^{1}H NMR (300 MHz): δ 3.04 (dd, 1H, $^{2}J_{6,6}$=15.5, $^{3}J_{6,7}$=7.6 Hz, one of H-6), 3.26 (dd, 1H, $^{2}J_{5a,5b}$=14.5, $^{5}J_{5a,6}$=2.0 Hz, H-5a), 3.58 (d, 1H, $^{2}J_{9,9}$=13.2 Hz, one of H-9), 3.69 (d, 1H, $^{2}J_{5b,5a}$=14.5 Hz, H-5b), 3.81 (d, 1H, $^{2}J_{9,9}$=13.2 Hz, the other of H-9), 4.29 (ddd, 1H, $^{2}J_{6,6}$=15.5, $^{3}J_{6,7}$=4.6, $^{5}J_{6,5a}$=1.7 Hz, the other of H-6), 4.96 (dd, 1H, $^{3}J_{8b,7}$=17.2, $^{2}J_{8b,8a}$=0.8 Hz, H-8b), 5.11 (s, 1H, H-2), 5.15 (dd, 1H, $^{3}J_{8a,7}$=10.2, $^{2}J_{8a,8b}$=0.7 Hz, H-8a), 5.62 (m, 1H, H-7), 7.17–8.28 (m, 9H, arom. CH). ^{13}C NMR (75 MHz): δ 42.9 (C-6), 55.0 (C-5), 57.0 (C-9), 80.6 (C-2), 119.0 (C-8), 124.0–145.0 (arom. CH and C_q), 131.8 (C-7), 170.6 (C-4, C=O). EI-MS; *m/z* (%): 337.4 (1) [M^+], 291.5 (41), 263.2 (6), 216.3 (9), 215.1 (100), 201.1 (15), 118.0 (12), 90.9 (84), 64.8 (7), 40.9 (11). Anal. Calcd for $C_{19}H_{19}N_3O_3$: C 67.64 H 5.68 N 12.46. Found C 67.44 H 5.59 N 12.32.

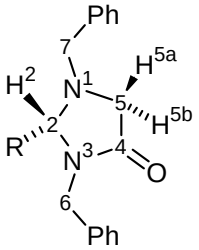
3-Allyl-2-(2-allyoxyphenyl)-1-benzylimidazolidin-4-one (3e): Flash chromatography (1:3) – Slightly yellow oil. IR (NaCl): ν^{-1} = 3079 (w), 3066 (w), 3029 (w), 2919 (w), 2852 (w), 2804 (w), 1707 (s), 1598 (w), 1490 (m), 1434 (m), 1284 (w), 1240 (m), 1097 (w), 1020 (w), 755 (m), 700 (m). ^{1}H NMR (300 MHz): δ 3.24 (dd, 1H, $^{2}J_{6,6}$=15.5, $^{3}J_{6,7}$=7.8 Hz, one of H-6), 3.22 (dd, 1H, $^{2}J_{5a,5b}$=14.5, $^{5}J_{5a,6}$=1.7 Hz, H-5a), 3.56 (d, 1H, $^{2}J_{9,9}$=13.2 Hz, one of H-9), 3.63 (d, 1H, $^{2}J_{5b,5a}$=14.5 Hz, H-5b), 3.87 (d, 1H, $^{2}J_{9,9}$=13.2 Hz, the other of H-9), 4.20 (ddd, 1H, $^{2}J_{6,6}$=15.5, $^{3}J_{6,7}$=5.3, $^{5}J_{6,5a}$=1.7 Hz, the other of H-6), 4.58 (d, 1H, ^{3}J=5.0 Hz, $OC\underline{H}_2CH=CH_2$), 5.01 (d, 1H, $^{3}J_{8b,7}$=17.2 Hz, H-8b), 5.06 (d, 1H, $^{3}J_{8a,7}$=10.9 Hz, H-8a), 5.34 (dd, 1H, ^{3}J=10.6, ^{2}J=1.7 Hz, $OCH_2CH=C\underline{H}_2$), 5.46 (dd, 1H, ^{3}J=17.5, ^{2}J=1.7 Hz, $OCH_2CH=C\underline{H}_2$), 5.67 (s, 1H, H-2), 6.10 (m, 1H, $OCH_2C\underline{H}=CH_2$), 6.91–7.57 (m, 9H, arom. CH). ^{13}C NMR (75 MHz): δ 42.8 (C-6), 55.1 (C-5), 56.7 (C-9), 69.1 ($O\underline{C}H_2CH=CH_2$), 74.7 (C-2), 111.9–157.7 (arom. CH and C_q), 117.6 and 117.7 (C-8 and $OCH_2CH=\underline{C}H_2$), 132.3 and 133.1 (C-7 and $OCH_2\underline{C}H=CH_2$), 171.1 (C-4, C=O). EI-MS;

