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ARTICLE TYPE

# Titanium dioxide supported on MWCNTs as an eco-friendly catalyst in the synthesis of 3,4-dihydropyrimidin-2-(1*H*)-ones accelerated under microwave irradiation

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Some transition metal oxides supported on CNTs have been prepared as novel heterogeneous acids using a facile process. Then the catalytic behaviour of transition metal oxides-CNTs nanocomposites was investigated in Biginelli one-pot cyclocondensation of aldehydes,  $\beta$ -dicarbonyl compounds and urea (thiourea) in solvent free media under microwave irradiation as the energy source. The experimental results showed among studied transition metal oxides-CNTs, TiO<sub>2</sub>-CNTs were the most efficient nanocatalyst in the Biginelli reaction. This study provides new insights to develop this three components methodology by the microwave-assisted dry media technology. The current catalytic process is an environmentally, sustainable, and economical acceptable synthetic tool, because it operates under solvent free conditions, with high chemical efficiency, easy work-up procedures, and the feasible reusability of the nanocomposites.

## Introduction

2-Oxo (thioxo)-1,2,3,4-tetrahydropyrimidines are very important heterocyclic motifs in natural, synthetic, pharmacological, therapeutic and bioorganic chemistry.<sup>1</sup> This chemical entity, also is called 3,4-dihydropyrimidin-2(1*H*)-one (thione) ('Biginelli compounds', DHPMs), have been reported to exhibit diverse biological activities. These compounds use as adrenoceptor blocking,<sup>2</sup> antiviral,<sup>3,4</sup> anti-inflammatory,<sup>5</sup> antihypertensive,<sup>6</sup> antitumor,<sup>7</sup> antimicrobial,<sup>8</sup> anticarcinogenic,<sup>9</sup> antibiotic<sup>10</sup> and also are efficient as calcium channel modulators and  $\alpha$ -antagonists.<sup>4</sup> Furthermore, structures of these Molecular scaffolds have been found in some natural marine alkaloids such as batzelladine alkaloids A and B, which were reported to inhibit potentially binding of HIV envelope protein gp-120 to human CD4 cells opening a new field in AIDS therapy.<sup>11-14</sup> In addition, batzelladines C-E were reported to be cytotoxic.<sup>11</sup> Batzelladines F and G might be beneficial to treat autoimmune diseases and allograft rejection.<sup>15</sup> 3,4-Dihydropyrimidinones are used as starting material in the synthesis of 'superstatin' rosuvastatin competitive and selective inhibitor of HMGCoA reductase, the enzyme responsible for the biosynthesis of cholesterol.<sup>16</sup> 3,4-DHPM scaffolds have been also suggested as valuable building blocks to synthesize versatile heterocyclic derivatives.<sup>17-19</sup>

Due to the importance of the Biginelli reaction products (DHPMs), numerous modifications and improvements have been developed to perform the Biginelli reaction with different types of catalysts such as ionic liquids,<sup>20</sup> phase-transfer catalysis,<sup>21</sup>

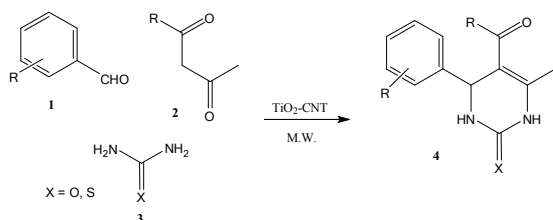
Brønsted acids,<sup>22</sup> Brønsted bases,<sup>23</sup> Lewis acids,<sup>24</sup> heterogeneous catalysts,<sup>25</sup> ion-exchange resins,<sup>26</sup> polymer supported catalysts,<sup>27,28</sup> solid phase reagents,<sup>29,30</sup> and conditions such as solvent free,<sup>31</sup> ultrasounds,<sup>32</sup> microwave synthesis,<sup>33</sup> green approach synthesis<sup>34</sup> and grindstone technique.<sup>35</sup> The replacement of conventional toxic and polluting reagents with environmentally benign and reusable catalysts and alternative cleaner, safer and environmentally friendly technologies are an active area of research. Therefore, the discovery of novel and active catalysts is in prime importance to synthesize this type of heterocyclic compounds under mild conditions.

