Research Article

Synthesis of 2,3-dihydroquinazolinones using nano-ovalbumin as a non-toxic biocatalyst

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Abstract
Bio-catalysts are non-toxic, metal-free, abundant, and efficient materials with less waste generation that decrease the environmental pollution. Nano-ovalbumin is a biodegradable phosphoglyco protein with isoelectric point (pI) of 4.5, molecular weight of 44.5 kDa containing 385 residues of amino acids. Nano-ovalbumin can be used as a non-toxic heterogeneous and eco-friendly catalyst for promotion of organic compounds. Quinazolinones have many biological and medicinal activities such as anticonvulsant, antitumor, anticancer, hypnotic/sedatives, antimalarial, antibacterial, antioxidant, antimicrobial, antifungal, cytotoxic, antiproliferative, and inhibitory activities on α-glucosidase. In this research, nano-ovalbumin was ready by a new, easy, inexpensive and convenient protocol from egg white and used as a heterogeneous biocatalyst in the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones via two-component reaction of 2-aminobenzamide with aldehyde or ketone. This eco-friendly catalyst carried out the reaction in green conditions and with good to excellent yields. The structure of products were determined by Fourier Transform-Infrared (FT-IR), ^{1}H-Nuclear Magnetic Resonance (^{1}H-NMR) and their physical properties were compared with those reported in others work.

Keywords Nano-biocatalyst · 2,3-Dihydroquinazolinone · Eco-friendly catalyst · Nano-ovalbumin

1 Introduction

2,3-Dihydroquinazolin-4(1*H*)-ones are a significant class of heterocyclic compounds that form vary useful moiety of pharmaceutical, agricultural chemical and veterinary products [1, 2]. Quinazolinone and its derivatives have many biological and medicinal activities such as anticonvulsant [3], antitumor [4], anticancer [5], hypnotic/sedatives [6], antimalarial [7], antibacterial and antioxidant [8], antimicrobial [9], antifungal and cytotoxic [10], antiproliferative [11], and inhibitory activities on α-glucosidase [12]. Several examples of marketed drugs with the 2,3-dihydroquinozolinones (DHQ) framework are shown in Fig. 1. Several methods have been published for the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones including the two-component reaction of 2-aminobenzamide with aldehyde or ketone and the three-component reaction of isatoic anhydride, aldehydes, and amines, or ammonium acetate [13].

This reaction has been catalyzed by different catalysts including (MNPs-PSA) [14], Wang-OSO_3H [15], 2-morpholinoethanesulfonic acid [16], nanometasilica disulfuric acid (NMSDSA) [17], $CuCl_2$/Fe_3O_4-TEDETA [18], [Bmim]PF_6 [19], nano-Fe_3O_4/$TiCl_2$/cellulose [20], tetrabutylammonium-bromide (TBAB) [21], ammonium chloride [22], NH_2SO_3H and MCM-41@serine@Cu(II) [23]. However, some of these methods have disadvantages such as the use of costly reagents or toxic organic solvents, difficulty in preparation

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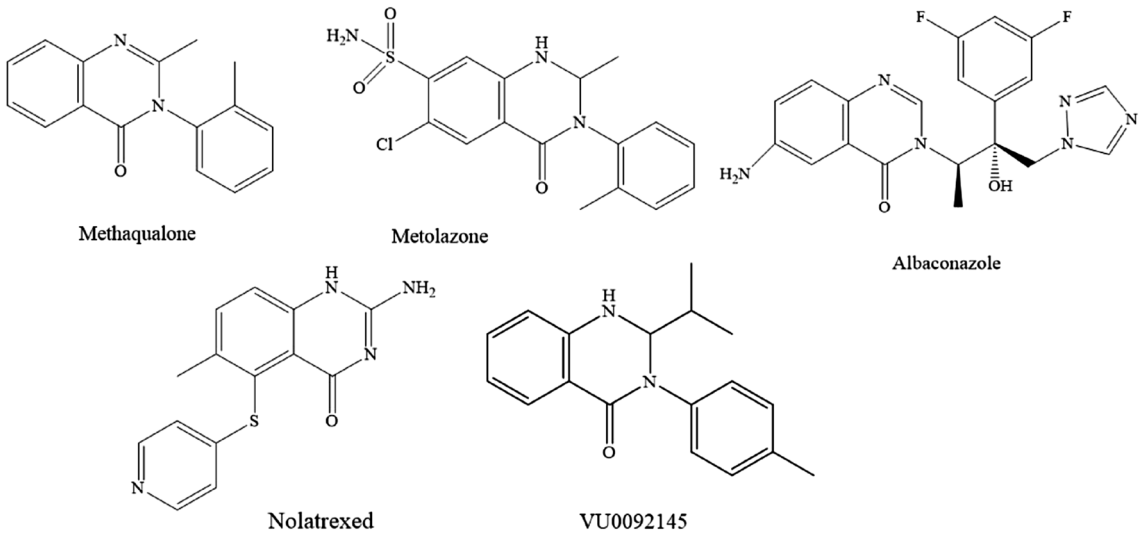


