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RESEARCH ARTICLE

A FACILE SYNTHESIS OF (±)-BACLOFEN AND (±) ROLIPRAM *via* Fe(acac)$_3$ CATALYZED MICHAEL ADDITION REACTION

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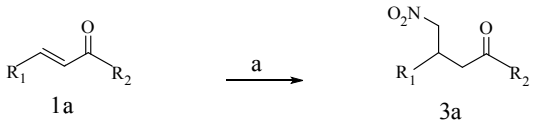
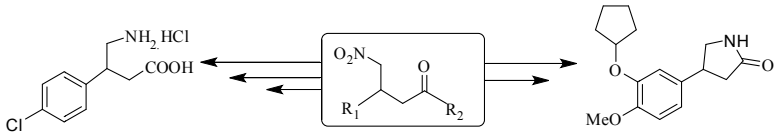
ABSTRACT

An effective and convenient procedure for the Michael Addition using Fe (acac)3 (5 mol %) as an effective catalyst, catalyses the Michael addition reaction of nitro methane to Chalcone to produce corresponding γ- nitro ketone derivatives with good yields (85-95 %) under mild condition with high yield. Accordingly, we applied this synthetic strategy for synthesis of (±)-Baclofen and (±)-Rolipram.



1a 3a

Reaction Conditions: a) Chalcone (0.82 mmol), Nitromethane (2) (4.10 mmol), 5 mol % Fe(acac)$_3$, anhy. DMSO (2mL), rt.



(±)-Baclofen (±)-Rolipram

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INTRODUCTION

The transition metal catalysis plays an important role in modern organic chemistry (Carsten *et al.,* 2004). The most of the reaction catalyzed by Lewis acid are stoichiometric therefore, recently great attention towards the transition metal catalyzed reaction in synthetic chemistry due to their numerous advantages low cost, nontoxic or interesting catalytic activity, reaction proceed cleanly with high efficiency and easy to handle, at ambient reaction condition without formation of salt. Although precious metal catalysts have their own impact on the field, alternatively non-precious metals like Cu, Co, Ce, Ni and Fe are emerging as important catalysts.

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To access C-C bonds, novel transition metal complexes or salts have previously been used as catalysts. Iron is well known as one of the most abundant and cheapest metals. However, the use of Iron salt as important Lewis acid in organic transformation such as homo coupling (Allena *et al.,* 2009), Grignard reaction (Volla, 2008), alkylation (Cahiez, 1996), alkenylation of organo manganese (Seck *et al.,* 2004), aryl coupling reaction (Xu *et al.,* 2006), N-Arylatation (Buchwald, 2009), C-N bond cleavage (Kuninobu *et al.,* 2010) and Michael addition (Christoffers *et al.,* 2000) *etc*. The Michael addition is the nucleophilic addition of carbanion to an α, β unsaturated conjugated double bond is one of the fundamental C-C bond forming reaction in organic synthesis (Ballini *et al.,* 2005). Among various nucleophiles, nitroalkanes have been demonstrated to be a valuable stabilized carbanion for the conjugate addition, due to the strong electron withdrawing