m/z (%): 348.5 (1) [M^+], 291.3 (28), 288.0 (6), 215.2 (100), 201.1 (17), 117.5 (16), 92.1 (7), 90.9 (100), 64.8 (9), 40.8 (15). Anal. Calcd for $C_{22}H_{24}N_2O_2$: C 75.83 H 6.94 N 8.04. Found C 75.81 H 6.89 N 7.99.

3-Allyl-1-benzylimidazolidin-4-one (3h): Flash chromatography (1:1) – Yellow oil. IR (NaCl): ν^{-1} = 3081 (w), 3062 (w), 3027 (w), 2919 (m), 2848 (w), 2802 (w), 1706 (s), 1496 (w), 1456 (m), 1373 (m), 1342 (m), 1139 (m), 931 (w), 746 (m), 701 (m). ^{1}H NMR (300 MHz): δ 3.04 (dd, 1H, $^2J_{6,6}$=15.5, $^3J_{6,7}$=7.6 Hz, one of H-6), 3.26 (dd, 1H, $^2J_{5a,5b}$=14.5, $^5J_{5a,6}$=2.0 Hz, H-5a), 3.58 (d, 1H, $^2J_{9,9}$=13.2 Hz, one of H-9), 3.69 (d, 1H, $^2J_{5b,5a}$=14.5 Hz, H-5b), 3.81 (d, 1H, $^2J_{9,9}$=13.2 Hz, the other of H-9), 4.29 (ddd, 1H, $^2J_{6,6}$=15.5, $^3J_{6,7}$=4.6, $^5J_{6,5a}$=1.7 Hz, the other of H-6), 4.96 (dd, 1H, $^3J_{8b,7}$=17.2, $^2J_{8b,8a}$=0.8 Hz, H-8b), 5.11 (s, 1H, H-2), 5.15 (dd, 1H, $^3J_{8a,7}$=10.2, $^2J_{8a,8b}$=0.7 Hz, H-8a), 5.62 (m, 1H, H-7), 7.17–8.28 (m, 9H, arom. CH). ^{13}C NMR (75 MHz): δ 43.8 (C-6), 56.3 (C-5), 59.3 (C-9), 69.4 (C-2), 118.4 (C-8), 127.7–137.4 (arom. CH and C_q), 132.1 (C-7), 171.0 (C-4, C=O). EI-MS; *m/z* (%): 217.4 (7) [M^++1], 216.4 (11) [M^+], 215.2 (15), 175.2 (7), 174.0 (8), 131.9 (8), 75.0 (30), 92.1 (14), 90.9 (100), 64.8 (14), 41.9 (56). Anal. Calcd for $C_{13}H_{16}N_2O$: C 72.19 H 7.46 N 12.95. Found C 72.15 H 7.39 N 12.92.

