Graphene oxide-THEIC-ECH-Chitosan network nanocomposite: a novel, efficient and recyclable catalyst for green synthesis of polyhydroquinoline derivatives

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Abstact

In this present research, two linkers have been utilized for the covalent attachment of graphene oxide with chitosan. Graphene oxide (GO) and chitosan (Cs) were crosslinked by using 1,3,5-tris(2-hydroxyethyl) isocyanurate (THEIC) and epichlorohydrin (ECH) which resulted in forming the expected biopolymer network nanocomposite. The obtained network was characterized by Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), energy dispersive X-ray spectroscopy (EDS) and thermal gravimetric analysis (TGA) technique. The catalytic application of the GO-THEIC-ECH-Cs nanocatalyst was then investigated in one-pot four-component Hantzsch condensation reaction for the synthesis of polyhydroquinoline derivatives in EtOH under reflux conditions. The obtained results indicated that the applied catalyst in this study exhibited some significant advantages such as reusability and highly efficiency, stability, low required loading, avoiding the use of toxic transition metals, short reaction times, higher yields, easy separation and purification of the products.

KEYWORDS: Chitosan; Graphene Oxide; Polyhydroquinoline; Biopolymeric network; Nanocomposite; Heterogeneous catalysis; Green chemistry.

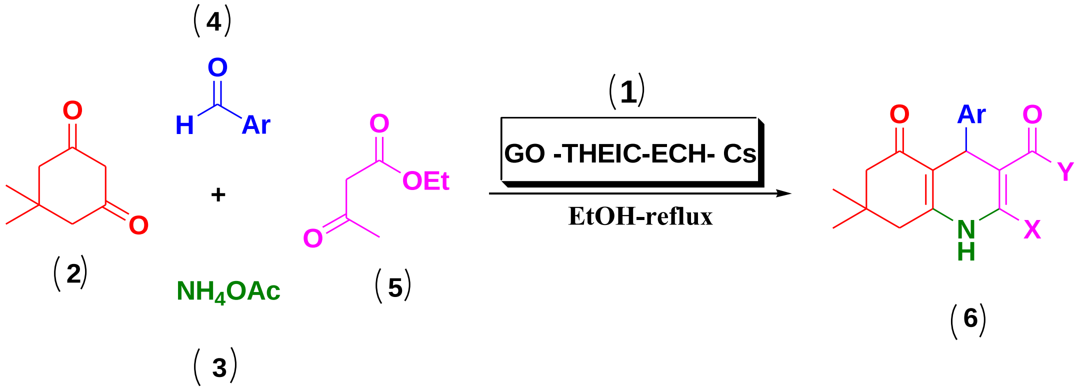
1. INTRODUCTION

Multicomponent reactions (MCRs) have emerged as important organic synthesis approaches which involve reactions of three or more reactants come together in a single reaction vessel to form new products that have portions of all the components. MCRs strategies grant remarkable advantages over conventional bimolecular reactions owing to their convergence, atom-economy, operational simplicity, structural diversity and short synthetic pathway. MCRs have recently gained a new dimension in the field of designing methods to produce elaborate biologically active compounds and new molecular frameworks for potential drugs with diverse pharmacological activities [1,10, 16].

Nowadays, nanocomposites are known as the hot topics among chemists, physicists, biologists and other scientists because of their novel and unique applications in various fields. We are living in an era in which everything is becoming smaller and smaller in size with improvements in properties. Using these composites especially in organic reactions appears to be essential and important. For comprehending the importance of the issue, we have introduced a green nanocomposite that has valuable properties such as thermal stability, mechanical strength and a wide surface.

Graphene, as a new type of nanocarbon material, has received a lot of interest among researchers from different fields in this regard. Graphene oxide (GO) is a derivative of graphene and it has two dimensional oriented structure with good chemical stability and other excellent properties [2,3,4]. This material also has a high theoretical surface area of 2600 $m^2 g^{-1}$ [5]. Sheets of graphene oxide possess numerous oxygen containing functional groups: hydroxyl and carboxylic acid groups are located around the edges, whereas carbonyl and epoxide groups are in the center. The existence of various types of hydrophilic groups allows graphene oxide to be easily exfoliated when it is in the wet state. These active groups can be used to induce chemical reactions and provide graphene oxide with additional functional groups after the modification, therewith, increasing the flexibility and diversity of graphene oxide applications. For example, graphene oxide layers can be intercalated or cross-linked with primary aliphatic amines, alcohols amino acids, diaminoalkanes, boronates, acyl chloride, and isocyanates, or they can be covalently linked with polymers through proper chemical reactions such as esterification or chelation [6,7,11,16]. Furthermore, chitosan is the second abundant natural biopolymers on the earth which has been used widely for different applications [8,9,10].

There have been a few reports on graphene based chitosan composite with enhanced mechanical properties but these studies involved simple physical mixing of two components [12,13,14,15]. To the best of our knowledge, the covalent functionalization of chitosan with graphene oxide achieved by employing 1,3,5-tris(2-hydroxyethyl) isocyanurate (THEIC)-epichlorohydrin (ECH), as linkers, simultaneously has not been reported yet. In this present study, GO and chitosan are crosslinked by using THEIC and ECH to form the expected biopolymer network nanocomposite. It is believed that the applied catalyst in this study has some significant advantages such as reusability and highly efficiency, stability, low required loading, avoiding the use of toxic transition metals, short reaction times, higher yields, easy separation and purification of the products. Herein, we report our results for a one-pot Synthesis of polyhydroquinoline derivatives using GO-THEIC-ECH-Cs **(1)** as a highly efficient metal free organocatalyst.