Recently, interest to multiwall carbon nanotubes (MWCNTs) - crystalline carbon materials- as heterogeneous catalyst supports has been increasing because of their unique morphologies and various potential applications.<sup>36-40</sup> Carbon nanotubes as support possess a high surface area for high dispersion of nanosized catalysts, well-defined porosity of structure for maximum reactants contact, excellent crystallinity or low electrical resistance to facilitate electron transport during reactions, and good interactions between the catalyst nanoparticles and the carbon support.<sup>41</sup> On the other hand, the transition metals and/or metal oxides nanoparticles (NPs) are an important family of inorganic nanomaterials with interesting several areas of chemistry especially in heterogeneous catalysis.<sup>42-46</sup> Recently, owing to high cost of noble metals limiting their application, more and more interest has been focused on inexpensive transition metal oxides, such as iron oxide (Fe<sub>3</sub>O<sub>4</sub>), nickel oxide (NiO), manganese dioxide (MnO<sub>2</sub>) and titanium dioxide (TiO<sub>2</sub>). Titanium dioxide (TiO<sub>2</sub>) has attracted extensive attention in recent two decades due to inexpensiveness, high chemical and

thermal stability, non-toxicity, biological and chemical inertness and an appropriate energy band configuration for charge transfer at the interface.<sup>47</sup> In addition, nickel oxide (NiO) is attractive in view of its low toxicity and cost, easily availability and non-flammable properties making it safe to handle and easy for processing.<sup>48</sup> Iron oxide (Fe<sub>3</sub>O<sub>4</sub>) has the ability to enhance electrode conductivity and facilitate electron transfer.<sup>49</sup> Also, manganese dioxide (MnO<sub>2</sub>) is a widely used because of its natural abundance, environmental safety, cost effectiveness, large specific capacitance and easy preparation.<sup>50,51</sup>

Consequently, functionalization of carbon nanotubes with metal nanoparticles have been widely studied to afford supported catalysts<sup>52-56</sup> which successfully combines the advantages of metal NPs and CNTs and causes more widely potential application.<sup>57-61</sup> The scientists indicated that carbon nanotubes not only provided a large surface area support for the metal nanosized catalyst, but also stabilized the charge separation by trapping the electrons transferred from metal to hinder charge recombination.<sup>62</sup> Attaching metal nanoparticles to the CNTs surface is difficult because the pristine surface of carbon nanotubes is inert. Surface functionalization of CNTs is usually carried out before metal deposition to afford more binding sites and surface anchoring groups, resulting avoidance from the aggregation of metal NPs, improvement of the dispersion and reduction of the size of metal NPs.<sup>63</sup> The most common covalent functionalization includes the addition of polar groups such as acid functional groups (-OH, -COOH, -CO, etc.). Aggressive oxidation treatment of the sidewalls of CNTs with HNO<sub>3</sub> or HNO<sub>3</sub>/H<sub>2</sub>SO<sub>4</sub> mixture provides a useful means to attach CNTs to metal nanoparticles for the production of CNT-metal composites.<sup>64-66</sup>

In view of the above observation, we wish to report herein the synthesis of biologically active heterocyclic systems containing pyrimidinone derivatives in a simple but effective modification of the Biginelli reaction. According to this methodology, we prepared efficiently and environmentally these compounds by using metal oxides supported on multi-walled carbon nanotubes (MWCNTs) as heterogeneous catalyst for the remarkably faster condensation of a variety of aldehydes with ethyl acetoacetate, and urea/thiourea in microwave irradiation under solvent free conditions (Scheme 1). In this paper, we describe our findings on the role of supported acid catalyst in promoting reactions.