nature of the nitro group (Ono, 2001). Which represent a very important functionality in organic transformation due to its easily converted into elaborated functionalities in bioactive molecules such as amino carbonyls, aminoalcohols (Luzzio, 2001), Diketones (Ballini and Petrini, 2004) and pharmacologically active intermediates γ-lactams for synthesis of (R)-Baclofen (Corey *et al.,* 2000) and (R)-Rolipram (Peter *et al.,* 2008). Michael addition reactions usually carried out under strong basic (Kim *et al.,* 2010) or acidic condition (Moon *et al.,* 2001). There are few reports with transition metal Lewis acid (Cu, (Watanabe *et al.,* 1982) Zn, (Irie *et al.,* 1980) Co, (Schionato *et al.,* 1989) Ni (Comelles *et al.,* 2005) and fe (Christoffers *et al.,* 2000) etc.) (II) Complexes and Mg-Al-O-*t*-Bu hydrotalcite (Choudary *et al.,* 2000) to the Michael addition reactions of nitro alkanes. These reaction suffering from some limitation such as harsh reaction condition, limiting the yield, high amount catalyst loading, particularly unsuitable for industrial and economical synthesis. Hence, we will wish to develop an efficient and environmentally acceptable synthetic method is an important task of modern chemistry, which can overcome some limitation associated with existing methodologies and extended scope of present methodology for synthesis of (±)-Rolipram and (±)-Baclofen via novel Baeyer Villiger reaction. The Baeyer Villiger oxidation is a widely used reaction for converting ketone to esters. The oxidizing agent that is generally used for the reaction is *m*-CPBA, and because this contains about 20% *m*-chlorobenzoic acid, it is safe to both store and use (Baeyer *et al.,* 1899). In recent years, some alternative methods are available for carrying out Baeyer Villiger reaction in their research laboratories (Ali *et al.,* 1976). In this communication, we also wish to report a novel and simple procedure for Baeyer Villiger reaction on γ- nitro ketone which includes H_2O_2 in AcOH (Horner *et al.,* 1973).

Experimental

MATERIALS AND METHODS

All reactions were carried out in dry solvents, unless otherwise stated. Reactions were monitored by thin layer chromatography (TLC) on silica gel plates (Kieselgel 60 F_{254}, Merck). Visualization of the spots on TLC plates was achieved either by UV light or by staining the plates in 2, 4-dinitrophenylhydrazine/ anisaldehyde and charring on hot plate. All products were characterized by ^{1}H NMR and ^{13}C NMR, IR, Mass and Elemental analysis. ^{1}H NMR and ^{13}C NMR were recorded on Varian Mercury 300 MHz spectrometer. Chemical shifts are expressed in ppm values and ^{1}H NMR spectra are referenced to 0.00 ppm for Me_4Si (TMS) and ^{13}C NMR spectra are referenced to 77.00 ppm for $CDCl_3$. Peak multiplicities are designated by the following abbreviations: s, singlet; brs, broad singlet; d, doublet; t, triplet; q, quartet; m, multiplet; J, coupling constant in Hz. IR spectra were obtained on a Shimadzu FTIR-8400 with samples loaded as thin films on KBr plate, neat or with CH_2Cl_2 as indicated. Mass spectra were recorded at an ionization potential of 70 eV; Elemental analyses were recorded on Flash E. A. 1112 Thermo instrument. Melting points recorded are uncorrected. Column chromatography on silica gel (100-200 mesh) was performed with reagent grade ethyl acetate and hexane as an eluent.

Synthesis of the γ- nitro ketone derivatives

Typical experimental procedure

A mixture of chalcone (200 mg, 0.82 mmol), $Fe(acac)_3$ (5 mol %) in DMSO (2 mL) were stirred at room temperature. Nitro methane (4.00 mmol) was added and reaction mixture was further stirred for 1.0h. After completion of reaction the mixture was diluted with water. The reaction mixture was extracted with EtOAc (2 X 20mL) and organic layer was washed with brine and dried with Na_2SO_4. Evaporation of solvent furnished the crude product that was purified by column chromatography over silica gel using EtOAc in petroleum ether to give pure product. This procedure is followed for all the reactions listed in (Table 1). Known compounds and were identified by spectroscopic data (IR, ^{1}H, ^{13}C NMR, GCMS) and are in good agreement with those of the reported. The spectroscopic and analytical data of new products whose spectroscopic data are not readily available are provided here in order of their below.

