Arabian Journal of Chemistry (2020) 13, 8995–9004

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Green synthesis of 4,6-bisarylpyrimidin-2(1*H*)-ones and azo-linked 4-arylpyrimidin-2(1*H*)-ones using $NiFe_2O_4@SiO_2{}^nPr@$glucose amine as a mild nano catalyst

Mohammad Nikpassand [a,*], **Elaheh hoseinnezhad** [b]

[a] *Department of Chemistry, Rasht Branch, Islamic Azad University, Rasht, Iran*
[b] *Department of Chemistry, Ghadr Institute, Rasht, Iran*

Received 28 April 2020; accepted 14 October 2020
Available online 22 October 2020

KEYWORDS

Pyrimidin-2(1H)-one;
$NiFe_2O_4@SiO_2{}^nPr@$glucose amine;
Urea;
Nanoparticle;
Green synthesis

Abstract The clean, environmentally benign and effective synthesis of novel azo-linked 4-arylpyrimidin-2(1*H*)-one derivatives and 4,6-bisarylpyrimidin-2(1*H*)-ones via three-component reaction of various aldehydes or synthetized azo-linked aldehydes, urea, and acetophenone promoted by $NiFe_2O_4@SiO_2{}^nPr@$glucose amine at room temperature (25 ℃) was reported. $NiFe_2O_4@SiO_2{}^nPr@$glucose amine were synthesized and characterized by transmission electron microscope (TEM), fourier transform infrared spectroscopy (FT-IR), vibrating sample magnetometry (VSM), X-ray powder diffraction (XRD) and X-ray spectroscopy (EDX). These compounds were obtained in high yields and short reaction times. The catalyst could be easily recovered and reused for six cycles with almost consistent activity. The structures of the synthesized 4,6-bisarylpyrimidin-2(1*H*)-one compounds were confirmed by ^{1}H NMR, ^{13}C NMR and FTIR spectral data and elemental analyses.

© 2020 The Author(s). Published by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Heterocyclic compounds play an important role in regulating biological activities and many of them are used as medicines. Nitrogen-containing heterocyclic compounds are of great importance due to their wide range of drug activities, and among the heterocyclic ring systems, pyrimidines have a particular position (Kumar et al., 2011). Pyrimidines exist as constituents of many valuable chemotherapeutic agents (bleomycine), vitamins (vitamin B1), anti-bacterial and anti-malarial drugs, and nucleic acids (cytosine and uracil) (Pothiraj et al., 2008). Dihydropyrimidinones are an important class of heterocyclic compounds due to therapeutic activities such as anti-bacterial, anti-hypertensive, anti-cancer, anti-virus, anti-inflammatory, AIDS inhibitor, calcium channel blocker and anti-calcium channel blocker (Kappe and

* Corresponding author.
E-mail address: nikpassand@iaurasht.ac.ir (M. Nikpassand).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.arabjc.2020.10.022
1878-5352 © 2020 The Author(s). Published by Elsevier B.V. on behalf of King Saud University.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Fabian, 1997; Overman et al., 1995; Chaudhari and Shah, 2011; Deres et al., 2003; Couto et al., 2011; Duguay et al., 2008).

Different methods have been reported for the synthesis of diphenyl pyrimidines. Three component reaction among benzaldehyde, ethyl acetoacetate and urea in ethanol solvent using a recoverable catalyst SBA-15@Fe_3O_4 is one of these (Mondal et al., 2012). Synthesis of 3,4-dihydro-pyrimidine-2-(1*H*)-ions (thions) in solvent-free conditions and in the presence of Fe_3O_4 (Nasr-Esfahani et al., 2011), pyrido (Pothiraj et al., 2008; Kappe and Fabian, 1997; Overman et al., 1995; Chaudhari and Shah, 2011; Deres et al., 2003; Couto et al., 2011; Duguay et al., 2008; Mondal et al., 2012; Nasr-Esfahani et al., 2011; Rad and Mokhtary, 2015; Ebraheem, 2012; Heravi, 2009; Zhu and Bienayme, 2005; Rakhi et al., 2016; Wang, 2004; Abaszadeh and Seifi, 2017; Bigi et al., 1999; Rani et al., 2001; Yadav et al., 2000; Yadav et al., 2004; Salehi et al., 2003; Martinez et al., 2003; Li et al., 2010; Aghazadeh and Nikpassand, 2019; Zare Fekri et al., 2019; Nikpassand, 2020; Nikpassand and Farokhian, 2016; Nikpassand and Pirdelzendeh, 2016; Nikpassand et al., 2015; Nikpassand et al., 2017; Nikpassand et al., 2018; Heravi et al., 2008; Pourghobadi and Derikvand, 2010) pyrimidines nanoparticles, by direct mononuclear reaction 6-Euroacyl and its derivatives, with aryl aldehydes and malononitrile together with MgO nanoparticles (Rad and Mokhtary, 2015), Preparation of pyrimidine-2-one and pyrimidine-2-thionyl compounds from the combination of chalcone with benzaldehydes with acetophenone in sodium hydroxide and 50% ethanol (Ebraheem, 2012) and direct, one-pot, three component, oxidation reaction among 1,3-diketone, benzaldehyde and ammonium acetate in the presence of some heteropolytic acid as a catalyst (Heravi, 2009) is another example of published scientific reporting methods for the synthesis of various diphenyl pyrimidines.

Various acid catalysts have been proposed for the synthesis of these organic compounds. In the past, traditionally, strong Bronsted acids such as hydrochloric acid and sulfuric acid were utilized. But today, the use of Lewis acids such as BF_3OEt_2, CuCl, $LaCl_3$, $FeCl_3$, $NiCl_2$, Yb(OTf)$_3$, La(OTf)$_3$, $LnCl_3$, $LnBr_3$, Ln(OTf)$_3$, LiBr, $CoCl_2$, $BiCl_3$, $LiClO_4$, Mn(OAc)$_3$, $ZrCl_4$, Cu(OTf)$_2$, $CuCl_2$, Bi(OTf)$_3$, $CeCl_3$, VCl_3, Zn(OTf)$_2$, Sm$(NO_3)_3$ and $SmCl_3$ (Zhu and Bienayme, 2005); -cyclodextrin (Rakhi et al., 2016) KF-Al_2O_3 (Wang, 2004; Abaszadeh and Seifi, 2017) is common. Solid acid catalysts such as clay, zeolite, ion exchange agents such as amberlite or a heteropolytic acid such as $Ag_3PW_{12}O_{40}$ have also been used today as catalysts (Bigi et al., 1999; Rani et al., 2001; Yadav et al., 2000; Yadav et al., 2004). In addition, materials such as silica sulfuric acid or nanoparticles or silica-iron oxide nanocomposites have also been reported as catalysts (Salehi et al., 2003; Martinez et al., 2003; Li et al., 2010).

Thus, it is essential to design an efficient, green and novel method for the preparation of 4,6-bisarylpyrimidin-2(1*H*)-ones without those disadvantages such as toxic solvents and catalysts, long reaction times, low yields and use of costly catalysts, we report herein synthesis of 4,6-bisarylpyrimidin-2 (1*H*)-ones with various synthetized azo-linked aldehydes or benzaldehydes, urea and acetophenone in the presence of $NiFe_2O_4$@$SiO_2{}^n$Pr@glucose amine nanoparticles as an effective and reusable catalyst.