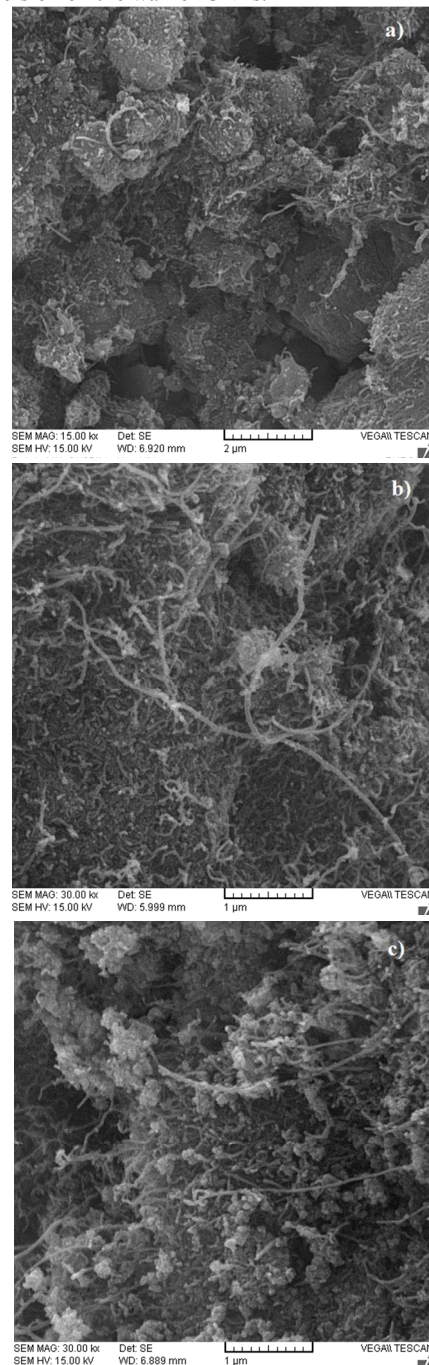


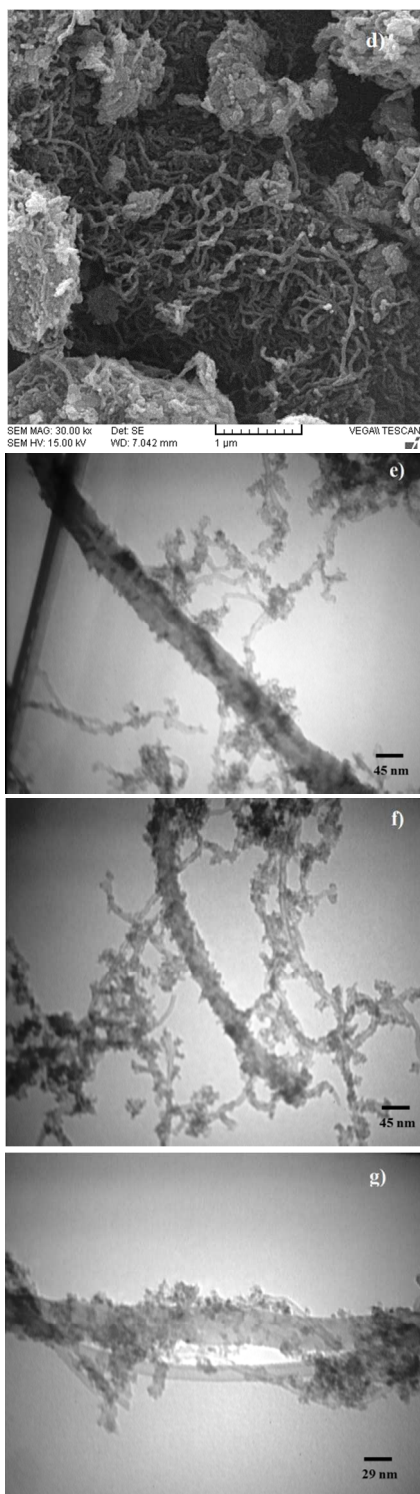
**Scheme 1.** Three-component one-step microwave mediated synthesis of pyrimidinones/thiones using TiO<sub>2</sub>-CNTs

## Results and discussion

The objectives of the present study are indeed: (i) to prepare 3,4-dihydropyrimidinones, (ii) to explore metal oxides decorated on CNT nanocomposites application as catalyst system, (iii) to identify the best nanocomposites as catalyst, (iv) and to develop