3-(4-chlorophenyl)-1-(4-methoxyphenyl)-4-nitrobutan-1-one (3e): white solid, m. p. 105 - 109 °C ; ^{1}H NMR (300 MHz, $CDCl_3$): 3.38 (m, 2H), 3.86 (s, 3H), 4.17- 4.22 (m, 1H), 4.61 - 4.68 (dd, 1H, J = 12.6 Hz, 8.5 Hz) 4.78- 4.85 (dd, 1H, J = 12.6 Hz, 6.4 Hz), 6.91 - 6.94 (d, 2H, J = 8.8 Hz), 7.20 - 7.23 (d, 2H, J = 8.5Hz), 7.29 - 7.31 (d, 2H, J = 8.5Hz), 7.87 - 7.90 (d, 2H, J = 9.1Hz). ^{13}C NMR (75 MHz, $CDCl_3$): 38.69, 40.82, 55.41, 79.28, 113.79, 128.80, 129.04, 129.15, 130.20, 133.42, 137.73, 163.80, 168.46; IR: KBr(cm^{-1}) : 1680 (C=O), 1546 (NO_2), 1371 (NO), 1217. Exact Mass Calcd : $C_{17}H_{16}ClNO_4$: 333.08, MS (GC/MS) m/z: 333; Anal. Calcd : $C_{17}H_{16}ClNO_4$, C 61.18, H 4.83, N 4.20; found C 61.04, H 4.69, N 4.32.

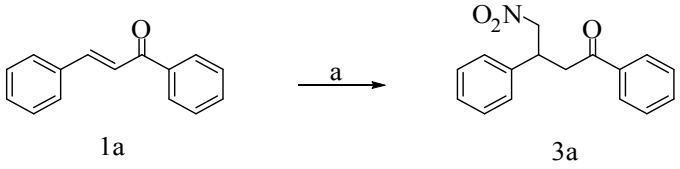
3-(3-(cyclopentyloxy)-4-methoxyphenyl)-1-(4-methoxyphenyl)-4-nitrobutan-1-one (8): white solid, m. p. 91 - 93 °C ; ^{1}H NMR (300 MHz, $CDCl_3$) : 1.52-1.68 (m, 2H), 1.72-1.98 (m, 2H), 3.31-3.42 (m, 2H), 3.79 (s, 3H), 3.84 (s, 3H), 4.10- 4.14 (m, 1H), 4.60 - 4.67 (m. 1H) 4.74 - 4.83 (m, 2H), 6.75 - 6.85 (m, 3H), 6.89 - 6.92 (d, 2H, J = 8.5Hz), 7.87 - 7.90 (d, 2H, J = 8.5Hz). ^{13}C NMR (75MHz, $CDCl_3$): 23.88, 32.61, 39.04, 41.16, 55.37, 55.87, 79.74, 80.38, 112.15 113.72, 114.60, 119.14 129.42, 130.22, 131.44, 147.63, 149.42, 163.67, 195.48; IR: KBr(cm^{-1}) : 1683 (C=O), 1545 (NO_2), 1363 (NO),1257; Exact Mass Calcd : $C_{23}H_{27}NO_6$ = 413.18, MS (GC/MS) m/z: 413; Anal. Calcd : C, 66.81; H, 6.58; N, 3.39; found; C, 66.31; H, 6.91; N, 3.59.

4-methoxyphenyl 3-(3-(cyclopentyloxy)-4-methoxyphenyl)-4-nitrobutanoate(9): white solid, m. p. 84 - 86 °C ; ^{1}H NMR (300 MHz, $CDCl_3$) : 1.60-1.78 (m, 2H), 1.80-1.91 (m, 2H), 2.90-3.05 (m, 2H), 3.77 (s, 3H), 3.83 (s, 3H), 3.98-4.06 (m, 1H), 4.63 - 4.69 (m, 1H), (4.71- 4.77 (m, 2H), 6.78-6.86 (m, 7H); ^{13}C NMR (75MHz, $CDCl_3$): 24.02, 32.75, 37.92, 39.98, 55.57, 56.06, 79.65, 80.60, 109.98, 114.40, 114.42 119.37, 122.08, 130.20, 143.60, 147.67, 149.89, 156.58, 172.03; IR: KBr : 1745 (C=O), 1543, 1501, (NO_2), 1371 (NO), 1259; Exact Mass Calcd : $C_{23}H_{27}NO_7$ = 429.18 , MS (GC/MS) m/z: 429; Anal. Calcd : C, 64.32; H, 6.34; N, 3.26; found C 64.80, H 6.53, ; N, 3.10.