2. Material and methods

2.1. Apparatus and analysis

Chemicals were purchased from Merck and Fluka and used as purchased. Melting points were measured on an Electrothermal 9100 apparatus and are uncorrected. ^{1}H NMR spectra were obtained on a Bruker DRX 500Avance spectrometer in DMSO-d_6 as solvent and with TMS as internal standard. FT-IR spectra were recorded on a Shimadzu FT-IR-8400S spectrometer. Elemental analyses were recorded on a Carlo-Erba EA1110CNNO-S analyzer. For the ultrasound reactions, ultrasound apparatus astra 3D (9.5 dm3, 45 KHz frequency, input power with heating, 305 W, number of transducers, 2) from TECNO-GAZ was used.

2.2. Procedure for the synthesis of $NiFe_2O_4$@$SiO_2{}^n$Pr@glucose amine nanoparticles

2.2.1. Synthesis of $NiFe_2O_4$ & $NiFe_2O_4$@$SiO_2{}^n$PrCl MNPs

The synthetized $NiFe_2O_4$ and $NiFe_2O_4$@$SiO_2{}^n$PrCl MNPs were synthesized by Zare Fekri, et al. (Aghazadeh and Nikpassand, 2019; Zare Fekri et al., 2019).

2.2.2. Synthesis of $NiFe_2O_4$@$SiO_2{}^n$Pr@glucose amine using of ultrasound irradiation

0.5 g $NiFe_2O_4$@$SiO_2{}^n$PrCl were dispersed into 50 mL xylene and sonicated for 30 min, followed by the drop wise addition of 0.5 mL glucose amine. Then, the mixture was irradiated in a water bath by ultrasound at room temperature (25 ℃) for 20 min under a nitrogen flow. The resulting functionalized $NiFe_2O_4$@$SiO_2{}^n$Pr@glucose amine was collected by magnetic separation followed by washing with toluene and ethanol several times and drying at 60 ℃ for 10 h.

2.3. General procedure for preparation of 4,6-Bisarylpyrimidin-2 (1*H*)-ones **4a-n** and novel azo-linked 4,6-Bisarylpyrimidin-2 (1*H*)-ones **4o-s** using $NiFe_2O_4$@$SiO_2{}^n$Pr@glucose amine nanoparticles

A mixture of synthetized azo-linked aldehydes or benzaldehydes (1 mmol), acetophenone (1 mmol), urea (1 mmol), 0.05 g $NiFe_2O_4$@$SiO_2{}^n$Pr@glucose amine and H_2O (10 mL) were placed into Pyrex-glass open vessel and stirred at room temperature (25 ℃) for the required reaction times. After completion of the reaction, as indicated by TLC (TLC Silica gel 60F, ethyl acetate: *n*-hexane 1: 2), the resulting mixture was dissolved in hot ethanol (20 mL) and the catalyst separated by a 1.4 Tesla external magnet and washed with hot distilled water (5 mL) and ethanol (5 mL) two times. The resulting 4,6-bisarylpyrimidin-2(1*H*)-ones was isolated and purified using a thin layer chromatography. The structures of most of the synthesized 4,6-bisarylpyrimidin-2(1*H*)-one compounds were characterized (^{1}H, ^{13}C NMR and FTIR) and elemental analyses.

4-(2-bromophenyl)-6-phenylpyrimidin-2(1H)-one (4a): White solid, Yield: 94%, mp 215–217 ℃; IR (KBr, cm^1) $_{max}$: 3430 (N-H stretching), 2971 (C-H stretching), 1668 (C = O stretching), 1611 and 1522 (C = C stretching), 1371 (C-N

stretching), 1023 (C-Br stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 6.25 (s, 1H), 6.69 (d, J = 6.3 Hz, 1H), 7.20–7.95 (m, 8H) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 123.8, 128.9, 129.3, 129.5, 130.1, 130.7, 134.1, 134.6, 137.4, 142.5, 156.5, 158.8, 161.1, 193.2 (C = O) ppm. Anal Calc. for $C_{16}H_{11}BrN_2O$: C, 58.74; H, 3.39; N, 8.56. Found: C, 58.73; H, 3.40; N, 8.58.

4-(3-bromophenyl)-6-phenylpyrimidin-2(1H)-one (4b): White solid, Yield: 94%, mp 246–248 ℃; IR (KBr, cm^{-1}) $_{max}$ 3408 (N-H stretching), 2983 (C-H stretching), 1672 (C = O stretching), 1632 and 1553 (C = C stretching), 1390 (C-N stretching), 1009 (C-Br stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 5.79 (s, 1H), 6.88 (d, J = 7.5 Hz, 1H), 7.29–7.59 (m, 4H), 7.76–7.91 (m, 4H), 8.00 (s, 1H) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 122.1, 125.6, 128.5, 128.6, 129.0, 129.5, 131.2, 132.1, 133.6, 135.9, 158.2, 160.5, 166.7, 195.7 (C = O) ppm. Anal Calc. for $C_{16}H_{11}BrN_2O$: C, 58.74; H, 3.39; N, 8.56. Found: C, 58.75; H, 3.37; N, 8.55.

4-(4-bromophenyl)-6-phenylpyrimidin-2(1H)-one (4c): White solid, Yield: 93%, mp 238–240 ℃; IR (KBr, cm^{-1}) $_{max}$: 3450 (N-H stretching), 2923 (C-H stretching), 1671 (C = O stretching), 1597, 1542 and 1468 (C = C stretching), 1367 (C-N stretching), 1048 (C-Br stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 5.76 (s, 1H), 6.05 (s, 1H), 6.81–7.90 (m, 8H), 13.0 (s, br, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 127.2, 128.6, 130.4, 131.3, 131.6, 132.0, 133.5, 142.5, 158.2, 160.4, 167.2, 197.6 (C = O) ppm. Anal Calc. for $C_{16}H_{11}BrN_2O$: C, 58.74; H, 3.39; N, 8.56. Found: C, 58.76; H, 3.40; N, 8.58.

4-(4-chlorophenyl)-6-phenylpyrimidin-2(1H)-one (4d): White solid, Yield: 92%, mp 268–270 ℃; IR (KBr, cm^{-1}) $_{max}$: 3446 (N-H stretching), 2962 (C-H stretching), 1680 (C = O stretching), 1594 and 1466 (C = C stretching), 1372 (C-N stretching), 1090 (C-Cl stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 5.70 (s, 1H), 7.32–7.66 (m, 6H), 7.90–7.93 (d, J = 8.7 Hz, 3H) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 128.3, 129.1, 130.1, 131.5, 132.0, 138.2, 142.0, 156.3, 158.1, 160.1, 167.0, 197.3 (C = O) ppm. Anal Calc. for $C_{16}H_{11}ClN_2O$: C, 67.97; H, 3.92; N, 9.91. Found: C, 67.95; H, 3.93; N, 9.89.

4-(2,4-dichlorophenyl) 6-phenylpyrimidin-2(1H)-one (4e): White solid, Yield: 94%, mp 234–236 ℃; IR (KBr, cm^{-1}) $_{max}$: 3451 (N-H stretching), 2976, 2925 (C-H stretching), 1671 (C = O stretching), 1592, 1545, 1470 (C = C stretching), 1369 (C-N stretching), 1049 (C-Cl stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): 6.27 (s, 1H), 6.78–6.87 (m, 3H), 7.43–7.52 (m, 4H), 7.92 (d, J = 6.5 Hz, 1H), 10.4 (s, br, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 127.4, 128.5, 128.7, 129.0, 129.1, 129.6, 133.2, 133.6, 138.9, 139.2, 155.6, 157.7, 181.3, 198.9 (C = O) ppm. Anal Calc. for $C_{16}H_{10}Cl_2N_2O$: C, 60.59; H, 3.18; N, 8.83. Found: C, 60.60; H, 3.16; N, 8.81.