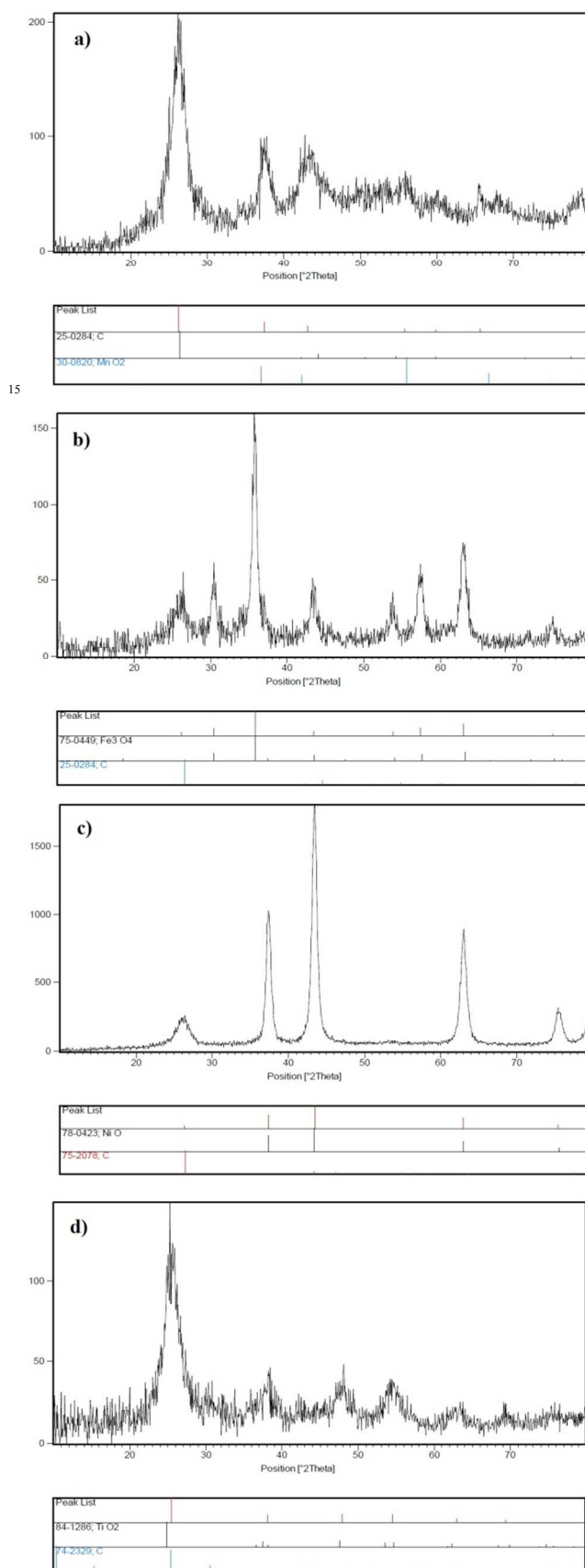
an efficient microwave-assisted synthetic process for the facile condensation of Biginelli reaction under optimal conditions. In the First, we prepared a number of MO<sub>x</sub>-CNTs catalysts such as MnO<sub>2</sub>-CNTs, TiO<sub>2</sub>-CNTs, NiO-CNTs and Fe<sub>3</sub>O<sub>4</sub>-CNTs according to the procedures of literature<sup>67-70</sup> to study the catalytic efficiency of transition metal oxides supported on CNTs. We also treated MWCNTs with sulfuric and nitric acids to afford functionalities on CNTs surface before metal deposition. The morphologies of composites were investigated by scanning electron microscope (SEM) and transmission electron microscope (TEM). Metal oxide nanoparticles were uniformly grown on individual CNT. As is shown in Fig. 1, TEM images of the composite confirm that TiO<sub>2</sub> nanoparticles grow directly with a good dispersion on the wall of CNTs.





5 **Figure 1.** SEM of a)  $\text{TiO}_2$ -CNT, b)  $\text{MnO}_2$ -CNT, c)  $\text{Fe}_3\text{O}_4$ -CNT, d)  $\text{NiO}$ -CNT, and e,f,g) TEM images obtained from  $\text{TiO}_2$ -CNT catalysts.

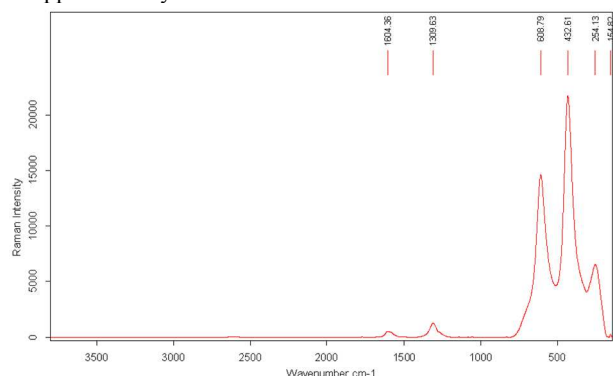
10 The metal oxides crystal structure on the CNTs is ensured by XRD pattern in Fig. 2. In the XRD patterns, a sharp peak at around  $25.92^\circ$  is corresponding to MWCNT-COOH and the other peaks are conforming to the presence of metal oxide nanoparticles.



