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A NEW CYCLOPENTANOL AS A SIDE PRODUCT IN THE REDUCTION OF THE CHALCONE

ŞALKONUN REDÜKSİYONUNDA BİR YAN ÜRÜN OLARAK YENİ BİR SİKLOPENTANOL

Vildan ALPTÜZÜN*[0], Belkis GÖZLER

Ege University, Faculty of Pharmacy, Department of Pharmaceutical Chemistry, 35100 Bornova-izmir, TURKEY

ABSTRACT

As a part of an ongoing study on the synthesis of 1,3-diphenylpropanones, as key intermediates in the total synthesis of 11,12-dihydro-10,5-(iminomethano)-5H,10H-dibenzo[a,d]cyclooctenes with potential Central Nervous System activity, 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)-2-propenone is obtained by the Claisen-Schmidt reaction of 3,4-dimethoxybenzaldehyde and 3-methylacetophenone. At the second step, the reduction of the olefinic bond of chalcone was attempted by using Zn/acetic acid. Although the desired saturated ketone was obtained during this reduction, the major product was a new cyclopentanol, formed by cyclodimerization. The structure and the stereochemistry of this new compound was elucidated by ID and 2D NMR analyses.

Key Words: *Propanones, chalcones, Claisen-Schmidt reaction, hydrodimerization*

ÖZET

1,3-difenilpropanonlar üzerinde sürdürülmekte olan sentez çalışmalarının devamı olarak, potansiyel Santral Sinir Sistemi aktivitesine sahip olan 11,12-dihidro-10,5-(iminometano)-5H,10H-dibenzo[a,d]sikloooktenlerin total sentezinde anahtar araürün olan, 3-(3,4-dimetoksifenil)-l-(3-tolil)-2-propenon, 3,4-dimetoksibenzaldehit ve 3-metilasetofenonun Claisen-Schmidt reaksiyonu ile elde edilmiştir. ikinci basamakta, şalkonun olefinik bağının redüksiyonu, Zn/asetik asit kullanılarak yapılmıştır. Her nekadar redüksiyon sırasında doymuş keton elde edilmiş olsa da, ana ürün siklodimerizasyonla oluşan yeni bir siklopentanoldür. Bu yeni bileşiğin kimyasal yapısı ve stereokimyası ID ve 2D NMR analizleri ile aydınlatılmıştır.

Anahtar Kelime: *Propanonlar, şalkınlar, Claisen-Schmidt reaksiyonu, hidrodimerizasyon*

* Corresponding Author
[0]M.S. Thesis

As a part of a comprehensive study on the total synthesis of homoisopavines with potential activity on the Central Nervous System, derivatives of 1,3-diphenyl-2-propanones are synthesized as key intermediates by using a two-step sequence. The initial step leading to the a,P-unsaturated ketone (chalcone) is a Claisen-Schmidt reaction of the appropriate substituedaldehyde with an acetophenone. The a,P-unsaturated ketone moiety of the chalcone thus obtained is an active center for a nucleophilic attack, and can alkylate nucleophiles, such as

thiol, amino and hydroxyl groups by a Micheal type addition. Documented pharmacological potential of chalcones, such as antibacterial, antiviral, gastric protectant, antimutagenic, retinoid, antimitotic, antioxidant and antiinflamatory activities [1-5], are attributed in part to the alkylating ability of the olefin conjugated with a carbonyl group.

At the second step, the olefinic bond of the cc,(3-unsaturated carbonyl compound is saturated to furnish the corresponding propanone derivative. In this study, a mild reduction was attempted by using zinc in acetic acid instead of catalytic hydrogenation, due to the unavailability of the latter experimental conditions in our laboratories. However, during the course of the reduction of 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)-2-propenone (1) with zinc/acetic acid to obtain the expected 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)propanone (2), another compound proved to be the major product of the reaction at the expense of the desired 2. The structure of this side product, elucidated by high resolution ID and 2D NMR experiments, proved to be a new cyclopentanol derivative (3). It has been amply documented in literature that the intramolecular cycloreductive coupling of a,|3-unsaturated ketones in the presence of metals such as Yb, Zn, Nd, Sn, In, Sm yield cyclopentanol derivatives in high yields [6,7]. Since it is also known that similar reductions with different reagents and reaction conditions result in cyclopentanols with either *cis* or *trans* configurations at C-3 and C-4 [6-9] stereochemical preferences of 3 were established by using NMR data.