4-(2,6-dichlorophenyl)-6-phenylpyrimidin-2(1H)-one (4f): White solid, Yield: 93%, mp 250–252 ℃; IR (KBr, cm^{-1}) $_{max}$: 3366 (N-H stretching), 1664 (C = O stretching), 1624, 1600, 1482 (C = C stretching), 1377 (C-N stretching), 1134 (C-Cl stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 6.67–6.70 (m, 1H), 6.99–7.60 (m, 7H), 7.93 (d, J = 7.0 Hz, 1H), 10.4 (s, br, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_c$; 128.4, 128.5, 128.8, 129.1, 129.6, 130.2, 130.4, 131.1, 133.6, 133.9, 166.1, 190.0 (C = O) ppm. Anal Calc. for $C_{16}H_{10}Cl_2N_2O$: C, 60.59; H, 3.18; N, 8.83. Found: C, 60.57; H, 3.20; N, 8.84.

6-phenyl-4-(m-tolyl)pyrimidin-2(1H)-one (4 g): White solid, Yield: 87%, mp > 300 ℃; IR (KBr, cm^{-1}) $_{max}$: 3445 (N-H stretching), 2922 (C-H stretching), 1651 (C = O stretching), 1605, 1552 (C = C stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 2.27 (s, 3H), 6.07 (t, J = 7.8 Hz, 1H), 6.65 (d, J = 8.0 Hz, 2H), 7.03–7.95 (m, 7H) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): c; 20.4, 124.4, 127.9, 129.1, 129.4, 129.8, 130.0, 131.1, 134.8, 138.5, 143.8, 159.2, 161.3, 169.1, 194.6 (C = O) ppm. Anal Calc. for $C_{17}H_{14}N_2O$: C, 77.84; H, 5.38; N, 10.68. Found: C, 77.85; H, 5.36; N, 10.67.

6-phenyl-4-(p-tolyl)pyrimidin-2(1H)-one (4 h): White solid, Yield: 91%, mp 284–286 ℃; IR (KBr, cm^{-1}) $_{max}$: 3442 (N-H stretching), 2928 (C-H stretching), 1673 (C = O stretching), 1598, 1462 (C = C stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 2.32 (s, 3H), 5.68 (s, 1H), 6.07 (s, 1H), 6.69 (s, 1H), 7.11–7.35 (m, 6H), 7.78 (s, 1H) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 22.5, 127.3, 129.6, 130.0, 130.5, 130.7, 131.0, 137.6, 140.9, 159.2, 161.3, 169.0, 194.0 (C = O) ppm. Anal Calc. for $C_{17}H_{14}N_2O$: C, 77.84; H, 5.38; N, 10.68. Found: C, 77.85; H, 5.37; N, 10.67.

4-(4-nitrophenyl)-6-phenylpyrimidin-2(1H)-one (4i): Yellow solid, Yield: 96%, mp 343–345 ℃; IR (KBr, cm^{-1}) $_{max}$: 3437 (N-H stretching), 2982 (C-H stretching), 1675 (C = O stretching), 1597 and 1542 (C = C stretching), 1538 (NO_2 stretching), 1367 (C-N stretching), 1349 (NO_2 stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 5.73 (s, 1H), 6.11 (s, 1H), 6.68–7.97 (m, 8H), 11.63 (s, br, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 124.6, 127.5, 129.4, 131.4, 131.5, 133.3, 133.9, 142.8, 153.5, 158.5, 163.5, 196.1 (C = O) ppm. Anal Calc. for $C_{16}H_{11}N_3O_3$: C, 65.53; H, 3.78; N, 14.33. Found: C, 65.55; H, 3.76; N, 14.35.

4-(4-isopropylphenyl)-6-phenylpyrimidin-2(1H)-one (4j): White solid, Yield: 90%, mp 289–291 ℃; IR (KBr, cm^{-1}) $_{max}$: 3453 (N-H stretching), 3091 and 2938 (C-H stretching), 1634 (C = O stretching), 1541 and 1563 (C = C stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 1.25 (d, J = 6.8 Hz, 6H), 7.51–7.56 (m, 4H), 8.11 (d, J = 7.8 Hz, 2H), 8.17 (d, J = 6.8 Hz, 2H) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): c; 19.3, 28.5, 122.4, 124.5, 130.4, 131.5, 131.7, 133.5, 139.4, 142.4, 155.7, 158.6, 165.8, 194.3 (C = O) ppm. Anal Calc. for $C_{19}H_{18}N_2O$: C, 78.59; H, 6.25; N, 9.65. Found: C, 78.58; H, 6.27; N, 9.66.

4-(2-hydroxyphenyl)-6-phenylpyrimidin-2(1H)-one (4 k): White solid, Yield: 89%, mp 295–297 ℃; IR (KBr, cm^{-1}) $_{max}$: 3324 and 3216 (N-H stretching), 3075 and 2920 (C-H stretching), 1689 (C = O stretching), 1498 and 1450 (C = C stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 2.25 (d, J = 8.7 Hz, 1H), 2.31 (dd, J = 8.7, 2.8 Hz, 1H), 4.05 (d, J = 3.8 Hz, 1H), 6.94–6.99 (m, 2H), 7.26–7.29 (m, 2H), 7.35–7.60 (m, 4H), 7.65–7.72 (m, 2H), 7.57 (s, 1H), 10.58 (s, 1H, OH) ppm.^{13}C NMR (62 MHz, DMSO-d_6): c; 123.2, 124.4, 129.2, 129.9, 131.7, 131.9, 133.5, 133.8, 141.5, 153.0, 156.6, 157.4, 163.6, 190.2 (C = O) ppm. Anal Calc. for $C_{16}H_{12}N_2O_2$: C, 72.72; H, 4.58; N, 10.60. Found: C, 72.74; H, 4.56; N, 10.62.

4-(4-hydroxyphenyl)-6-phenylpyrimidin-2(1H)-one (4 l): White solid, Yield: 90%, mp 259–261 ℃; IR (KBr, cm^{-1}) $_{max}$: 3383 (N-H stretching), 3253 (O-H stretching), 2922 (C-H stretching), 1631 (C = O stretching), 1515 and 1450 (C = C stretching) cm^{-1}. ^1H NMR (250 MHz, DMSO-d_6): $_H$; 6.92–7.00 (m, 2H), 7.53–7.68 (m, 3H), 7.69–7.78 (m, 3H), 8.07–8.18 (m, 2H), 10.18 (s, 1H, OH) ppm. ^{13}C NMR (62 MHz,

DMSO-d_6): c; 122.7, 124.7, 129.6, 131.4, 133.0, 133.1, 142.4, 154.6, 158.4, 159.2, 165.0, 193.6 (C = O) ppm. Anal Calc. for $C_{16}H_{12}N_2O_2$: C, 72.72; H, 4.58; N, 10.60. Found: C, 72.70; H, 4.59; N, 10.58.

4-(2-hydroxy-5-((3-nitrophenyl)diazenyl)phenyl)-6-phenyl pyrimidin-2(1H)-one (4o): Yellow solid, Yield: 93%, mp > 300° C; IR (KBr, cm^1) $_{max}$: 3393 (N-H stretching), 3251 (O-H stretching), 2959 (C-H stretching), 1668 (C = O stretching), 1542 (NO_2 stretching), 1551, 1468 (C = C stretching), 1540 (NO_2 stretching) cm^1. ^{1}H NMR (250 MHz, DMSO-d_6): $_H$; 6.58–6.64 (m, 3H), 7.49–7.72 (m, 5H), 7.78–8.19 (m, 5H), 10.09 (s, 1H, OH), 12.40 (s, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 112.8, 118.9, 119.6, 122.7, 124.8, 126.0, 126.6, 127.0, 128.4, 129.5, 130.8, 131.6, 133.4, 133.5, 146.7, 147.9, 153.3, 157.2, 160.6, 190.6 (C = O) ppm. Anal Calc. for $C_{22}H_{15}N_5O_4$: C, 63.92; H, 3.66; N, 16.94. Found: C, 63.94; H, 3.64; N, 16.93.