(*R*)-Rolipram: Yield 90%; colorless solid, m.p. 131-133 ^{o}C; $[\alpha]_D^{25}$ -17.8^{o} (c = 1.01, MeOH); IR: KBr 3196, 2962, 1687, 1518, 1264, 1237, 1141, 1029, 815 cm-^{1}; NMR (300MHz, $CDCl_3$): δ. 6.86-6.75 (m, 3H), 4.74-4.77 (m, 1H), 3.83 (s, 3H), 3.80 (app t, *J* = 9.4, 1H C$\underline{H}_A$H$_B$NH), 3.70-3.59 (m, 1H Ar$\underline{CH}$*), 3.43 (dd, *J* = 7.4, 9.1 Hz, 1H CH$_A\underline{H}_B$NH), 2.78 (dd, *J* = 8.8, 17.0 Hz, 1H), 2.53 (dd, *J* = 8.8, 17.0 Hz, 1H), 2.92-1.82 (m, 6H), 1.77-1.62 (m, 2H); ^{13}C NMR (75MHz, $CDCl_3$): δ 175.5, 149.1, 147.9, 134.5, 118.8, 113.8, 112.2, 80.6, 56.1, 49.8, 39.9, 32.8, 24.0.

RESULTS AND DISCUSSION

As part of our ongoing research program herein, we wish to report on a new catalyst for Michael addition. However, we are first time demonstrating that the use of $Fe(acac)_3$ for Michael addition of Nitromethane **2** on Chalcone **1a** furnished the **3a** with good yield at ambient reaction condition in 1.0h (Scheme 1).



Scheme 1.[a] Reaction Conditions: a) Chalcone (0.82 mmol), Nitromethane(2) (4.10 mmol), 5 mol % $Fe(acac)_3$, anhy. DMSO (2mL), rt.

For optimization of reaction condition, screening of various solvents such as $CHCl_3$, CH_2Cl_2, EtOH, DMF, and DMSO. The reaction was carried out as shown in Scheme 1 and consequent results in Table 1.While in DMF and DMSO catalyze the reaction to provided in good yields in 1.0-1.5h, the other solvents provided lower yields under similar reaction condition.

We found that DMSO is having the yield of **3a** (90 %, entry 5) has been emerged as the most convenient solvent and DMF is also having the yield of **3a** (87 %, entry 4). It is interesting to note that (DMF and DMSO) are highly polar solvent and they have lack of the ability to form hydrogen bonding. But these solvents are still able to solvate cation by donating electron from oxygen. As a result of investigation several solvents, DMSO was found to be the most effective solvent for promoting favorable reaction condition and **3a** was obtained in 90 % yield.

Table 1. Solvent effect for the synthesis γ- nitro ketone

Entry	Solvent	Time (h)	Yield (%)[b]
1	CH_2Cl_2	12.0	45
2	$CHCl_3$	13.0	40
3	EtOH	8.5	75
4	DMF	1.5	87
5	DMSO	1.0	90

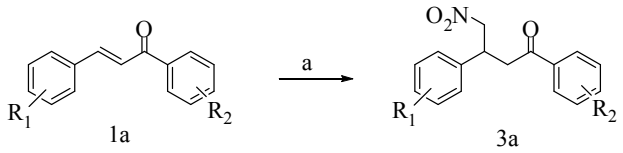
[a]**Reaction Conditions**: a) Chalcone (0.82 mmol), Nitromethane (4.10 mmol); 5 mol % $Fe(acac)_3$, solvents (2mL), rt [b] Isolated yield after purification; [c] acac = acetyl acetonate, rt = room temp