3-Allyl-1-benzyl-2-(2-propyl)imidazolidin-4-one (3i): Flash chromatography (1:3) – Yellow oil. IR (NaCl): ν^{-1} = 3062 (w), 3027 (w), 2964 (m), 2925 (m), 2873 (w), 1691 (s), 1525 (w), 1452 (w), 1263 (w), 1078 (w), 742 (w), 700 (m). ^{1}H NMR (300 MHz): δ 0.85 (d, 3H, ^3J=6.9 Hz, one of CH(C<u>H</u>$_3$)$_2$), 0.96 (d, 3H, ^3J=6.9 Hz, the other of CH(C<u>H</u>$_3$)$_2$), 1.92 (m, 1H, C<u>H</u>(CH$_3$)$_2$), 3.13 (dd, 1H, $^2J_{5,5}$=16.5 Hz one of H-5), 3.41 (dd, 1H, $^2J_{6,6}$=15.5, $^3J_{6,7}$=8.0 Hz, one of H-6), 3.51 (d, 1H, $^2J_{5,5}$=16,5 Hz, the other of H-5), 3.70 (d, 1H, $^3J_{9,9}$=13.2 Hz, one of H-9), 3.92 (d, 1H, $^2J_{9,9}$=13.2 Hz, the other of H-9), 4.22 (s, 1H, H-2), 4.44 (dd, 1H, $^2J_{6,6}$=15.5, $^3J_{6,7}$=4.6 Hz, the other of H-6), 5.24 (d, 1H, $^3J_{8a,7}$=10.6 Hz, H-8a), 5.25 (d, 1H, $^3J_{8b,7}$=15.2 Hz, H-8b), 5.75 (m, 1H, H-7), 7.27–7.49 (m, 5H, arom. CH). ^{13}C NMR (75 MHz): δ 14.8 (one of CH(<u>C</u>H$_3$)$_2$), 18.4 (the other of CH(<u>C</u>H$_3$)$_2$), 31.3 (<u>C</u>H(CH$_3$)$_2$), 42.9 (C-6), 56.9 (C-5), 62.9 (C-9), 83.8 (C-2), 118.6 (C-8), 127.6–138.6 (arom. CH and C_q), 132.5 (C-7), 171.7 (C-4, C=O). EI-MS; *m/z* (%): 259.2 (6) [M^++1], 257.2 (4), 216.5 (11), 215.3 (100), 91.0 (95), 64.9 (13), 40.8 (18). Anal. Calcd for $C_{16}H_{22}N_2O$: C 74.38 H 8.58 N 10.84. Found C 74.41 H 8.52 N 10.80.

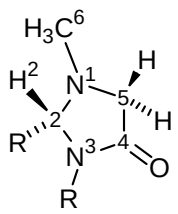
1,3-Dibenzyl-2-(4-chlorophenyl)imidazolidin-4-one (3f): Flash chromatography (1:2) – Slightly yellow crystals, mp 81-82^o C (petroleum ether/ethyl acetate). IR (KBr): ν^{-1} = 3080 (m), 3064 (m), 3029 (m), 2850 (w), 1710 (s), 1431 (m), 1411 (m), 1371 (w), 1098 (w), 701 (m). ^{1}H NMR (300 MHz): δ 3.28 (dd, 1H, $^2J_{5,5}$=14.5, ^5J=1.9 Hz, one of H-5), 3.59 (d, 1H, $^2J_{5,5}$=14.5 Hz, the other of H-5), 3.77 (d, 1H, $^2J_{7,7}$=13.2 Hz, H-7), 4.03 (d, 1H, $^2J_{7,7}$=13.2



Hz, the other of H-7), 4.25 (d, 1H, $^2J_{6,6}$=15.5, one of H-6), 4.63 (d, 1H, $^2J_{6,6}$=15.5 Hz, the other of H-6), 4.83 (s, 1H, H-2), 7.20–7.49 (m, 14H, arom. CH). ^{13}C NMR (75 MHz): δ 45.3 (C-6), 56.7 (C-5), 58.6 (C-9), 81.4(C-2), 126.6–147.3 (arom. CH and C_q), 171.8 (C-4, C=O). Anal. Calcd for $C_{23}H_{21}N_2OCl$: C 73.30 H 5.62 N 7.43. Found C 73.25 H 5.64 N 7.41.

1,3-Dibenzyl-2-[4-(*N*,*N*-dimethylamino)phenyl]imidazolidine-4-one (3g): Flash chromatography (1:2) – Slightly yellow crystals, mp 93-94^o C (petroleum ether/ethyl acetate). IR (KBr): ν^{-1} = 3079 (m), 3063 (m), 3028 (m), 2851 (w), 1708 (s), 1439 (m), 1404 (m), 1375 (w), 1105 (w), 708 (m). ^{1}H NMR (300 MHz): δ 3.00 (s, 6H, $N(CH_3)_2$), 3.34 (dd, 1H, $^2J_{5,5}$=14.6, ^5J=2.1 Hz, one of H-5), 3.62 (d, 1H, $^2J_{5,5}$=14.6 Hz, the other of H-5), 3.77 (d, 1H, $^2J_{7,7}$=13.1 Hz, H-7), 4.03 (d, 1H, $^2J_{7,7}$=13.1 Hz, the other of H-7), 4.32 (d, 1H, $^2J_{6,6}$=15.5, one of H-6), 4.69 (d, 1H, $^2J_{6,6}$=15.5 Hz, the other of H-6), 4.87 (s, 1H, H-2), 7.19–7.49 (m, 14H, arom. CH). ^{13}C NMR (75 MHz): δ 41.2 ($N(CH_3)_2$), 45.3 (C-6), 56.9 (C-5), 58.1 (C-9), 80.7(C-2), 126.1–147.7 (arom. CH and C_q), 171.4 (C-4, C=O). Anal. Calcd for $C_{25}H_{27}N_3O$: C 77.89 H 7.06 N 10.90. Found C 77.85 H 7.09 N 10.86.