4-(2-hydroxy-5-((4-nitrophenyl)diazenyl)phenyl)-6-phenyl pyrimidin-2(1H)-one (4p): Yellow solid, Yield: 94%, mp > 300° C; IR (KBr, cm^1) $_{max}$: 3452 (N-H stretching), 3237 (O-H stretching), 2928 (C-H stretching), 1670 (C = O stretching), 1540 (NO_2 stretching), 1517 and 1461 (C = C stretching), 1351 (NO_2 stretching) cm^1. ^{1}H NMR (250 MHz, DMSO-d_6): $_H$; 6.56–6.68 (m, 2H), 7.66–8.26 (m, 11*H*), 10.31 (s, 1H, OH), 11.82 (s, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 113.8, 118.2, 123.8, 124.9, 126.4, 126.8, 127.0, 127.8, 129.4, 130.1, 133.0, 133.6, 145.7, 147.4, 151.8, 161.0, 161.4, 192.2 (C = O) ppm. Anal Calc. for $C_{22}H_{15}N_5O_4$: C, 63.92; H, 3.66; N, 16.94. Found: C, 63.94; H, 3.64; N, 16.93.

4-(5-((4-bromophenyl)diazenyl)-2-hydroxyphenyl)-6-phenylpyrimidin-2(1H)-one (4q): White solid, Yield: 95%, mp > 300 ℃; IR (KBr, cm^1) $_{max}$: 3365 (N-H stretching), 3262 (O-H stretching), 2983 (C-H stretching), 1681 (C = O stretching), 1548 and 1473 (C = C stretching) cm^1. ^{1}H NMR (250 MHz, DMSO-d_6): $_H$; 6.59–6.72 (m, 4H), 7.52–8.09 (m, 7H), 10.09 (s, 1H, OH), 11.92 (s, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 115.5, 119.5, 123.6, 124.7, 126.6, 127.5, 127.7, 129.7, 129.9, 130.7, 133.4, 134.8, 143.67, 146.0, 152.5, 161.6, 162.5, 189.3 (C = O) ppm. Anal Calc. for $C_{22}H_{15}BrN_4O_2$: C, 59.08; H, 3.38; N, 12.53. Found: C, 59.06; H, 3.40; N, 12.55.

4-(5-((3-chlorophenyl)diazenyl)-2-hydroxyphenyl)-6-phenylpyrimidin-2(1H)-one (4r): White solid, Yield: 96%, mp > 300 ℃; IR (KBr, cm^1) $_{max}$: 3338 (N-H stretching), 3268 (O-H stretching), 2993 (C-H stretching), 1675 (C = O stretching), 1562 and 1474 (C = C stretching) cm^1. ^{1}H NMR (250 MHz, DMSO-d_6): $_H$; 6.70–6.79 (m, 3H), 7.37–7.77 (m, 6H), 7.84–8.21 (m, 4H), 10.24 (s, 1H, OH), 12.09 (s, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 113.5, 118.8, 119.4, 123.1, 124.4, 124.7, 126.4, 128.4, 128.5, 129.4, 130.7, 131.4, 131.8, 133.8, 147.4, 149.3, 151.9, 155.7, 158.6, 185.5 (C = O) ppm. Anal Calc. for $C_{22}H_{15}ClN_4O_2$: C, 65.59; H, 3.75; N, 13.91. Found: C, 65.61; H, 3.76; N, 13.89.

4-(5-((4-chlorophenyl)diazenyl)-2-hydroxyphenyl)-6-phenylpyrimidin-2(1H)-one (4 s): White solid, Yield: 95%, mp > 300 ℃; IR (KBr, cm^1) $_{max}$: 3379 (N-H stretching), 3205 (O-H stretching), 2984 (C-H stretching), 1674 (C = O stretching), 1583 and 1448 (C = C stretching) cm^1. ^{1}H NMR (250 MHz, DMSO-d_6): $_H$; 6.51–6.70 (m, 4H), 7.73–8.05 (m, 9H), 9.97 (s, 1H, OH), 12.47 (s, 1H, NH) ppm. ^{13}C NMR (62 MHz, DMSO-d_6): $_C$; 113.5, 119.0, 121.7, 123.5, 125.6, 126.0, 127.4, 129.4, 129.7, 130.3, 131.4, 133.5, 142.5, 145.7, 151.5, 160.4, 161.4, 190.5 (C = O) ppm. Anal Calc. for $C_{22}H_{15}ClN_4O_2$: C, 65.59; H, 3.75; N, 13.91. Found: C, 65.58; H, 3.76; N, 13.89.

3. Results and discussion

The morphology and size of the $NiFe_2O_4$@SiO_2^{n}Pr@glucose amine MNPs was investigated by TEM spectrum as shown in Figs. 1 and 2. In order to investigate the reusing performance of $NiFe_2O_4$@SiO_2^{n}Pr@glucose amine, the recyclability of catalyst was tested in **4a**.

The FT-IR spectra of $NiFe_2O_4$, $NiFe_2O_4$@SiO_2 and $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose MNPs are shown in Fig. 3. The absorption band in 594 cm^1 is related to the stretching vibration of the Fe–O bond of bare $NiFe_2O_4$ that was appeared in 590 cm^1 in the FT-IR spectrum of $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose MNPs. The absorption bands of Si-O-Si vibrations in SiO_2 shell were appeared in 1045 and 1130 cm^1 in $NiFe_2O_4$@SiO_2 spectra that seemed at 1033, 1137 and 767 cm^1 in the spectrum of the $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose MNPs. Also, the peaks at 1645 and 3429 cm^1 (in the spectrum of the $NiFe_2O_4$) and at 1645 and 3423 cm^1 (in the spectrum of the $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose MNPs) are attributed to the stretching vibrations of the hydroxyl (–OH) groups on the surface of MNPs. The peaks in region 2950 and 3120 cm^1 refer to the stretching band of C-H aliphatic and NH stretching in $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose MNPs (Fig. 3).

The structure of $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose was also confirmed by XRD analysis. In Fig. 4, the XRD patterns of $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose MNPs and pure $NiFe_2O_4$ (from JCPDS No. 54–0964) are illustrated. The comparison of the XRD patterns indicated that both patterns exhibits peaks with 2 at 30°,36°, 45°, 50°, 54°, 58° and 62° which are representative of the structure and broad peak in 10-30° is related to $NiFe_2O_4$ covered by SiO_2 (Fig. 4).

The results of energy dispersive X-ray spectroscopy (EDX) analysis of the synthesized $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose

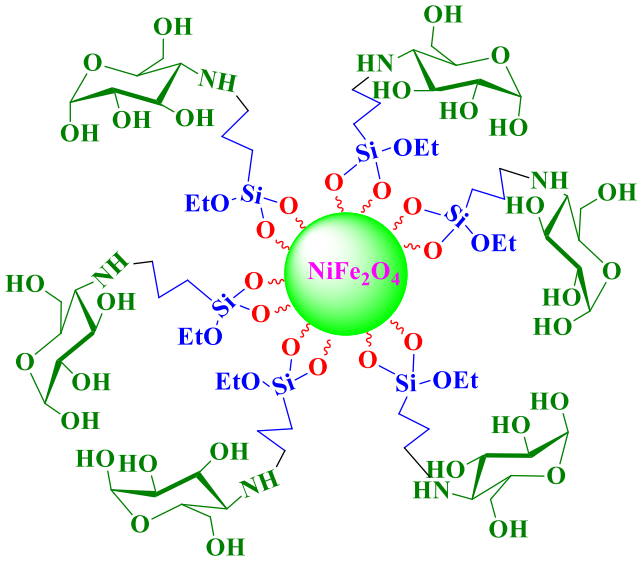


Fig. 1 The structure of amino glucose-functionalized silica--coated $NiFe_2O_4$ nanoparticles.