MATERIAL AND METHODS

Instrumentation

UV spectra were taken on Shimadzu UV-160 spectrometer in methanol solution; IR spectra (KBr) were recorded on a Perkin Elmer 297 Infrared Spectrophotometer; EI Mass spectra were obtained on a Finnigan-Mat SSQ 700 spectrometer; ID and 2D NMR spectra were recorded with a Bruker AMX-600 spectrometer.

Material

All solvents were purchased from Merck. Chemicals were of analytical grade and purchased from Merck, Fluka and Aldrich.

Methods

Synthesis of 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)-2-propenone (1)

3-methylacetophenone (0.039 mol, 5.3 ml) and 3,4-dimethoxybenzaldehyde (0.039 mol, 6.5 g) in ethanol was added to a solution of NaOH (1,989 g) in H_20 (20 ml) and was stirred at room temperature for 10.5 hr. The mixture was extracted twice with $CHC1_3$ (2x50 ml). Organic phase was dried over Na_2S0_4 and the solvent was removed *in vacuo.* The crude product was purified by preparative tic on silica gel plates using n-hexane-$CHCl_3$-acetone (45:4:25) for devolepment to furnish compound 1 as yellow oil (6.4 g, 58%)

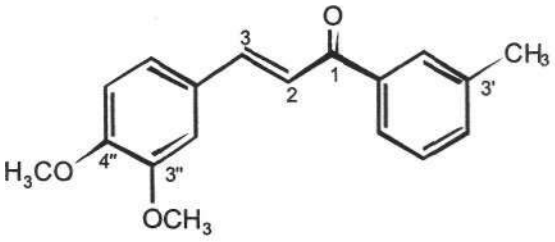
Synthesis of 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)-l-propanone (2)

Zinc powder (15 g) was added to 1 (0.0354 mol, 10 g) in glacial acetic acid and was stirred at room temperature for 1 hr. After the completion of the reaction, pH was adjusted to 5 with aqueous NaOH solution. The mixture was extracted twice with $CHC1_3$ (2x50 ml).The organic phase was dried over Na_2S0_4 and the solvent was removed *in vacuo.* The residue was washed with diethylether. The white residue, unsoluble in ether, was filtered and crystallized from methanol (3) (2.74 g, 41%) (mp: 145-146°C). The ethereal was distilled under reduced pressure and the residue was purified by column chromatography on Kieselgel 60 (170-230 Mesh) by eluting with n-hexane-ethylacetate (4:1) to yield compound 2 as a yellowish solid **(1.14** g, 34%).

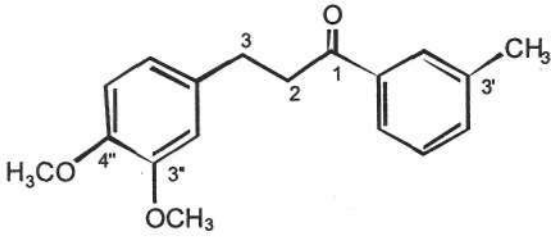
RESULTS AND DISCUSSION

The first stage of the designed reaction was the condensation of 3,4-dimethoxybenzaldehyde and 3-methylacetophenone under the Claisen-Schmidt Reaction conditions. The formation of the target compound, 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)-2-propenone (1), was corroborated from the 'H NMR spectrum taken in $CDC1_3$, where the two doublets at _ 7.38 and 7.76 *(J* 15.4 Hz) pointed to the presence of *trans-olefmic* hydrogens. The relatively high frequency values of these chemical shifts accounted for the conjugation with the aromatic moiety. Further high frequency signals consisted of a clearly interpretable ABX system for ring B hydrogens, and a non-first-order pattern for four hydrogens of ring A. The aliphatic region was characterized by three sharp singlets at _ 2.45, 3.94 and 3.96, integrating for three protons each, for the resonances of the methyl and two methoxyl groups, respectively. The presence of the cross-conjugated carbonyl group was clearly discernible from the strong absorption signal at 1658 cm^{-1} in the IR spectrum. In the EIMS of 1, the molecular ion was at m/z 282, a value which was in accordance with the calculated molecular formula of $C_{18}H_{18}0_3$. 1 is a new compound, hitherto not reported in literature.