20 **Figure 2.** XRD spectra of a)  $\text{MnO}_2$ -CNT, b)  $\text{Fe}_3\text{O}_4$ -CNT, c)  $\text{NiO}$ -CNT and d)  $\text{TiO}_2$ -CNT nanocomposites



Fig. 3 shows the Raman spectrum of TiO<sub>2</sub>-CNT composites. From this spectrum, vibrational modes around 1307 cm<sup>-1</sup> (D band), and 1596 cm<sup>-1</sup> (G band) is corresponding to MWCNT-COOH. Signals correlated to TiO<sub>2</sub> can be shown by strong peaks at approximately 154-608 cm<sup>-1</sup>.



**Figure 3.** Raman spectra of TiO<sub>2</sub>/MWCNT nanocomposites

All nanocomposites have demonstrated their ability to act as promoter in multi-component Biginelli condensation reaction. It can be seen from Table 1 that TiO<sub>2</sub>-CNTs is the most efficient catalyst among all the supported catalysts studied in the model condensation reaction of benzaldehyde, ethyl acetoacetate, and urea as a very cheap nitrogen source. TiO<sub>2</sub>-CNTs act as highly efficient heterogeneous catalyst to synthesize pyrimidinones and provide the product in excellent yields under microwave in solvent free conditions. Thus, the importance of titanium dioxide supported on CNTs as catalyst was clearly revealed in these special cases. From this observation we conclude that catalytic character of nanocomposites for promoting condensation reaction follows the order: TiO<sub>2</sub>-CNTs > MnO<sub>2</sub>-CNTs > Fe<sub>3</sub>O<sub>4</sub>-CNTs > NiO-CNTs. The most advantage of present catalyst among above-mentioned heterogeneous acid catalysts is the more number of unfilled d-orbitals of the metal particle and using the low amount of solid catalyst in the reaction. In general, the ability of transition metals for bond to carbon atoms increases with the number of unfilled d-orbitals resulting to their stability. It prevents from aggregation of metal oxide nanoparticles together on CNTs. With enhancement in the empty d-orbitals of metal, the metal cation also acts as better Lewis acid and this plays a significant role in increasing the electrophilic character of the electrophiles. Therefore, the reaction is more activated by the coordination of the empty orbitals of metal. Additionally, the reactions were also performed under classical thermal method. By comparing with the conventional procedure presents that acidic TiO<sub>2</sub>-CNTs coupled with microwave heating is the best condensing system to synthesize 3,4-dihydropyrimidinones.

**Table 1.** Screening of different nanocomposites for Biginelli reaction<sup>a</sup>

Entry	Catalyst	Time (min)	Yield (%)
1	MnO <sub>2</sub> -CNTs	15	85
2	TiO <sub>2</sub> -CNTs	5	96
3	NiO-CNTs	30	75

4 Fe<sub>3</sub>O<sub>4</sub>-CNTs 20 81

<sup>a</sup> Microwave power :600 W, Amount of catalyst: 0.025 g, Molar ratios of benzaldehyde: ethyl acetoacetate: urea: 1:1:1.5

MW irradiation has been directly absorbed by the reagents and this rapid heat transfer leads to rapid enhancement of temperature and reactivity and this cause to decrease energy consumption (the sixth principle of the green chemistry). In order to decrease the reaction time, microwave irradiation was used in the absence of solvents. Using metal oxides supported on CNTs under solvent-free conditions offers significant rate enhancement, the catalytic activity rise, improved yields and environmentally benign reaction conditions. This technique is superior to the existing methods, because leads to economical, safe and environmentally friendly organic synthesis. These features comply with the principles of green chemistry in terms of safer solvents and less hazardous chemical synthesis (principle 5) as well as atom economy (principle 2) and catalytic processes (principle 9). In order to show specific microwave effects, the model reaction also was studied under conventional solvent-free heating conditions. But in this case, reactions slowly proceeded and lower yields were observed even after heating for longer times (Table 2). This indicates that the effect of microwave irradiation is not only thermal.