3-Cyclohexyl-1-methyl-2-(4-chlorophenyl)imidazolidine-4-one (3j): Flash chromatography (1:1) – Yellow oil. IR (NaCl): ν^{-1} = 2963 (s), 2853 (w), 1701 (s), 1412 (w), 1261 (w), 1086 (w), 1017 (m), 801 (m). ^{1}H NMR (300 MHz): δ 0.88-1.74 (m, 10H, CH_2 from cyclohexyl), 2.20 (s, 3H, H-6), 3.12 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=1.7 Hz, one of H-5), 3.40 (m, 1H, CH from cyclohexyl), 3.63 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=1.7 Hz, the other of H-5), 4.70 (s, 1H, C-2), 7.34–7.37 (m, 4H, arom. CH). ^{13}C NMR (75 MHz): δ 25.4 (CH_2), 26.0 (CH_2), 30.4 (CH_2), 38.7 (C-6), 53.3 (CH from cyclohexyl), 57.6 (C-5), 82.7 (C-2), 128.9–137.8 (arom. CH and C_q), 171.4 (C-4, C=O). EI-MS; *m/z* (%): 293.5 (3) [M^++1], 292.4 (5) [M^+], 291.3 (6), 182.4 (7), 181.2 (100), 166.1 (42), 99.0 (52), 55.0 (13), 43.9 (24). Anal. Calcd for $C_{16}H_{21}N_2OCl$: C 65.63 H 7.23 N 9.57. Found C 65.59 H 7.25 N 9.55.



1-Methyl-2-(4-chlorophenyl)-3-(2-propyl)imidazolidin-4-one (3k): Flash chromatography (1:2) – White crystals, mp 25-26° C (not recrystallized). IR (KBr): ν^{-1} = 2964 (m), 2852 (w), 2790 (w), 1704 (s), 1411 (w), 1261 (m), 1089 (m), 1018 (m), 800 (m). ^{1}H NMR (300 MHz): δ 0.95 and 1.18 (d, 6H, ^3J=6.9 Hz, $NCH(C\underline{H}_3)_2$), 2.22 (s, 3H, H-6), 3.10 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=1.7 Hz, one of H-5), 3.67 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=1.0 Hz, the other of H-5), 3.69 (m, 1H, $NC\underline{H}(CH_3)_2$), 4.67 (s, 1H, C-2), 7.34–7.37 (m, 4H, arom. CH). ^{13}C NMR (75 MHz): δ 20.0 and 20.5 ($NCH(\underline{C}H_3)_2$), 38.6 (C-6), 45.0 ($N\underline{C}H(CH_3)_2$), 57.7 (C-5), 82.9 (C-2), 128.9–137.6 (arom. CH and C_q), 171.4 (C-4, C=O). EI-MS; *m/z* (%): 253.4 (6) [M^++1],

252.6 (7) [M^+], 251.4 (8), 141.2 (100), 91.0 (58), 64.9 (16), 40.8 (28). Anal. Calcd for $C_{13}H_{17}N_2OCl$: C 61.78 H 6.78 N 11.08. Found C 61.80 H 6.75 N 11.10.