Compound 1 was then subjected to a zinc/acetic acid reduction with the aim of saturating the double bond without affecting the ketonic function, which yielded two compounds, 2 and 3, the latter being the major product.



1



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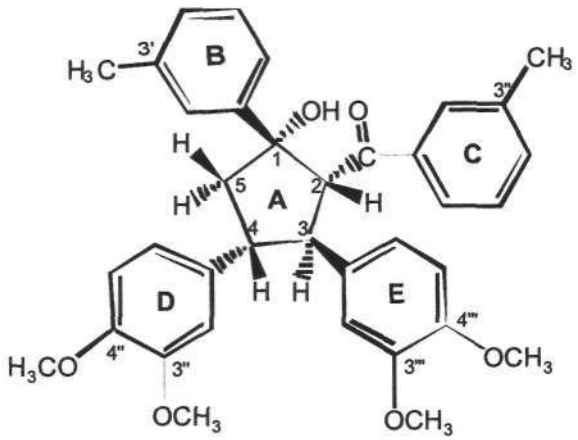

3

The strong absorption at 1682 cm"[1] in the IR spectrum of 2 proved that the ketone carbonyl has survived through the reduction. The shift of the absorption to a higher frequency was indicative of the diminished conjugation as a result of bond saturation. As expected, the molecular ion peak in the mass spectrum of 2 was two units higher (m/z 284) as compared to that of 1, confirming the addition of only one molecule of hydrogen to the olefinic bond. In the 'H NMR of 2, the appearance of two triplets of two protons each at _ 3.02 and 3.26 provided further proof to the hydrogenation of the olefinic bond. The remaining 'H NMR spectral data were also in agreement with the structural features of 3-(3,4-dimethoxyphenyl)-l-(3-tolyl)-l-propanone (2), which is also a new compound.

The major product of dehydrogenation (3) crystallized from methanol as white needles. The first indication of its dimeric structure was obtained from the 'H NMR spectrum taken in $CDC1_3$, where the methyl and methoxyl signals were duplicated. Likewise, the integration of aromatic signals in this spectrum revealed the presence of fourteen hydrogens instead of the expected seven. Moreover, the ^{13}C NMR DEPT spectrum established the presence of thirty-six carbons as six methyls, a methylene, seventeen methines and twelve quaternary carbons, only one of which was a carbonyl function. The latter was also authenticated by a strong 1645 cm"' absorption in the IR spectrum. A supportive fact pointing to the presence of a dimer was provided by the CI-MS of 3, where the $[M+H]^+$ ion was observed at m/z 567. 2D NMR

experiments ('H,1H DQF COSY, HSQC and HMBC) were performed for the structure elucidation of 3.

With the aid of the information gathered from the coupling constants deduced from the well-resolved 'H NMR spectrum and also from the 'H,'H DQF COSY experiment **(Tablel),** the latter of which furnished ample evidence for the interacting hydrogens, four aromatic rings, designated as B, C, D and E were constructed. As expected, two of these rings were in the form of m-tolyl and two in the form of 3,4-dimethoxyphenyl moieties, pointing once again to the postulated dimerization of the monomeric intermediate. More interesting features of the 1H and ^{13}C NMR spectra were the resonances observed in the aliphatic region, accounting for the presence of one quaternary, three methine and one methylene carbons. Relevant connectivities in the 'H,'H DQF COSY spectrum suggested a probable sequential arrangement of these carbons to form a five-membered ring (ring A). The broad singlet observed at _ 5.16 in the 'H NMR spectrum hinted at the presence of a hydroxyl function, which was further confirmed by the 3440 cm"[1] absorption signal in the IR spectrum of 3.