**Table 2.** The model Biginelli reaction in thermal conditions

Entry	Temperature (°C)	Time (min)	Yield (%)
1	30	110	15
2	40	90	20
3	60	75	35
4	80	60	50
5	100	55	65
6	120	50	65

Based on earlier investigations of the thermal heating method, our initial efforts were focussed on optimizing power of microwave irradiation to see their efficiency in the reaction. As shown in Table 3 the highest yield of the product was obtained at the power of 600 W.

**Table 3.** Effect of microwave power in the model Biginelli reaction

Entry	Power (W)	Time (min)	Yield (%)
1	100	20	40
2	200	15	59
3	300	10	70
4	400	5	87
5	600	5	96
6	800	5	91

The effect of catalyst quantity on the synthesis of the desired 3,4-dihydropyrimidin-2(1*H*)-one was investigated by varying the

catalyst amount from 0 to 0.03 g (Table 4) in the model reaction at the same molar ratios of substrates. It was observed that in the absence of catalyst, the product **4a** has been afforded only in trace amounts even after the extended time. In the presence of catalyst, the reaction yield improves gradually in a shorter time with an increase in the amount of catalyst. Higher amount of catalyst leads to increasing yield to 98% at the longer time (10 min). This behaviour would be explained that with enhancing amount of catalyst occurs increase in the number of acidic active sites which causes decrease in concentration of reactants at the active sites and finally decline in yield. Accordingly, optimum catalyst amount was found to be 0.025 g to prepare 3,4-dihydropyrimidin-2(1*H*)-ones.

**Table 4.** Effect of catalyst amount on the microwave-assisted synthesis of compound **4a** under solvent-free conditions

Entry	Catalyst (g)	Time (min)	Yield (%)
1	0	40	Trace
2	0.01	30	70
3	0.015	20	81
4	0.02	10	90
5	0.025	5	96
6	0.03	10	98

A comparative study with reported methods in the literature to synthesize **4a** is compiled in Table 5 to show the efficiency of the catalyst. So, it is apparent that TiO<sub>2</sub>-CNTs catalytic system accelerates the Biginelli reaction.

**Table 5.** Comparison of catalytic efficiency of TiO<sub>2</sub>-CNTs with several catalysts in the literature for Biginelli reaction

Entry	Catalyst	Time (min)	Yield (%)	Lit.
1	TiO <sub>2</sub> -CNTs	5	96	This Work
2	DCDMH	240	89	71
3	Zn(BF <sub>4</sub> ) <sub>2</sub>	180	73	72
4	SnCl <sub>4</sub> ·5H <sub>2</sub> O	65	91	73
5	FeCl <sub>3</sub> /DMAP	240	85	74
6	Cu(NH <sub>2</sub> SO <sub>3</sub> ) <sub>2</sub>	300	79	75
7	Nickel oxide	60	96	76
8	Ca(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	60	84	77
9	CellSA	300	80	78
10	CaF <sub>2</sub>	120	98	79

After establishing the optimal conditions, in order to prove the generality of this method, we evaluated a variety of aromatic aldehydes carrying either electron-releasing or electron-withdrawing substituents in presence of microwave irradiation under solvent-free condition. Both substituents on the aromatic ring of the aldehydes treated successfully to provide the corresponding products in excellent yields. This shows that electronic effects do not play role on the yield of the desired product. The scope of the reaction was further expanded when the thiourea instead of urea was successfully used to provide the

corresponding 3,4-dihydropyrimidin-2(1*H*)-thiones, which are also more interesting due to their biological activities. Furthermore, the present route was successfully applied with various alkyl acetoacetate esters under the optimal reaction conditions, and we obtained excellent yields with the desired 3,4-dihydropyrimidin-2(1*H*)-ones and -thiones. The results of this study are summarized in Table 6. The structures of the compounds were confirmed on the basis of their spectroscopic data and were compared with authentic samples.