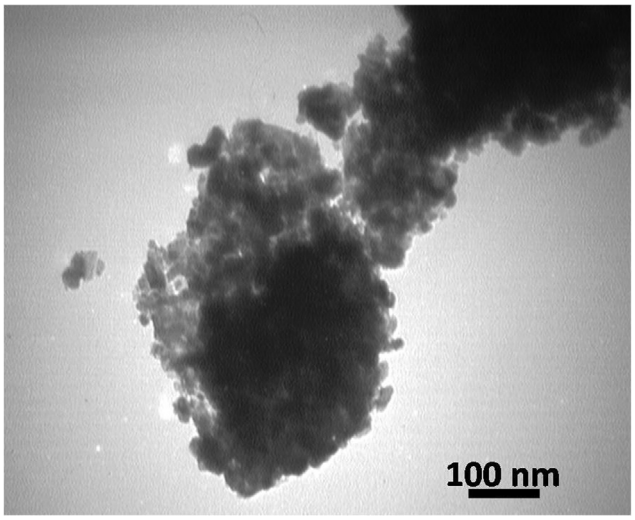


Fig. 2 The TEM image of the synthesized $NiFe_2O_4@SiO_2{}^n$-Pr@amino glucose.

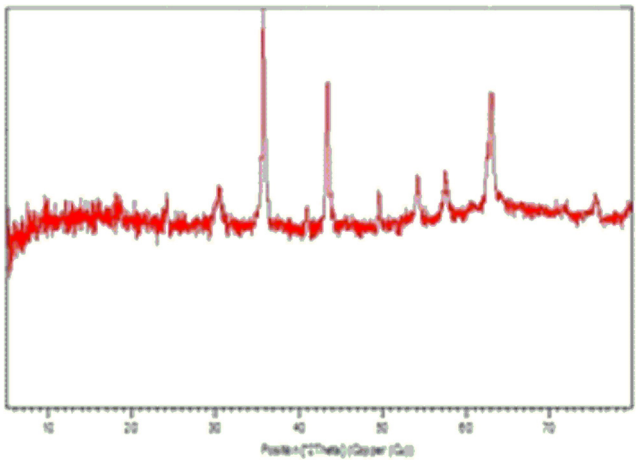


Fig. 4 The XRD patterns of a) $NiFe_2O_4@SiO_2{}^n$Pr@amino glucose and b) $NiFe_2O_4$.

MNPs (Fig. 5) proved existence of Fe (30.17 w/w%), O (16.21 w/w%), Si (2.2 w/w%), N (0.45 w/w%), C (5.30 w/w%) and Ni (31.12 w/w %) atoms in the structure that confirms the presence of $NiFe_2O_4$ core in the structure of MNP.

Fig. 6 shows the hysteresis loop of the synthesized $NiFe_2O_4@SiO_2{}^n$Pr@amino glucose MNPs. VSM measurements were carried out at room temperature (25 ℃) by taking the solid sample on the tips of the vibrating rod and analyzing in an applied magnetic field sweeping from 20 to 20 kOe (Fig. 6).

In order to achieve a more efficient synthetic process, improving the yields and reaction times minimize by-products, decrease the number of separate reaction steps and also in extending our research on the synthesis and study of heterocyclic and pharmaceutical compounds (Nikpassand, 2020; Nikpassand and Farokhian, 2016; Nikpassand and Pirdelzendeh, 2016; Nikpassand et al., 2015; Nikpassand et al., 2017; Nikpassand et al., 2018; Heravi et al., 2008; Pourghobadi and Derikvand, 2010), in this work, the first synthesis of some derivatives of 4,6-bisarylpyrimidin-2(1*H*)-ones from various aldehydes, urea, acetophenone and $NiFe_2O_4@SiO_2{}^n$Pr@glucose amine as a catalyst is reported (Scheme 1).

The structure of $NiFe_2O_4@SiO_2{}^n$Pr@glucose amine magnetic nanoparticle that was synthesized in three steps from commercially available materials. The $Fe_3O_4@SiO_2$ core-shell structures were then sequentially treated with 3-chloropropyl

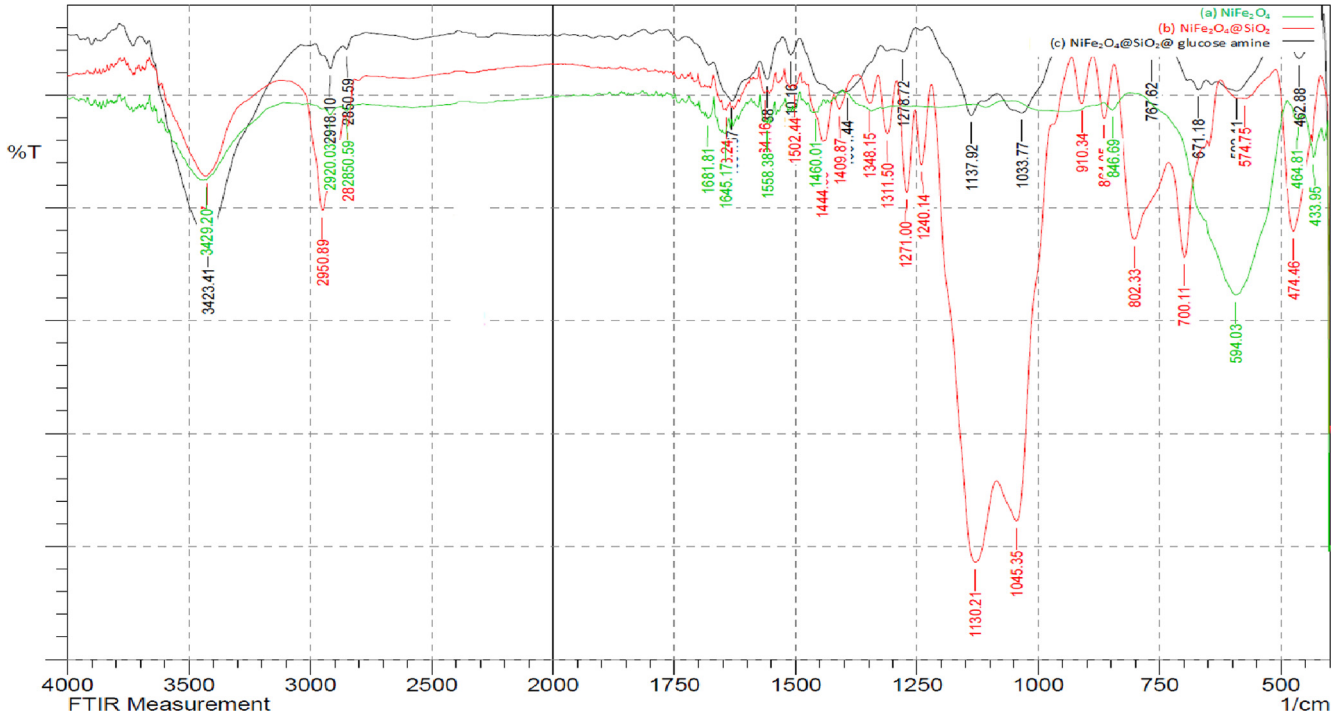


Fig. 3 FT-IR spectra of (a) $NiFe_2O_4$, (b) $NiFe_2O_4@SiO_2$, (c) $NiFe_2O_4@SiO_2{}^n$Pr@amino glucose MNPs.