Table 2. Effect of catalyst loading for synthesis of γ- nitro ketone

Entry	Mol%	Time (h)	Yield (%)[b]
1	10.0	1.0	83
2	5.0	1.0	90
3	1.0	1.0	86
4	0.5	1.0	70
5[c]	0.0	1.0	--

[a]**Reaction Conditions**: a) Chalcone (0.82 mmol), Nitromethane (4.10 mmol) ; 5 mol % $Fe(acac)_3$, anhydrous DMSO (2mL) rt.; [b]Isolated yield after purification; [c] no reaction;

By choosing the reaction parameters as shown in (Scheme 1), we have studied the influence of amount of catalyst in DMSO as a solvent on yield of 3a. It has been observed that, the model reaction did not initiate at all without a catalyst for 1.0 h in DMSO. The amount of catalyst used for this reaction was varied from 10 mol % to 0.5 mol %. As can be expected, by decreasing the amount catalyst loading from 10 mol % to 1 mol %; the yield of 3a is approximating same. However, a very less (0.5 mol %) of catalyst gave less yield (70%, entry 4). The influence of the two experimental parameters (solvent and catalyst load) was studied and the experiment that probe to the scope of chalcone substrate as shown in (Scheme 2) and summarized in (Table 3) Both Electron donating and electron withdrawing substituent on Chalcone 1a-1j underwent clean reactions affording the desired product with high yield (85-95 %). The substituent on α phenyl ring of chalcone with electron withdrawing group such as chloro, nitro, proceeds at faster rate than those with electron donating group such as methoxy, Cyclopentaoxy etc. All products were characterized by spectroscopic data (IR, ^{1}H NMR, ^{13}C NMR and Mass) with elemental analysis.



Scheme 2

Table 3. Fe catalyzed Michael addition reaction of nitro methane to substituted Chalcone in DMSO

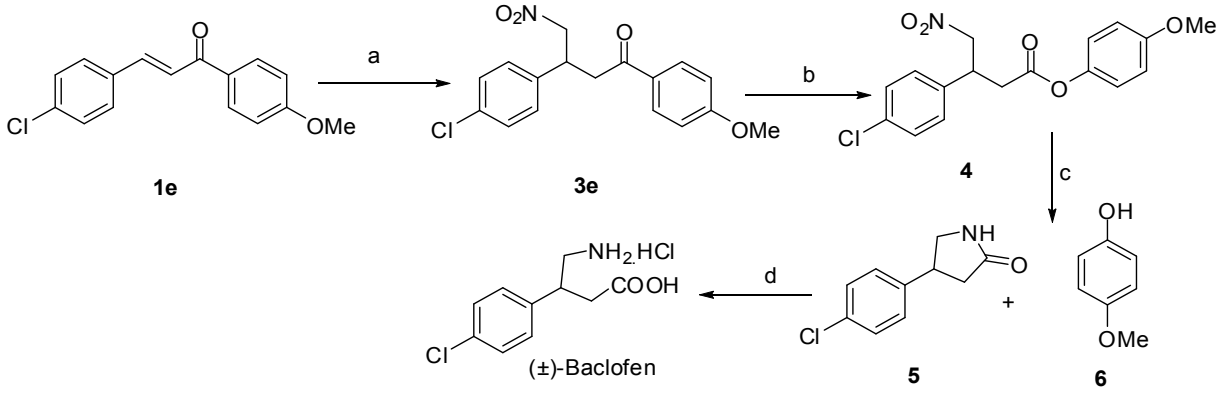
Entry	Reactant	R_1	R_2	Product	Time(h)	Yield(%)[b]
1	1a	H	H	3a	1.0	90
2	1b	4-Cl	H	3b	1.2	89
3	1c	2-Cl	H	3c	1.5	86
4	1d	3-Cl	H	3d	1.2	87
5[c]	1e	4-Cl	4-OMe	3e	6.0	85
6	1f	4-Br	H	3f	1.5	87
7	1g	4-NO_2	H	3g	0.3	95
8	1h	3-NO_2	H	3h	0.4	87
9	1i	2-NO_2	H	3i	0.3	90
10	1j	H	4-Cl	3j	2.0	88