3-Cyclohexyl-1-methyl-2-(2-propyl)imidazolidin-4-one (3l): Flash chromatography (1:3) – Yellow oil . IR (NaCl): ν^{-1} = 2968 (m), 2930 (m), 2871 (w), 1695 (s), 1535 (w), 1445 (w), 1261 (w), 1075 (w), 740 (w), 700 (m). ^{1}H NMR (300 MHz): δ 0.88-1.85 (m, 17H, C<u>H</u>(C<u>H</u>$_3$)$_2$ and CH_2 from cyclohexyl), 2.20 (s, 3H, H-6), 3.12 (dd, 1H, $^3J_{5,5}$=14.3, ^5J=1.8 Hz, one of H-5), 3.40 (m, 1H, CH from cyclohexyl), 3.49 (d, 1H, $^2J_{5,5}$=14.3 Hz, the other of H-5), 4.25 (s, 1H, H-2). ^{13}C NMR (75 MHz): δ 14.7 (one of CH(<u>C</u>H$_3$)$_2$), 18.3 (the other of CH(<u>C</u>H$_3$)$_2$), 25.4 (CH_2), 26.0 (CH_2), 30.4 (CH_2), 31.4 (<u>C</u>H(CH$_3$)$_2$), 53.3 (CH from cyclohexyl), 42.9 (C-6), 57.4 (C-5), 83.8 (C-2), 172.1 (C-4, C=O). Anal. Calcd for $C_{10}H_{20}N_2O$: C 65.18 H 10.94 N 15.20. Found C 65.11 H 10.91 N 15.24.

1,2-Dimethyl-3-(2-propyl)imidazolidin-4-one (3m): Flash chromatography (1:2) – Yellow oil. IR (NaCl): ν^{-1} = 2964 (m), 2852 (w), 2790 (w), 1705 (s, C=O), 1411 (w), 1261 (m), 1089 (m), 1018 (m), 800 (m). ^{1}H NMR (300 MHz): δ 0.95 and 1.17 (d, 6H, ^3J=6.9 Hz, NCH(C<u>H</u>$_3$)$_2$), 1.68 (d, 3H, ^3J=7.2 Hz, C<u>H</u>$_3$), 2.25 (s, 3H, H-6), 3.14 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=1.7 Hz, one of H-5), 3.69 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=0.9 Hz, the other of H-5), 3.75 (m, 1H, NC<u>H</u>(CH$_3$)$_2$), 4.62 (d, 1H, ^3J=7.1 Hz, C-2). ^{13}C NMR (75 MHz): δ 20.1 and 20.5 (NCH(<u>C</u>H$_3$)$_2$), 28.1 (CH_3), 38.7 (C-6), 45.8 (N<u>C</u>H(CH$_3$)$_2$), 57.1 (C-5), 82.1 (C-2). Anal. Calcd for $C_8H_{16}N_2OCl$: C 61.50 H 10.32 N 17.93. Found C 61.48 H 10.34 N 17.91.

3-Cyclohexyl-1,2-dimethylimidazolidin-4-one (3n): Flash chromatography (1:3) – Yellow oil. IR (NaCl): ν^{-1} = 2964 (m), 2929 (m), 2870 (w), 1701 (s), 1534 (w), 1446 (w), 1271 (w), 1071 (w), 741 (w), 701 (m). ^{1}H NMR (300 MHz): δ 0.88-1.85 (m, 10H, CH_2 from cyclohexyl and CH_3), 2.21 (s, 3H, H-6), 3.12 (dd, 1H, $^3J_{5,5}$=14.2, ^5J=1.7 Hz, one of H-5), 3.40 (m, 1H, CH from cyclohexyl), 3.49 (d, 1H, $^2J_{5,5}$=14,2 Hz, the other of H-5), 4.27 (d, 1H, ^3J=7.2 Hz, H-2). ^{13}C NMR (75 MHz): δ 14.7 (one of CH(<u>C</u>H$_3$)$_2$), 18.3 (the other of CH(<u>C</u>H$_3$)$_2$), 25.4 (CH_2), 25.4 (CH_3), 26.0 (CH_2), 30.4 (CH_2), 31.4 (<u>C</u>H(CH$_3$)$_2$), 38.4 (C-6), 53.5 (CH from cyclohexyl), 57.4 (C-5), 82.8 (C-2), 171.7 (C-4, C=O). Anal. Calcd for $C_{11}H_{20}N_2O$: C 67.31 H 10.27 N 14.27. Found C 67.34 H 10.25 N 14.30.

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Dedicated to Professor Milan Kratochvíl on the occasion of his 80th birthday anniversary.

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