Following the exact assignment of the chemical shifts for the protonated carbons by using the data obtained from the HSQC experiment **(Table 1),** access to more valuable information was provided by the HMBC experiment **(Table 1),** unfolding the $^{2}J_{CH}$ and $^{3}J_{CH}$ connectivities, therefore, allowing a complete and precise assignment of the carbon chemical shifts. The most informative features in the HMBC experiment were the $^{3}J_{CH}$ correlations of the corresponding H-2 and H-6 on rings B, C, D and E **(Table 1).** These correlations allowed unambiguous connections of these four aromatic moieties to the centrally located five membered-ring A. Explicit assignments of each of the thirty-six carbons could be realized by detailed evaluations of the relevant connectivities observed in the HMBC spectrum. Consequently, the structure of the new compound (3) could be constructed as 3,4-di(3,4-dimethoxyphenyl)-2-(3-toluoyl)-l-(3-tolyl)cyclopentan-l-ol with a molecular formula of $C_{36}H_{38}0_6$ (MW 566).

Table 1. ID and 2D NMR Spectral Data for 3,4-di(3,4-dimethoxyphenyl)- 2-(3-toluoyl)-l-(3-tolyl)- cyclopentan-1-ol (3)

Rings	**Hydrogens**	^{1}H **NMR**	HSQC	**^{1}H,^{1}H DQF COSY**	**HMBC**
A	H-2	4.46	63.1	H-3	C-5, C-3, C-l, C=0, C-l"", C-l'
	H-3	4.01	59.1	H-2	C-5,C-2,C=0,C-2"",C-6""
	H-4	3.64	51.0	**H-3, H-5,** H-5	C-5, C-3, C-l, C-2"', C-6"', C-l"' ,C-1'"
	H-5	2.97	50.9	H-5	C-4,C-3,C-1'",C-1'
	H-5	2.54	50.9	H-5	C-4, C-3, C-2, C-l, C=0, **C-l'"**
B	H-2'	7.39	125.7	**H-6', H-4'**	3'-CH_3,C-l,C-6',C-4'
	H-4'	6.99	127.7	**H-2', H-5'**	3'-CH_3, C-6', C-2'
	H-5'	7.20-7.17	128.1	**H-6'**	C'-6,C-3',C-r
	H-6'	7.34	121.8	**H-2', H-5'**	C-l, C-2', C-4'
C	H-2"	7.20-7.17	128.7		3"-CH_3, C=0, C-6", C-4"
	H-4"	7.20-7.17	134.1	**H-5"**	3"-CH_3, C-3", C-6"
	H-5"	7.07	128.0	**H-2", H-4", H-6"**	C-6", C-l", C-3"
	H-6"	7.28	125.2	**H-2", H-4", H-5"**	C=0, C-5", C-2", C-4"
D	**H-2'"**	7.11	110.9	**H-6'"**	C-4, C-6'", C-l'", C-4'", C-3'"
	H-5'"	6.72	110.7	**H-6'"**	C-6'", C-l'", C-3'", C-4'"
	H-6'"	6.83	120.0	**H-2'", H-5'"**	C-4, C-2'", C-4'"
E	H-2""	6.52	113.3	**H-6""**	C-3, C-6"", C-l"", C-4"", C-3""
	H-5""	6.64	111.1	**H-6""**	C-6"", C-l"", C-4"", C-3""
	H-6""	6.74	119.1	**H-5"", H-2""**	C-3, C-2"", C-4""
	OCH_3	3.88	55.80		3'"-OCH_3
	OCH,	3.83	55.76		4'"-OCH_3
	OCH_3	3.75	55.7		4""-OCH_3
	OCH3	3.63	55.6		3""-OCH3
	CH_3	2.19	21.0		C-2", C-3", C-4"
	CH_3	2.30	21.5		C-2', C-4', C-3'
	OH	5.16			C-l, C-2