[a]**Reaction Conditions**: a) Chalcone (0.82 mmol), Nitromethane (4.10 mmol) and 5 mol % $Fe(acac)_3$, anhydrous DMSO (2mL), rt [b] Isolated yield after purification ; [c]3e new compound; [d] DMSO = Dimethyl Sulphoxide, acac = acetyl acetonate, rt = room temp. Furthermore, Application of our methodologies was extended to the concise synthesis of (±)-Baclofen and (±)-Rolipram. The synthesis of (±)-Baclofen

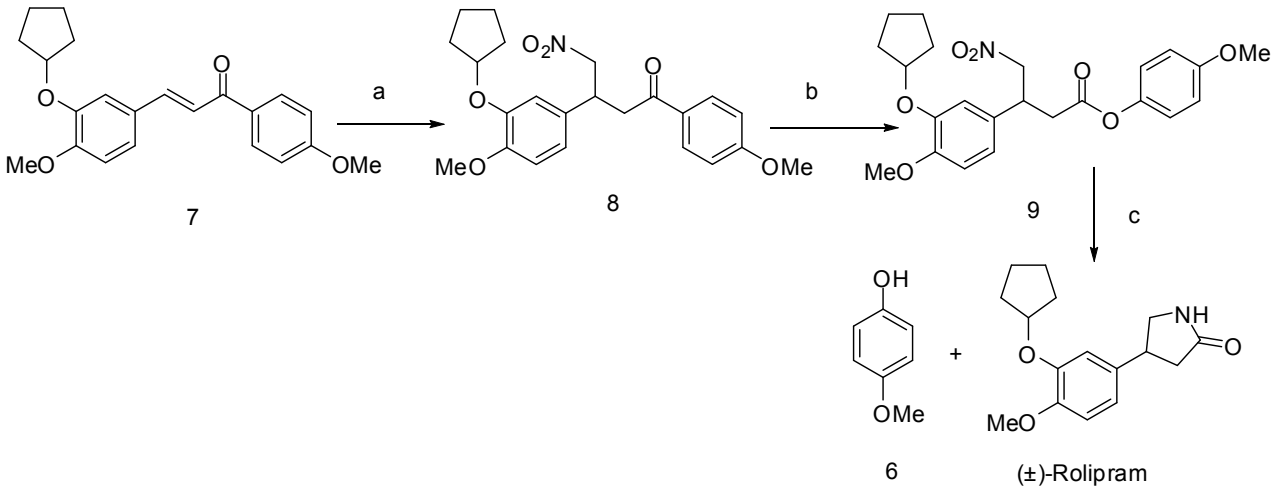
(Scheme 3) started from (4-chlorophenyl)-1-(4-methoxyphenyl) prop-2-en-1-one. A mixture of (4-chlorophenyl)-1-(4-methoxyphenyl)prop-2-en-1-one 1e and nitro methane in DMSO in presence of catalytic quantity (1 mol%) of Fe(acac)$_3$ to gives γ- nitro ketone 3e in 85% yield. Baeyer-Villiger reaction on 3e using H_2O_2 in AcOH to give corresponding γ- nitro ester 4, the resulting nitro group can be reduced with sodium borohydride in presence of nickel chloride it resulted to generate a pyrrolidine moiety 5. Finally, hydrolysis of pyrrolidine with HCl will lead to (±)-Baclofen as a neurotransmitter inhibitor drug molecule. Using this strategy, (±)-Baclofen was obtained in four steps with an overall of yield 53.55%. It is used therapeutically to treat spasms caused by spinal cord injury or disease.

neurotransmitter inhibitor drug molecule. We have achieved a synthesis of (±)-Rolipram in three steps with an overall yield of 52.16%. A broad scope of Baeyer Villiger oxidation by H_2O_2 as the oxidant has been accomplished in the presence of AcOH. Here, we found that the relative migratory ability of the methoxy substituent attached to a carbonyl which converts ketone to ester easily.