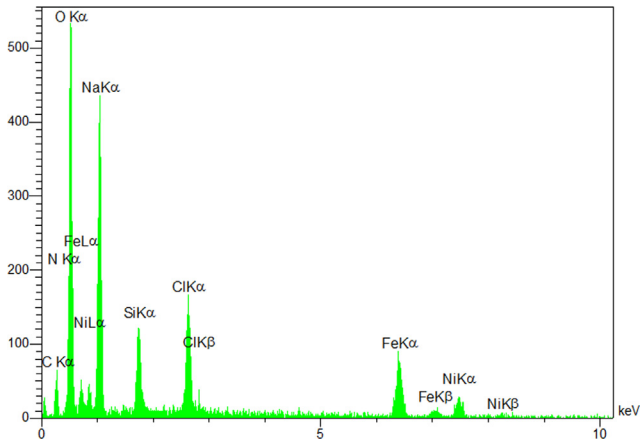


Fig. 5 EDX results of $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose nanocatalyst.

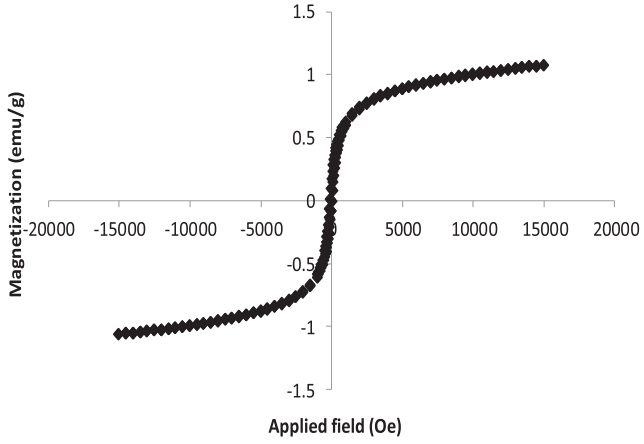


Fig. 6 Vibrating scanning magnetometery (VSM) curve of $NiFe_2O_4$@SiO_2^{n}Pr@amino glucose nanocatalyst.

trimethoxysilane. Next, it was treated with Tannic acid to obtain the Glucose amine-functionalized silica-coated $NiFe_2O_4$nanoparticles ($NiFe_2O_4$@SiO_2^{n}Pr@glucose amine).

Table 1 The effect of various solvents on the synthesis of 4-(2-bromophenyl)-6-phenylpyrimidin-2(1*H*)-one **4a.**

Entry	Solvent	Time (h)	Yield (%)
1	Et_2O	24	53
2	H_2O	8	77
3	EtOH	8	68
4	Hexane	24	54
5	$CHCl_3$	24	59
6	DMF	36	72

3.1. Catalytic studies

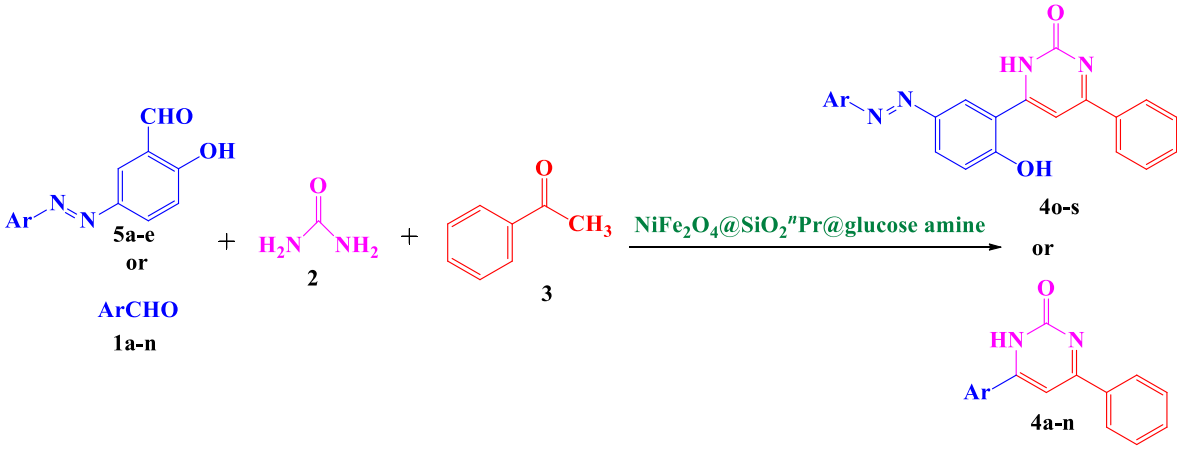
In order to evaluate the catalytic capability of the synthesized heterogeneous catalyst ($NiFe_2O_4$@SiO_2^{n}Pr@glucose amine) in organic reactions, we chose to examine its activity in an one-pot reaction for the reaction between various aldehydes, acetophenone and urea (Scheme 1).

3.2. Effect of solvent type

In order to optimize the model process and the efficiency of solvents in this reaction, for the sake of comparisons some commonly available solvents such as Et_2O, H_2O, EtOH, hexane, $CHCl_3$ and DMF were studied. In these experiments, 4-bromobenzaldehyde **1a** (1.0 mmol), acetophenone (1 mmol) and urea (1.0 mmol) were mixed with 10 mL solvent (Table 1). Among the tested solvents, we found that H_2O was the most appropriate solvent for these reactions (77% yields in 8 h).

3.3. Effect of catalyst type and temperature on reaction time

To find the appropriate catalyst, in order to synthesize the derivatives of 4,6-bisarylpyrimidin-2(1*H*)-one **4a** from the reaction of 2-bromobenzaldehyde **1a** (1 mmol), acetophenone **2** (1 mmol), urea **3** (1 mmol) in H_2O (10 mL) using of 0.1 g of available catalysts at room temperature (25 ℃) were used and the efficiency and reaction rate were compared. In comparison to other catalysts studied, $NiFe_2O_4$@SiO_2^{n}Pr@glucose amine catalyst at room temperature (25 ℃) showed the



Scheme 1 Preparation of 4,6-bisarylpyrimidin-2(1*H*)-ones using $NiFe_2O_4$@SiO_2^{n}Pr@glucose amine.

Table 2 Influence of catalyst types on reaction time and efficiency in synthesis of **4a.**

Entry	catalyst	Time (min)	Yield (%)[a,b]
1	–	480	77
2	*K*10	360	81
3	KSF	360	78
4	Fe^{+3}-montmorillonite *K*10	360	82
5	*L*-Proline	720	59
6	nano-Fe_3O_4	240	72
7	nano-SiO_2	360	70
8	$NiFe_2O_4$@SiO_2	240	74
9	Glucose amine	180	80
10	$NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine	120	94
11	$NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine (60 ℃)	120	94
12	$NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine (100 ℃)	120	94
13	[BBIM]Br	1200	76
14	[BBIM]HSO_4	900	83

*Reaction conditions: 2-bromobenzaldehyde **1a** (1 mmol), acetophenone **2** (1 mmol), urea **3** (1 mmol) were used in H_2O (10 mL) as solvent.[#] 2 mL of ionic liquid were used for ionic liquids in entries 13 and 14.

best results and efficiency and time for product **4a** preparation (entry 10, Table 2).

3.4. Effect of $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine catalyst value

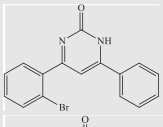
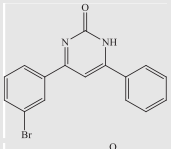
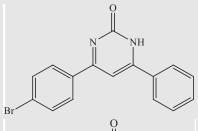
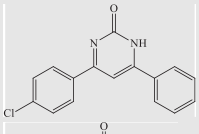
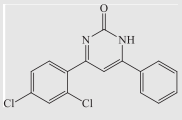
Synthesis of product **4a** with different amounts of $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine at room temperature (25 ℃) was investigated and it was found that using of 0.05 g of the desired catalyst per 1 mmol of primary reaction aldehyde with better yield and at shorter time (Table 3).