Scheme 1. Synthesis of polyhydroquinoline derivatives catalyzed by GO-THEIC-ECH-Cs (**1**).

2.Experimental

2.1. *General*

Reagents and Apparatus

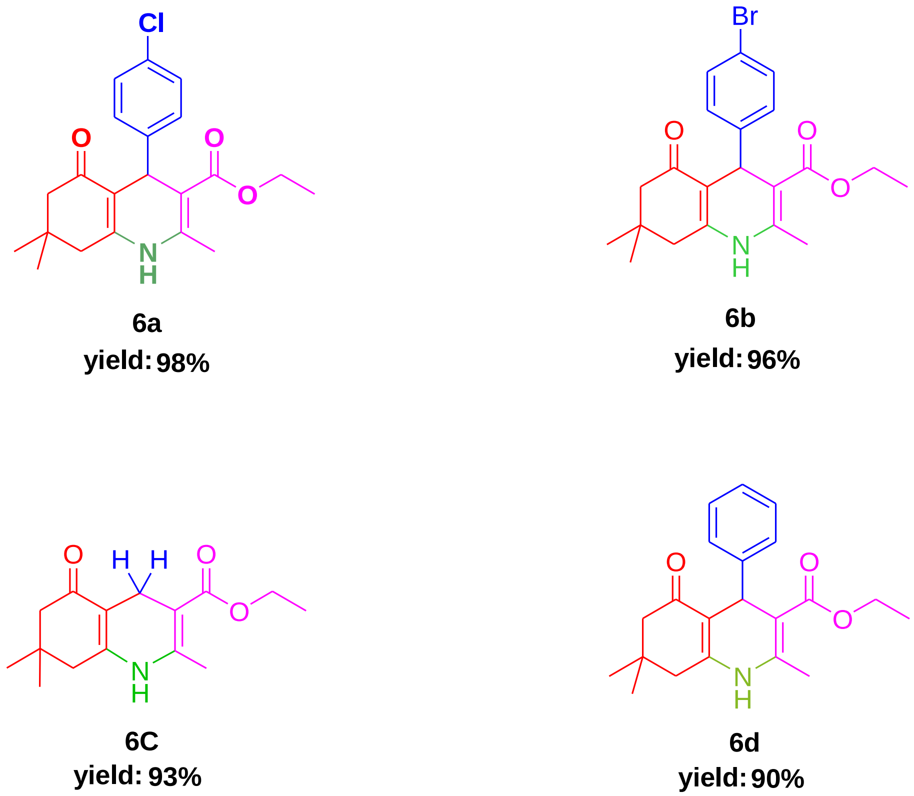
All chemical materials were obtained from commercial suppliers and purchased from the international chemical companies including Merck, Sigma-Aldrich and Fluka. Chitosan (MW = 100000–300000 Da) was purchased from Acros Organics. Melting points were measured on an Electrothermal 9100 apparatus and are uncorrected. The analytical thin layer chromatography (TLC) examination were accomplished using Merck 0.2 mm silica gel 60 F-254 Al-plates.

2.2. *General procedure for the synthesis of polyhydroquinoline derivatives(**6a-d**) by GO-THEIC-ECH-Cs nanocatalyst*

The reaction between 1.0 mmol dimedone, 1.0 mmol aryl aldehyde, 1.0 mmol ethyl acetoacetate, 2.0 mmol ammonium acetate and 1.0 mg of GO-THEIC-ECH-Cs nanocatalyst in 5 mL of EtOH under refluxing conditions was performed for the synthesis of polyhydroquinoline derivatives. The progress of the reaction was monitored by thin layer chromatography (TLC, (ethyl acetate/n-hexane 1/3). The mixture was then given time to complete the reaction process. The heterogeneous bionanocomposite was separated from the main product by adding hot EtOH and subsequent filtration.The recycled bionanocomposite was washed with acetone and n-hexane, dried and reused four times in subsequent reactions. Then isolated products were recrystallized using EtOH and EtOAc.

3. Results and discussion

The catalytic activity of GO-THEIC-ECH-Cs (**1**) was evaluated in the green synthesis of polyhydroquinoline derivatives by condensing dimedone, aryl aldehyde derivatives, ethyl acetoacetate and ammonium acetate in EtOH at reflux temperature. According to **scheme (2)**, using a small amount of GO-THEIC-ECH-Cs (**1**), as heterogeneous catalyst (about 10 mg), the desired products were synthesized with high yield and in short time. The ability to separate and recycle the catalyst easily from the reaction mixture with minimal effort is another advantage of this bio-based organocatalyst. This catalyst reused for at least 5 runs without significant loss of catalytic activity.



6a
yield: 98%

6b
yield: 96%

6C
yield: 93%

6d
yield: 90%

Scheme 2. Scope of polyhydroquinoline derivatives (**6a-d**) prepared in the presence of GO-THEIC-ECH-Cs (**1**).

4. Conclusion

In summary, the biopolymer network nanocomposite was prepared by using THEIC and ECH to crosslink graphene oxide and chitosan. The catalytic application of the GO-THEIC-ECH-Cs nanocatalyst was investigated in one-pot four-component Hantzsch condensation reaction for the synthesis of polyhydroquinoline derivatives in EtOH under reflux conditions. The obtained results indicated that the applied catalyst in this study exhibited some the significant advantages such as reusability and highly efficiency, stability, low required loading, avoiding the use of toxic transition metals, short reaction times, higher yields, easy separation and purification of the products. Also, this catalyst reused for at least five runs without significant loss of catalytic activity.

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