**Table 6.** TiO<sub>2</sub>-CNTs-mediated efficient synthesis of 3,4-dihydropyrimidin-2(1*H*)-ones under microwave irradiation

Product	R	R'	X	Time (min)	Yield (%)	Mp (°C)	
						Obs.	Lit.
<b>4a</b>	H	OEt	O	5	96	200–202	201–203 <sup>80</sup>
<b>4b</b>	4-NO <sub>2</sub>	OEt	O	7	90	208–210	209–210 <sup>81</sup>
<b>4c</b>	4-OMe	OEt	O	25	80	201–202	202–203 <sup>82</sup>
<b>4d</b>	2,4-Cl <sub>2</sub>	OEt	O	12	85	248–250	249–250 <sup>43</sup>
<b>4e</b>	4-NMe <sub>2</sub>	OEt	O	30	77	257–258	255–257 <sup>82</sup>
<b>4f</b>	4-F	OEt	O	15	79	182–184	183–185 <sup>84</sup>
<b>4g</b>	3-Br	OEt	O	10	87	184–185	185–186 <sup>83</sup>
<b>4h</b>	H	OEt	S	10	90	208–210	207–208 <sup>80</sup>
<b>4i</b>	3-NO <sub>2</sub>	OEt	S	15	89	206–208	206–209 <sup>85</sup>
<b>4j</b>	2-OMe	OEt	S	25	80	189–190	190–192 <sup>86</sup>
<b>4k</b>	4-Br	OEt	S	20	84	215–217	216–218 <sup>87</sup>
<b>4l</b>	4-Me	OEt	S	30	76	191–193	192–194 <sup>88</sup>
<b>4m</b>	H	OMe	O	15	90	208–210	209–211 <sup>83</sup>
<b>4n</b>	4-Cl	OMe	O	20	81	204–205	204–206 <sup>89</sup>
<b>4o</b>	4-NO <sub>2</sub>	OMe	O	15	88	235–237	236–238 <sup>83</sup>
<b>4p</b>	2,4-Cl <sub>2</sub>	OMe	O	25	80	254–255	252–253 <sup>83</sup>
<b>4q</b>	3-OMe	OMe	O	20	85	206–208	207–208 <sup>90</sup>
<b>4r</b>	2-Br	OMe	O	20	79	240–241	240242 <sup>91</sup>
<b>4s</b>	3-OMe-4-OH	OMe	O	25	75	225–226	225 <sup>92</sup>
<b>4t</b>	H	OMe	S	20	85	233–235	232–234 <sup>91</sup>
<b>4u</b>	4-OH	OMe	S	30	80	245–247	245–246 <sup>91</sup>
<b>4v</b>	4-OMe	OMe	S	25	84	178–180	179–180 <sup>91</sup>
<b>4w</b>	4-Br	OMe	S	20	80	152–154	153–154 <sup>91</sup>
<b>4x</b>	4-NMe <sub>2</sub>	OMe	S	30	78	151–153	152–155 <sup>89</sup>

From a green chemistry perspective, the stability of the supported catalyst has been studied by the possibility of their reusability. Upon completion of the reaction, isolation of the heterogeneous catalyst was easily performed by separation or centrifugation, was rinsed with minimum sodium bicarbonate dissolved in distilled water up to neutral pH and was dried at 100 °C in autoclave for 1 h. It was shown that the catalyst could be used for five runs without obvious drop in the product yield and its catalytic activity (Table 7).

**Table 7.** Study of recyclability of catalyst for the model reaction

Run	1	2	3	4	5

Yield (%)	96	96	94	93	93
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## Conclusions

In summary, we have described a simple modification of the Biginelli condensation promoted by highly versatile and general heterogeneous and solid phase protocol. We report here an expedient and efficient preparation of several metal oxides-CNT nanocomposites and disclose the successful outcome of MW/TiO<sub>2</sub>-CNTs strategy to synthesize 3,4-dihydropyrimidin-2-(1*H*)-one heterocycles in excellent isolated yields. TiO<sub>2</sub>-CNT nanocomposites are an excellent catalyst in compared with other catalysts because it is highly efficient and also exhibits higher yields of products and enhanced activity in shorter reaction duration. We also established that the performance of the catalytic system is significantly facilitated when it was used in microwave irradiation under solvent free conditions, which makes this methodology economically and environmentally acceptable. This method presents a special and remarkable technique toward a green synthesis of DHPMs under extremely milder conditions.