According to the results of the steps to evaluate the optimal conditions for the synthesis of 4,6-bisarylpyrimidin-2(1*H*)-ones from various benzaldehydes, acetophenone and urea, It was found that the best reaction conditions to use $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine in aqueous medium at room temperature (25 ℃) is the best conditions, so the same method was used to synthesize other derivatives of bisarylpyrimidin-2(1*H*)-one compounds (Scheme 1 and Table 3).

The process of performing this reaction for the synthesis of 4,6-bisarylpyrimidin-2(1*H*)-ones using a $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine nanocatalyst is presented in Scheme 2. Initially, $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine nanocatalyst seems to activate the enolization of acetophenone by forming a hydrogen bond with the carbonyl functional group. Next, the aldol condensation reaction of activated enolate **5** with aldehyde **1** leads to production chalcone **7** during dehydration. Subsequently, the urea is reacted with intermediate **7** and the corresponding imine **8** is produced. Then, a heterocyclic ring **9** is formed during the Michael addition within the molecular ring, and finally by oxidizing the compound **9**, the final product **4** is formed (Scheme 2).

The recyclability and reusability of catalyst were studied in the model one-pot reaction among various benzaldehyde, acetophenone and urea. At the end of the reaction, the separated catalyst can be reused after being washed with warm EtOH and drying at 80 ℃. $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine was used again for subsequent experiments under similar reaction conditions. The catalyst could be reused for the next cycle without any notable loss of its activity. Yields of the product

Table 3 Synthesis of 4,6-Bisarylpyrimidin-2(1*H*)-ones and azo-linked 4-Arylpyrimidin-2(1*H*)-ones using $NiFe_2O_4$@SiO_2-^{n}Pr@glucose amine.

Entry	Product	Structure	Time (min)	Yield (%)[a,b]	Observed Melting Point (℃)	Reported Melting Point (℃)
1	**4a**		120	94	215–217	–
2	**4b**		90	94	246–248	–
3	**4c**		60	93	238–240	251–254 (Heravi et al., 2008)
4	**4d**		60	92	268–270	258–260 (Pourghobadi and Derikvand, 2010)
5	**4e**		60	94	234–236	–

(*continued on next page*)

Table 3 (*continued*)

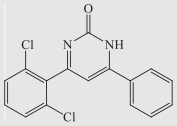
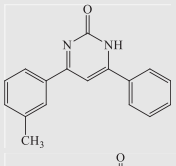
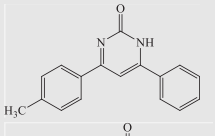
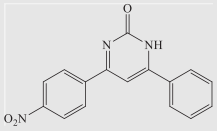
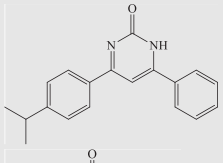
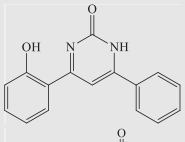
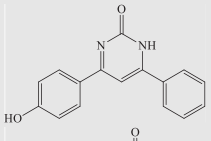
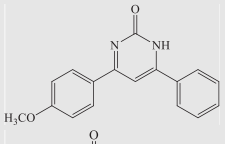
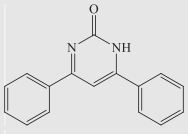
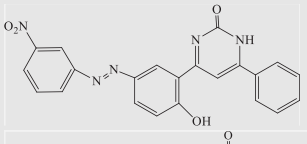
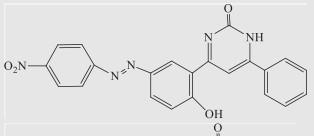
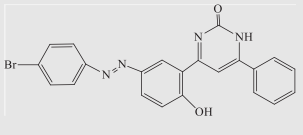
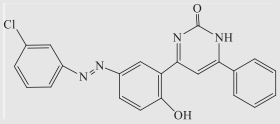
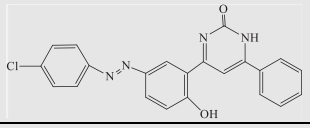
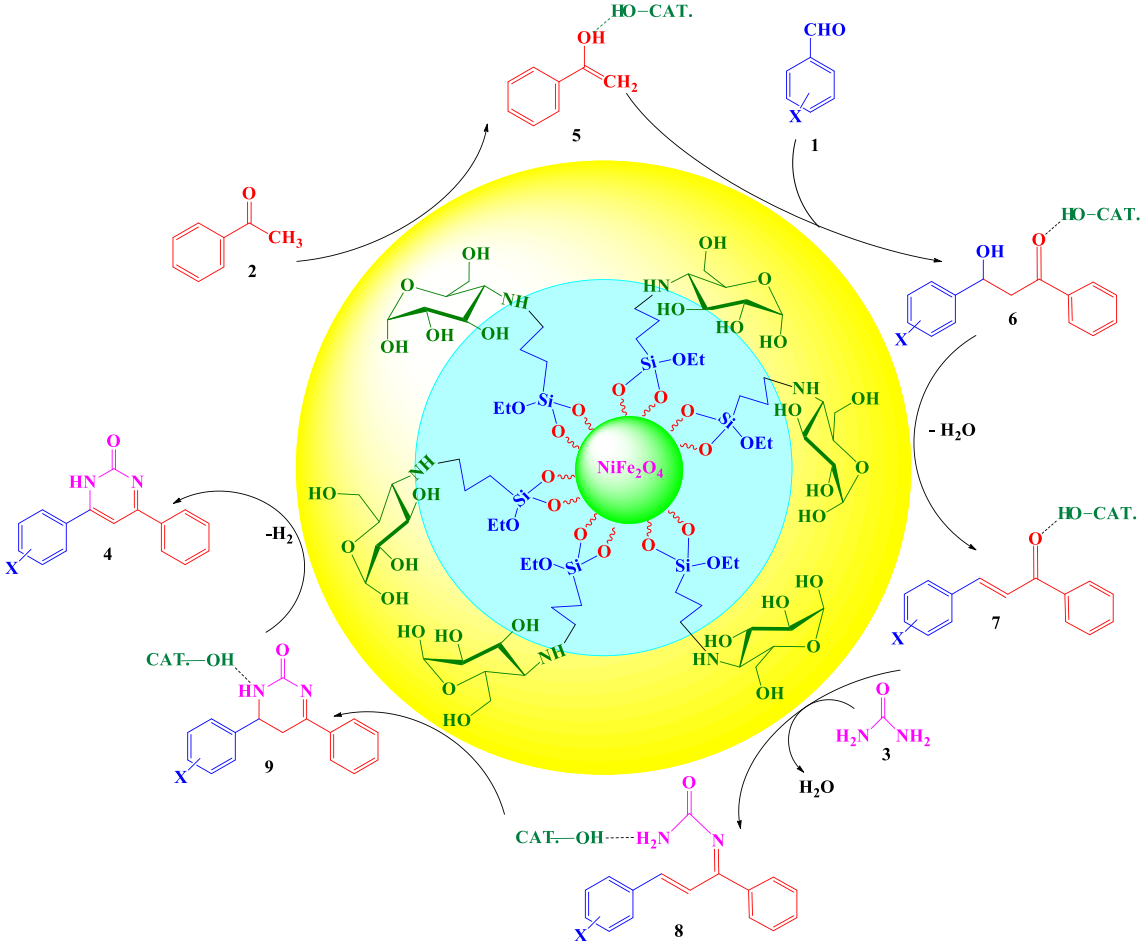
Entry	Product	Structure	Time (min)	Yield (%)[a,b]	Observed Melting Point (°C)	Reported Melting Point (°C)
6	**4f**		90	93	250–252	–
7	**4g**		120	87	> 300	–
8	**4h**		120	91	284–286	287–290 (Heravi et al., 2008)
9	**4i**		90	96	243–245	–
10	**4j**		180	90	289–291	287–288 (Heravi et al., 2008)
11	**4k**		180	89	295–297	–
12	**4l**		180	90	259–261	–
13	**4m**		120	92	253–255	258–260 (Heravi et al., 2008)
14	**4n**		120	90	233–245	238–242 (Pourghobadi and Derikvand, 2010)
15	**4o**		120	93	> 300	–
16	**4p**		90	94	> 300	–
17	**4q**		90	95	> 300	–