The methoxy group stabilizes positive charge in Baeyer Villiger oxidation for formation of desired product within short time as compared to litt (Corey *et al.,* 2000) and by product p-hydroxy anisole **6** is an important starting material for synthesis of bioactive molecules (Suresh *et al.,* 2008).



Scheme 3. a) Chalcone 1e(0.82 mmol), Nitromethane 2 (4.10 mmol), Fe(acac)$_3$, DMSO, 40 °C, 85%. b) H_2O_2 , H_2SO_4, AcOH 60 °C, 90% c) $NiCl_2.6H_2O$, $NaBH_4$, MeOH, 30 min 0 °C - rt, 70%. d) 6N HCl, reflux, 24 h



Scheme 4. a) Chalcone (0.82), Nitromethane 2 (4.10 mmol), Fe(acac)$_3$, DMSO, 50 °C, 82%. b) H_2O_2 , H_2SO_4, AcOH 60 ^{0}C, 92% c) $NiCl_2.6H_2O$, $NaBH_4$, MeOH, 30 min 0 ^{0}C - rt, 70%

We further interested to use present synthetic strategy for synthesis of (±)-Rolipram the novel synthetic route as represented in the Scheme 4. Accordingly, we subjected to chalcone 7 on iron catalyzed Michael addition of nitro methane to gives γ- nitro ketone **8** in 82 % yield. Baeyer-Villiger reaction on **8** using H_2O_2 in AcOH to offered corresponding γ-nitro ester **9**, followed by nickel catalyzed reduction of the nitro group with sodium borohydride in presence of nickel chloride to afford cyclic amide as a (±)-Rolipram act as

Conclusion

In summary, we have developed an environmentally friendly Michael addition of nitro methane on different Chalcone in the presence of transition metal catalyst at ambient reaction condition without formation of salt. The methodology has been applied successfully synthesis of (±)-Rolipram and (±)-Baclofen *via* novel Baeyer Villiger reaction. An advantage of this synthetic strategy includes simple catalyst, mild reaction, shorter reaction times and easy work-up procedure.

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REFERENCES

An iron-catalysed synthesis of amides from nitriles and amines Allena, C. L., Lapkin, A. A., Williams, J. M. J. 2009 *Tetrahedron Lett*. 50 4262

Baeyer-Villiger Oxidation and Rearrangement. Baeyer, A., Villiger, V. *Ber. Dtsch.* 1899 *Chem. Ges.* 32 3625

Catalytic C-C Bond Formation Promoted by Mg-Al-O-t-Bu Hydrotalcite Choudary, B. M., Kantam, M. L., Kavita, B., Reddy, C. V., Figueras, F. 2000 *Tetrahedron*. 56 9357

Conjugate Additions of Nitroalkanes to Electron-Poor Alkenes: Recent Results Ballini, R., Bosica, G., Fiorini, D., Palmieri, A., Petrini, M. 2005 *Chem. Rev*. 105 933

Construction of Quaternary Stereocenters by Nickel-Catalysis of Asymmetric Michael Reactions Christoffers, J., Robler, U., Werner, T. 2000 *Eur. J. Org. Chem*. 701

Enantioselective Michael Addition of Nitromethane to α,ß Enones Catalyzed by Chiral Quaternary Ammonium Salts. A Simple Synthesis of (*R*)-Baclofen Corey, E. J., Zhang, F. Y. 2000 *Org. Lett*. 2 4257