## Experimental

Chemical substances were obtained from Merck, Fluka and Aldrich and were used without further purification. MWNTs with outer diameter of CNT 10 and 20 nm were obtained from Nanotech Port Co. (Taiwan). These MWNTs were produced via the chemical vapor deposition (CVD, or sometimes called catalytic pyrolysis) method. Melting points (°C) were determined on an Electrothermal MK3 apparatus using open-glass capillary and are uncorrected. The completion of reactions were monitored by TLC technique on silica gel plates in the solvent system petroleum ether–EtOAc (V/V = 1:1). FTIR was employed to analyze the functional groups on the purified CNTs. IR spectra of all the compounds were measured on a Perkin Elmer FT–IR 550 spectrophotometer. <sup>1</sup>H NMR and <sup>13</sup>C NMR spectra were measured on a Bruker DRX–400 spectrometer using TMS as an internal standard and DMSO-*d*<sub>6</sub> as the solvent. The chemical shift values are on δ scale and the coupling constant values (*J*) are in Hz. X-ray diffraction analysis was carried out on Holland Philips Xpert X-ray diffraction (XRD) diffractometer (CuK, radiation, λ = 0.154056 nm), at a scanning speed of 2°/min from 10° to 100° (2θ). Scanning electron microscopy (SEM) images were obtained using a KYKY EM-3200 scanning electron microscope (SEM) operated at a 25 kV accelerating voltage. The TEM images were recorded using a Zeiss EM10C Transmission electron microscope (TEM) operated at a 80 kV accelerating voltage. The Raman spectra were measured on a Bruker SENTERRA spectrometer.

### Preparation of composites

The nanocomposites were prepared according to reported procedures in the literature. In brief, CNTs was functionalized by adding 100 mL acid solution containing 2.5 M HNO<sub>3</sub> and 0.5 M H<sub>2</sub>SO<sub>4</sub> at 100 °C for 6 h. Then, the acid-treatment CNTs were obtained by rinsing with deionized water and by drying in the air at 100 °C. MnO<sub>2</sub>-CNTs were prepared in a direct redox reaction

with mixing aqueous solution of KMnO<sub>4</sub> and modified CNTs under ultrasound irradiation. Then, acetic acid was added until pH 2 and was refluxed at 70 °C for 3 h. Then, the mixture was separated by centrifuge and was washed with deionized water and acetone and was dried at 70 °C for 12 h in a vacuum oven. NiO/MWNTs composites were prepared by mixing NiCl<sub>2</sub>·6H<sub>2</sub>O aqueous solution with acid treated MWCNTs. Next, NH<sub>4</sub>OH was dropped into the suspension to pH 8 under sonication for 20 min and the mixture was soaked in the solution for 5 h. Finally, intermediate product (Ni(OH)<sub>2</sub>/MWNTs) was separated by centrifuging and were washed with deionized water and was calcinated at 400 °C for 2 h to be achieved NiO/MWNTs nanocomposites. Fe<sub>3</sub>O<sub>4</sub>/CNT composites were prepared by chemical coprecipitation of aqueous solution (NH<sub>4</sub>)<sub>2</sub>Fe(SO<sub>4</sub>)<sub>2</sub>·6H<sub>2</sub>O (0.4 mmol) and NH<sub>4</sub>Fe(SO<sub>4</sub>)<sub>2</sub>·12H<sub>2</sub>O (0.8 mmol) at 50 °C in purified CNTs under sonication for 10 min. Next, to precipitate the iron oxides, 5 M NH<sub>4</sub>OH aqueous solution was added (pH 11–12) and the reaction was continued at 50 °C for 30 min under mechanical stirring. Then, the samples were separated by magnet from the suspension and were washed with doubly distilled water and were dried in a vacuum oven at 100 °C for 24 h. TiO<sub>2</sub>-CNTs were prepared by adding TiCl<sub>4</sub> solution containing a little HCl to acid treated MWCNTs under sonication for 2 h. Then, the suspension was stirred at room temperature for 22 h and up to 80 °C for 3 h. At last, the mixture was centrifuged and was calcinated in furnace at 370 °C for 3 h.

### General procedure for TiO<sub>2</sub>-CNTs-mediated preparation of pyrimidinones

Benzaldehyde (1 mmol, 0.107), ethyl acetoacetate (1 mmol, 0.13 g), urea or thiourea (1.5 mmol), and TiO<sub>2</sub>-CNTs (0.025 g) were successively charged into a 50-mL round-bottomed flask and contents were irradiated under microwave at 80 °C for an appropriate period, while the product formation was monitored by TLC. Upon completion, the catalyst was recovered by simple filtration. The filtrate was poured into crushed ice and the solid product was collected by filtration and was washed with cold ethanol, then it was recrystallized from ethanol to get pure crystals.

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## Notes and references

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