Fig. 1 Some important DHQs in marketed drugs

and/or storage of catalysts, tedious work-up and separation of catalyst from the products.

In recent decades, application of biocatalysts in organic synthesis has attracted more attention. Bio-catalysts are non-toxic, metal-free, abundant, and efficient materials with less waste generation that decrease the environmental pollution. Albumin as the major component of egg white is a phosphoglyco protein that has attracted considerable attention from the early twentieth-century. 9.7–12% of egg white is protein that 54% of it is ovalbumin. The isoelectric point (pI) of this protein is 4.5 and it contains 385 residues of amino acids with the molecular weight of 44.5 kDa [24].

Several methods have been proposed for the purification of this proteins, including gel penetration and anion exchange chromatography [25], Q Sepharose fast flow column [26], using polyethylene glycol precipitation and isoelectric precipitation [27]. In continuation of our works about application of heterogeneous catalysts in organic synthesis [28–30], In this research, nano-ovalbumin was ready by a new, easy, inexpensive and convenient protocol from egg white [31, 32] and used as a heterogeneous biocatalyst in the synthesis of 2,3-dihydroquinazolinones.

2 Experimental materials and methods

The chemical compounds were acquired from Merck, Aldrich, and Fluka chemical companies and were used without additional purification. 2-Aminobenzamide was prepared from Merck Company. All used aldehydes were previously prepared from Merck, Aldrich or Fluka Companies. Nano-ovalbumin was prepared from egg white according to reported procedure from our research team [31, 32]. The products were determined by FT-IR, 1H-NMR and their physical properties were compared with those reported in the other work. Fourier transform infrared (FT-IR) spectra were run on a Bruker, Equinox 55 spectrometer. A Bruker (DRX-400 Avance) nuclear magnetic resonance (NMR) was used to record the ^{1}H-NMR spectra. Melting points were determined by a Buchi melting point B-540 B.V.CHI apparatus and were uncorrected.

2.1 General procedure for the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones in the presence of nano-ovalbumin

In a 25-mL round bottom flask, nano-ovalbumin (0.2 g) was added to a solution of 2-aminobenzamide (1 mmol) and aldehyde (1.25 mmol) in 5 mL of EtOH: H_2O (2:1) and the mixture was refluxed for an appropriate time. After monitoring the reaction by TLC (Ethyl acetate: *n*-Hexane, 1:4) and completing, ethanol (5 mL) was added to the mixture for separating the catalyst from the product. Then, water (10 mL) was added to the filtrate and the solid products were appeared. The obtained products were filtered and washed with water (2 × 5 mL) and dried at room temperature.

3 Results and Discussion

The catalytic activity of nano-ovalbumin was evaluated in the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones under different conditions. For optimization of the conditions, the model reaction between 2-aminobenzamide

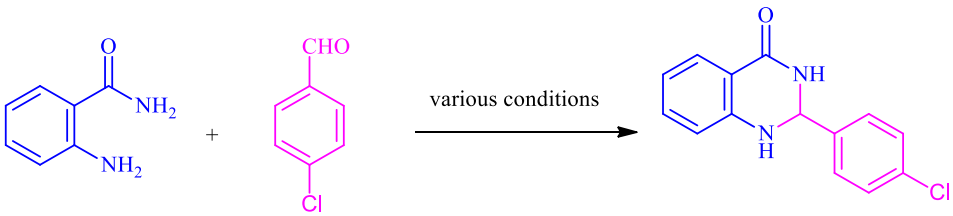
(anthranilamide; 1 mmol) and 4-chlorobenzaldehyde (1.25 mmol) was selected. The best condition was using 0.2 g of nano-ovalbumin under reflux (Ethanol/H_2O (2:1)) condition (Table 1, entry 12).