It is well established in literature that an oc,Punsaturated ketone can react with a metal or a low-valent metalic salt to furnish linear hydrodimeric coupling products by linkage of two P-carbons [6,9]. On the other hand, at certain conditions, cx,Punsaturated ketones can also undergo an intermolecular aldol reaction with Zn, Sm, In, Sn, Nd metals to afford cyclopentanol derivatives [6-11]. The configurations of these cyclodimerization products may vary at C-3 and C-4 as being *trans* or *cis,* depending on the reaction conditions and the reagents utilized in the

course of the reaction. However, in many cases, the *3,4-trans* configuration is reported to be the major product [6,7,9,10]. This stereochemical preference is explained by the fact that during the initial step of cyclodimerization, an electron is transferred from metal to the chalcone to afford a radical enolate, which then attacks the chalcone to form carbon-carbon bond. At this stage, an anti-position, which minimizes the steric interactions, is favored for both the radical anion and chalcone, thus allowing the phenyl groups at C-3 and C-4 to adopt *trans* dispositions [7]. The relative configurations at the remaining carbons of the cyclopentanol are such that 1-hydroxyl, 2-carbonyl and 4-phenyl substituents are on the same face, whereas 1-phenyl and 3-phenyl are on the opposite face. This is rationalized by the fact that at the final step of cyclodimerization procedure, when the metal forms a chelate with the carbonyl groups, the chair conformation is more favored as opposed to the boat. In this case, subsequently formed hydroxyl at C-l occurs on the same side with the carbonyl at C-2 [9].

The stereochemical preference of compound 3, deduced from the relevant coupling constants of the cyclopentanol hydrogens, is found to be in good accordance with the literature findings mentioned above. Thus, in the 'H NMR spectrum of 3, the coupling constants of H-3 (/ 11.8 and 10.3 Hz) reveal that neighboring H-2 and H-4 are in *trans* relationship with H-3. The suggested configurations at these chiral centers (1R, 25, *3R*, 45) are in agreement with those reported in literature [6,7,9,10].

During the reduction of conjugated systems, such as oc,P-unsaturated carbonyl compounds, with zinc in acetic acid to obtain the corresponding saturated carbonyl compounds, the unsaturated ketone can not function as a proton donor if it lacks an acidic hydrogen, as is the case with compound 1, thus resulting in the formation of dimers at the expense of the desired saturated monomeric species [12,13]. Therefore, the present study, emphasizing the need for the use of a proton donor in the reduction of a,(3-unsaturated propenones to afford the corresponding propanones, has guided our research in our future attempts for the reduction of analogous compounds.

Compound 1: UV (MeOH) A_{max} (log e) nm: 207 (4.59), 234 (4.17), 352 (3.68). IR v_{max} (KBr) cm^{1}: 3003, 2921, 2850, 1728, 1658, 1591, 1512, 1463, 1421, 1340, 1309, 1263, 1159, 1141, 1056, 1026, 983, 792, 719. ^{J}H **NMR** ($CDC1_3$): 8 2.45 (3H, s, 3'-CH_3), 3.94 (3H, s, 4''-OCH,*), 3.96 (3H, s, 3''-OCH_3*), 6.91 (1H, d, / 8.3 Hz, H-5''), 7.17 (1H, d, *J* 1.9 Hz, H-2''), 7.24 (1H, dd, *J* 8.4, 1.9 Hz, H-6''), 7.38 (1H, d, *J* 15.4 Hz, H-2), 7.35-7.40 (2H, m, H-4' and H-5'), 7.73-7.82 (2H, m, H-2' and H-6'), 7.76 **(1H,** d, *J* 15.7 Hz, H-3). **EIMS:** m/z (%) 283 [$(M+l)^+$, 23], 282 (M^+, 64), 281 (14), 267 (20), 251 (18), 191 (24), 165 (11), 138 (25), 119 (59), 105(11), 92 (10), 91 (100), 89 (30), 77 (22), 65 (35), 63 (17).