Table 3 (*continued*)

Entry	Product	Structure	Time (min)	Yield (%)[a,b]	Observed Melting Point (℃)	Reported Melting Point (℃)
18	**4r**		90	96	> 300	–
19	**4s**		120	95	> 300	–

[a] Yields based upon the starting aldehydes.
[b] Reaction conditions: aldehydes **1a-n** or **5a-e** (1 mmol), acetophenone **2** (1 mmol), urea **3** (1 mmol) $NiFe_2O_4$@SiO_2^{n}Pr@glucose amine (0.1 g) in H_2O (10 mL) were used.



Scheme 2 Proposed mechanism for synthesis of 4,6-bisarylpyrimidin-2(1*H*)-ones.

Table 4 Reusability of catalyst in the synthesis of **4a.**

Run	1	2	3	4	5	6	7
Yield (%)	94	94	92	93	93	92	83
Time (min)	120	120	120	120	120	120	300
Mp (℃)	215–217	215–217	213–215	214–216	212–214	215–217	211–213

decreased only slightly after reusing the catalyst six times (Table 4).

4. Conclusions

In conclusion, we have investigated $NiFe_2O_4$@SiO_2^{n}Pr@glucose amine as a new, eco-friendly, inexpensive, mild and reusable catalyst for the synthesis of 4,6-bisarylpyrimidin-2(1*H*)-ones and novel azo-linked 4-arylpyrimidin-2(1*H*)-ones at room temperature (25 ℃). High yield, a simple work-up procedure, ease of separation and recyclability of the magnetic catalyst, adherence to the basics of green chemistry, eco-friendly and based on natural ingredients and waste reduction are some advantages of this method.

Acknowledgements

Financial support from the Research Council of Islamic Azad University, Rasht Branch is sincerely acknowledged.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.arabjc.2020.10.022.

References

Kumar, K.S., Kanth, V.A., Reddy, K.T., Omprakash, G., 2011. Chem. Pharm. Res. 3, 234–252.
Pothiraj, C., Velan, A.S., Joseph, J., Raman, N., 2008. Soc. Mycology 36, 66–69.
Kappe, C.O., Fabian, W.M., 1997. Tetrahedron 53, 2803–2816.
Overman, L.E., Rabinowitz, M.H., Renhowe, P.A., 1995. J. Am. Chem. Soc. 117, 2657–2658.
Chaudhari, P.K., Shah, V.H., 2011. Adv. Dev. Res. 2, 54–63.
K. Deres, C.H. Schroeder, A. Paessens, S. Goldmann, H.J. Hacker, O. Weber, T. Kramer,. U. Niewoehner, U. Pleiss, J. Stoltefuss, E. Graef, D. Koletzki, R.N.A. Masantschek, A. Reimann, R. Jaeger, R. Grob, B. Beckermann, K.H. Schlemmer, D. Haebich, H.R. Waigmann, Science 299 (2003) 893-896.
Couto, I., Tellitu, I., Dominguez, E., 2011. Arkivoc., 115–126
Duguay, D.R., Zamora, M.T., Blacquiere, J.M., Appoh, F.E., Vogels, C.M., Wheaton, S.L., Baerlocher, F.J., Decken, A., Westcott, S.A., 2008. Cent. Eur. J. Chem. 6, 562–568.
Mondal, J., Sen, T., Bhaumik, A., 2012. Dalton Trans. 41, 6173–6181.
Nasr-Esfahani, M., Hosieni, J., Mohammadi, F., 2011. Chin. J. Catal. 32, 1484–1489.
Rad, A.M., Mokhtary, M., 2015. Int Nano Lett 5, 109–123.
Ebraheem, H.A., 2012. Rafidain j S 24, 120–127.
M.M. Heravi, S. sadjadi, H.A. Oskooie, R. Hekmat shoar, F.F. Bamoharram, Tetrahedron Lett, 50 (2009) 662-666.
Zhu, J., Bienayme, H., 2005. WILEY-VCH Verlag GmbH & Co KGaA, Weinheim. 110, 1581–1587.
Rakhi, C., Ramesh, K., Darbem, M.P., Branquinho, T.A., Oliveira, A. R.D., Manjari, P.S., Domingues, N.L.C., 2016. Tetrahedron Lett. 57, 1656–1660.
X.S. Wang, Zh.s. Zeng, D.Q. Shi, X.y. Wei, Zh.m. ZonS, Synth. commun, 34 (2004) 4331-4338.
Abaszadeh, M., Seifi, M., 2017. Iran. J. Chem. Chem. Eng. 36, 35–43.
Bigi, F., Carloni, S., Frullanti, B., Maggi, R., Sartori, G., 1999. Tetrahedron Lett. 40, 3465.
Rani, V.R., Srinivas, N., Kishan, M.R., Kulkarni, S.J., Raghavan, K. V., 2001. Green Chem.. 3, 305–306.
Yadav, J.S., Reddy, B.V.S., Reddy, E.J., Ramalingam, T., 2000. J. Chem. Res., 354–355
Yadav, J.S., Reddy, B.V.S., Sridhar, P., Reddy, J.S.S., Nagaiah, K., Lingaiah, N., Saiprasad, P.S., 2004. Eur. J. Org. Chem. 3, 552–557.
Salehi, P., Dabiri, M., Zolfigol, M.A., Fard, M.A.B., 2003. Tetrahedron Lett. 44, 2889–2891.
Martinez, S., Meseguer, M., Casas, L., Rodriguez, E., Molins, E., Moreno-Manas, M., Roig, A., Sebastian, R.M., Vallribera, A., 2003. Tetrahedron 59, 1553–1556.
Li, J.T., Yin, Y., Sun, M.X., 2010. Ultrason. Sonochem. 17, 363–1266.
Aghazadeh, B., Nikpassand, M., 2019. Carbohy. Res. 483, 107755.
Zare Fekri, L., Nikpassand, M., Nazari Khakshoor, S., 2019. J. Organomet. Chem. 894, 18–27.
Nikpassand, M., 2020. Dyes Pigm. 173, 107936.
Nikpassand, M., Farokhian, P., 2016. Ultrason. Sonochem. 28, 341–345.
Nikpassand, M., Pirdelzendeh, D., 2016. Dyes Pigm. 130, 314–318.
M. Nikpassand, L. Zare Fekri, L. Karimian, M. Rassa, Curr. Org. Synth. 12 (2015) 358-362.
Nikpassand, M., Zare Fekri, L., Sanagou, S., 2017. Dyes Pigm. 136, 140–144.
Nikpassand, M., Zare Fekri, L., Pourahmad, A., 2018. J. CO_2 Util. 27, 320–325.
Heravi, M.M., Ranjbar, L., Derikvand, F., Alimadadi, B., 2008. Mol. Div. 12, 191–196.
Pourghobadi, Z., Derikvand, F., 2010. Chin. Chem. Lett. 21, 269–272.