The catalytic activity of nano-ovalbumin was investigated in the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones by the reaction of various types of aldehydes with anthranilamide (Table 2). Checking different aldehydes with electron-donating or electron-withdrawing groups under optimized conditions showed good reactivity of the catalyst due to high yields without any side products (Table 2, entries 2–11).

In addition of aldehydes, we have also applied ketones for production of 2,3-dihydroquinazolin-4(1*H*)-ones. If we have applied cyclic ketones such as cyclohexanone or cyclopentanone, the product 2,3-dihydroquinazolin-4(1*H*)-ones with spiro skeletone have been formed (Scheme 1, Table 3).

A presumed mechanism for the preparation of 2,3-dihydroquinazolin-4(1*H*)-one corresponding to the

Table 1 Optimization of the reaction conditions for the synthesis of 2-(4-chlorophenyl)-2,3-dihydroquinazolin-4(1*H*)-one.



Ent	Solvent	Catalyst (g)	Conditions	Time (h)	Yield (%)[a]	Ref
1	–	Nano-ovalbumin (0.2)	r.t	2	_	–
2	–	Nano-ovalbumin (0.2)	80 °C	2	30	–
3	EtOH	Nano-ovalbumin (0.1)	Ultrasound	0.5	_	–
4	–	Nano-ovalbumin (0.1)	Ball-mill	0.6	_	–
5	–	Nano-ovalbumin (0.1)	Microwave	0.6	80	–
6	PEG-400	Nano-ovalbumin (0.1)	Microwave	0.75	85	–
7	PEG-400	Nano-ovalbumin (0.1)	100 °C	5	50	–
8	–	Nano-ovalbumin (0.1)	Grinding	0.75	50	–
9	H_2O	Nano-ovalbumin (0.2)	Reflux	3.5	50	–
10	EtOH	Nano-ovalbumin (0.2)	Reflux	3.5	85	–
11	EtOH:H_2O[b]	Nano-ovalbumin (0.2)	Reflux	3.5	92	–
12	EtOH:H_2O[c]	Nano-ovalbumin (0.2)	Reflux	1.5	96	–
13	EtOH:H_2O[c]	Nano-ovalbumin (0.1)	Reflux	3	78	–
14	EtOH:H_2O[c]	Nano-ovalbumin (0.05)	Reflux	5	65	–
15	EtOH:H_2O[c]	_	Reflux	3	50	–
16	EtOH	_	Reflux	3	45	
17	H_2O	_	Reflux	3	30	
18	H_2O	MNPs-PSA[d]	70 °C	0.4	90	[14]
19	EtOH:H_2O	MES[e]	60 °C	2	89	[16]
20	EtOH	$CuCl_2/Fe_3O_4$	Reflux	0.75	98	[18]
21	_	[Bmim]PF_6	75 °C	0.6	90	[19]
22	_	TBAB[f]	100 °C	1	75	[21]
23	H_2O	NH_2SO_3H	70 °C	0.58	89	[23]
24	H_2O	Wang-OSO_3H	100 °C	0.4	84	[15]