Compoud 2: UV (MeOH) A_{raax} (log e) nm: 206 (4.61), 237 (4.12), 280 (3.62). IR v_{max} ($CHC1_3$) cm^{1}: 3004, 2960, 2937, 2839, 1682, 1604, 1587, 1514, 1465, 1442, 1421, 1359, 1263, 1207, 1201, 1180, 1155, 1028, 981, 740. 'H **NMR** ($CDC1_3$): 5 2.40 (3H, s, 3'-CH_3), 3.02 (2H, t, *J* 7.4 Hz, H-2), 3.26 (2H, t, / 7.4 Hz, H-3), 3.86 (3H, s, 4''-OCH_3*), 3.87 (3H, s, 3''-OCH_3*), 6-.77-6.83 (3H, m, H-2'', H-5'' and H-6''), 7.31-7.38 (2H, m, H-4' and H-5') 7.31-7.38 (2H, m,-

H-2' and H-6'). **EIMS:** m/z (%) 284 (M^+, 11), 165 (29), 152 (9), 151 (100), 138 (6), 121 (5), 120 (8), 119 (63), 107 (9), 92 (6), 91 (60), 89 (8), 79 (8), 78 (6), 77 (11), 65 (21), 63 (5), 51 (5).

Compoud 3: UV (MeOH) X_{mm} (log *e)* nm: 206 (4.01), 254 (3.89), 277 (3.37). İR v_{max} (KBr) cm^{1}: 3440, 2963, 2947, 2848, 1645, 1609, 1594, 1594, 1474, 1452, 1419, 1367, 1259, 1229, 1165, 1142, 1061, 1026, 851, 806. 'H **NMR** ($CDC1_3$): Ring A: 5 2.54 (İH, dd, / 6.0, 14.6 Hz, H-5), 2.97 (İH, dd, y 11.3, 14.6 Hz, H-5), 3.64 (İH, m, H-4), 4.01 (İH, dd, *J* 10.3, 11.8 Hz, H-3), 4.46 (İH, d, / 12.0 Hz, H-2), 5.16 (İH, br. s, 1-OH); Ring B: 5 2.30 (3H, s, 3'-CH_3), 6.99 (İH, br. d, *J* 7.5 Hz, H-4'), 7.20-7.27 (İH, m, H-5'),7.34 (İH, d, *J* 7.9 Hz, H-6'), 7.39 (İH, br. s, H-2'); Ring C: 5 2.19 (3H, s, 3"-CH_3), 7.07 (İH, t, *J 1.1* Hz, H-5"), *120-1 Al* (2H, m, H-2" and H-4"), 7.28 (İH, d, / 7.9 Hz, H-6"); Ring D: 8 3.83 (3H, s, 4"'-OCH_3), 3.88 (3H, s, 3"'-OCH_3), 6.72 (İH, d, *J* 8.1 Hz, H-5"'), 6.83 (İH, dd, *J* 8.2, 1.9 Hz, H-6"'), 7.11 (İH, d, *J* 1.9 Hz, H-2"'); Ring E: 8 3.63 (3H, s, 3""-OCH_3), 3.75 (3H, s, 4""-OCH_3) 6.52 (İH, d, *J* 1.9 Hz, H-2""), 6.64 (İH, d, *J* 8.3 Hz, H-5""), 6.74 (İH, dd, / 8.0, 1.9 Hz, H-6""). ^{13}C **NMR** ($CDC1_3$): Ring A: 8 50.9 (C-5), 51.0 (C-4), 59.1 (C-3), 63.1 (C-2), 84.0 (C-1); Ring B: 8 21.5 (3'-CH_3), 121.8 (C-6'), 125.7 (C-2'), 127.7 (C-4'), 128.1 (C-5'), 137.87 (C-3'), 145.2 (C-1'); Ring C: 8 21.0 (3"-CH_3), J25.2 (C-6"), 128.0 (C-5"), 128.7 (C-2"), 134.1 (C-4"), 137.75 (C-1"), 137.88 (C-3"); Ring D: 8 55.76 (4"'-OCH_3), 55.8 (3"'-OCH_3), 110.7 (C-5"'), 110.9 (C-2"'), 120.0 (C-6"'), 136.8 (C-1"'), 147.5 (C-4"'), 148.9 (C-3"'); Ring E: 8 55.6 (3""-OCH_3), 55.7 (4""-OCH_3), 111.1 (C-5""), 111.3 (C-2""), 119.1 (C-6""), 132.6 (C-1""), 147.7 (C-4""), 148.5 (C-3""). **CIMS:** m/z (%) 567 $[M+H]^+$. **'H/H DQF COSY, HSQC** and **HMBC: Table 1.**