Enantioselective Michael Additions of nitroalkanes to chalcones by phase transfer catalysis using chiral quaternary ammonium salts

Enantioselective Michael Additions of Nitromethane to α,ß-Unsaturated Ketones Catalyzed By Transition Metal Complexes with Chiral Nitrogen Ligands Schionato, A., Paganelli, S., Botteghi, C., Chelucci, G. 1989 *J. Mol. Catal.* 50 11

Enantioselective organocatalytic conjugate addition of a-nitroacetate to α,ß-unsaturated ketones in water Moon, H. W., Huh. S. C. 2010 *Tetrahedron Lett*. 51 2906

Highly Chemo- and Stereoselective Fe-Catalyzed Alkenylation of Organomanganese Reagents Cahiez, G., Marquais, S. 1996 *Tetrahedron. Lett*. 37 1773.

Huh, H.C., Kim, D.Y. 2001 *Tetrahedron*. 57 8933

Iron Catalyzed reactions Synthesis Bolm, C., Legros, J., Le,Paih, J., Zani, L. 2004 *Chem. Rev*. 104 6217

Iron/copper-catalyzed C–C cross-coupling of aryl iodides with terminal alkynesVolla, C. M. R., Vogel, P. 2008 *Tetrahedron Lett*. 49 5961

Iron-Catalyzed Homocoupling of Bromide Compounds Xu, X., Cheng, D., Pen, W. 2006 *J. Org .Chem*. 71 6637

Michael Addition Catalyzed by Metal(II) Complexes Watanabe, K. I., Miyazu, K. I., Irie, K. 1982 *Bull Chem. Soc. Jpn.* 55 3212

Michael addition catalyzed by Nickel (II) or Cobalt (II) Acetate 2,2'-Bipyridine Complexes Irie, K., Miyazaom, K., Watanbe, K. I. 1980 *Chem. Lett*. 353

Michael additions catalyzed by transition metals and lanthanide species. A review Comelles, J., Mañas, M. M., Vallribera, A. 2005 *Arkivoc*. 9 207

On the Role of Metal Contaminants in Catalyses with $FeCl_3$ Buchwald, S. L., Bolm, C. 2009 *Anwge. Chem. Int. Ed*. 48 5586

Ono, N. 2001 *The Nitro Group in Organic Synthesis; Wiley-VCH: New York*, 392

o-Quinones(XXXIV), Quinones derived from fluorene & Fluorenone Horner L., Baston D. W. 1973 *Liebig's Annalen*. 910

Organocatalytic Asymmetric Total Synthesis of (R)-Rolipram and Formal Synthesis of (3S,4R)-Paroxetine Peter S. H., Paul A. S., Darren J. D 2008 *Org. Lett.* 7 1389

Photochemical H_2 production with noble-metal-free molecular devices comprising a porphyrin photosensitizer and a cobaloxime catalyst Kuninobu, Y., Nishi, M., Takai. K. 2010 *Chem. Commun*. 46 8860

Recent synthetic developments in the nitro to carbonyl conversion (Nef reaction) Ballini, M., Petrini, M. 2004 *Tetrahedron.* 60 1017

Synthesis of substituted quinolines by iron-catalyzed coupling reactions between chloroenynes and Grignard reagents Seck, M., Franck, X., Hocquemiller, R., Figadere, B., Peyrat, J. F.,Provot, O.,Brion, J. D., Alami, M. 2004 *Tetrahedron Lett*. 45 1881

Synthesis of α-methylene y-lactone involving Baeyer-Villiger oxidation of α-substituted cyclobutanes. Ali S. M., Robert S. M. 1976 *J. Chem. Soc. Perkin Trans.*1. 1934

The Henry Reactions: Recent Examples. Luzzio, F. A. 2001 *Tetrahedron.* 57 915

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