* interchangeable

REFERENCES

1. **Anto, R. J., Sukumaran, K., Kuttan, G., Rao, M., Subbaraju, V., Kuttan, R.,** "Anticancer and Antioxidant Activity of Synthetic Chalcones and Related Compounds", *Cancer Letter,* 97,33-37 (1995).

2. **Batt, D. G., Goodman, R., Jones, D. G., Kerr, J. S., Mantegna, L. R., Mcallister, C, Newton, R. C, Nürnberg, S., Welch, P. K., Covington, M .B.,** "2'-Substituted Chalcone derivatives as Inhibitors of Interleukin-1 Biosynthesis", *J. Med. Chem.,* 36, 1434-1448 (1993).

3. **Ram, V. J., Saxena, A. S., Srivastava,** S. , **Chandra,** S., "Oxgenated Chalcones and Bischalcones as Potential Antimalarial Agents", *Bioorganic Chemistry Letters,* 10,2159-2161 (2000).

4. **Hsieh, H., Tsao, L., Wangand, J., Lin, C,** "Synthesis and Anti-inflammatory Effect of Chalcones", *Journal of Pharmaceutical Pharmacology,* 52, 163-171 , (2000).

5. **El-subbagh, C. H. L, Abu-zaid, S.M., Mahran, M. A., Badria, F. A., Al-obaid, A. M.** "Synthesis and Biological Evaluation of Certain -Unsaturated Ketones and Their Corresponding Fused Pyridines as Antiviral and Cytotoxic Agents", *J. Med. Chem.,* 15, 2915-2921 (2000).

6. **Jong, S., Chen C, Fang, J., Liu, Y., Lee, G., Wang, Y.,** "Samarium Diiodide-Promoted Sequential Coupling-Aldol-Reduction Reactions of Ferrocene-Substituted Enones", C. R. *Acad. Sci. Paris, Chimie I Chemistry,* 4,487-496 (2001).

7. **Cabrera, A., Lagadec, R. L., Sharma, P., Arias, J. L., Toscano, R. A., Velasco, L., Gavino, R., Alvarez, C, Salmon, M.,** "Cyclo- and Hydrodimerization of____-unsaturated Ketones Promoted by Samarium Diiodide", /. *Chem. Soc, Perkin Trans. 1,* 3601-3608 (1998).

8. **Jong, S. J., Fang, J. M.,** Synthesis of [3]Ferrocenophanes via samarium Diiodide Promoted Reductive Cyclizations of l,l'-Dicinnamoylferrocenes", *Organic Lett., 2,* 1947-1949 (2000).

9. **Zhou, L. H., Shi, D. Q., Gao, Y., Shen, W. B., Dai, G. Y., Chen, W. X.,** "A Novel Cyclodimerization of____-Unsaturated Ketones Induced by Low-valent Titanium", *Tetrahedron Lett.,* 38,2729-2732 (1997).

10. Pitts, M. R., Harrison, J. R., Moddy, C. **J.,** "Indium Metal As A Reducing Agent In Organic Synthesis", /. *Chem. Soc, Perkin Trans. 1,*955-977, (2001).

11. **Enholm, J. E., Kinter, K. S.,** "Cyclization Reactions of Allylic O-Stannyl Ketyls", /. *Org. Chem.,* 60,4850-4855 (1995).

12. **House, H. O.** Modern Synthetic Reactions. Breslow, R. (Ed.), 2nd ed., The Benjamin/Cummings Publishing Company, California, (1972).

13. **Pine, H. S., Hendrickson, B. J., Cram, D. J., Hammond, G.S.** Organic Chemistry, 4th ed., McGraw-Hill Book Company, Singapore, (1987).

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