[a]Isolated yield

[b]Ratio 1:1

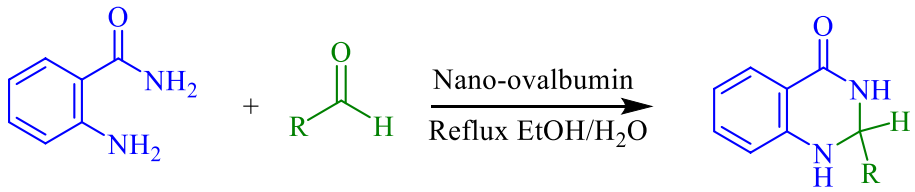
[c]Ratio 2:1

[d]*N*-Propylsulfamic acid supported on magnetic Fe_3O_4 nanoparticles

[e]2-Morpholinoethanesulfonic acid

[f]Tetrabutylammonium bromide

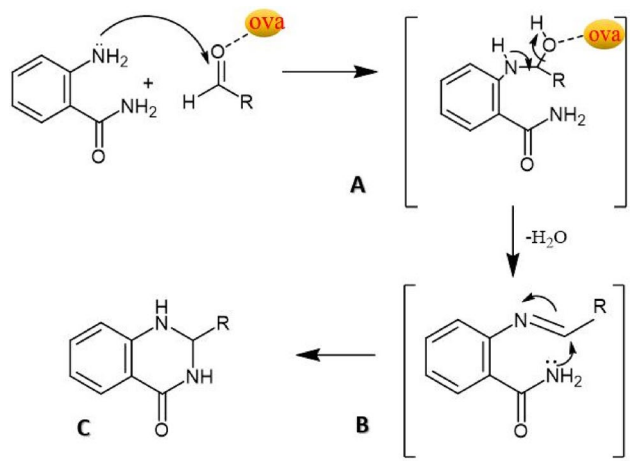
Table 2 Synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones catalyzed by nano-ovalbumin



Entry	R	Time (h)	Yield (%)[a]	M.P. (°C) Found	M.P. (°C) Reported [Ref.]
1	Ph	0.75	89	208–210	216–218 [22]
2	4-NO_2-Ph	1.5	94	202–207	200–202 [33]
3	4-Cl-Ph	1.5	96	214–216	214–216 [34]
4	4-Isopropyl-Ph	3.5	67	155–160	158–161 [20]
5	3-NO_2-Ph	1.5	89	190–193	193–195 [20]
6	2-NO_2-Ph	2	87	190–192	191–192 [35]
7	2-Cl-Ph	1	90	207–209	206–208 [36]
8	2,4-Cl_2-Ph	2	88	167–170	166–169 [20]
9	2,4-$(MeO)_2$-Ph	3	67	185–187	185–187 [37]
10	3-OMe-4-OH	1.25	60	225–230	238–240 [38]
11	4-(Me_2N)-Ph	1	84	197–202	208–210 [16]
12	*n*-Pentyl	1.5	77	152–155	154 [39]
13	Cyclohexyl	1	88	173–176	174–175 [40]

Reaction conditions: 2-aminobenzamide (1.0 mmol), aldehyde (1.25 mmol) and nano-ovalbumin (0.2 g)

[a]Isolated yield



Scheme 1 Presumed mechanism of the cyclocondensation of anthranilamide and an aldehyde

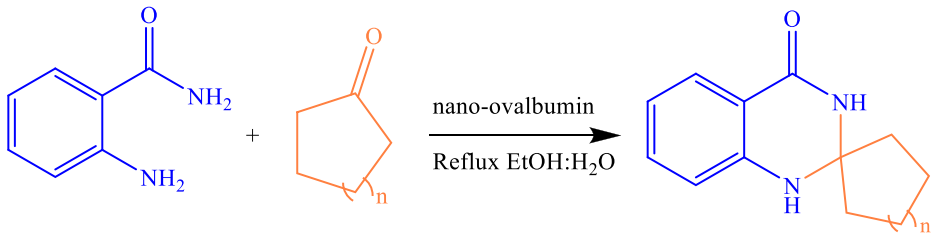
condensation of anthranilamide and an aldehyde in the presence of nano-ovalbumin was shown in scheme. Initially, the nucleophilic attack of the nitrogen of the amino group of the anthranilamide on the carbonyl carbon of the aldehyde, promoted by the catalyst, results in the formation of hydroxyl intermediate **A**. Next, the catalyst promotes the formation of the Schiff base **B** from **A** through the removal of a water molecule. Finally, the imine undergoes intramolecular cyclization by nucleophilic attack of the nitrogen of the amide group on the imine carbon to furnish the corresponding final product **C**.

The reusability of the catalyst as an important issue was also investigated. Nano-ovalbumin was recovered conveniently and efficiently from the reaction mixture by filtration, washing with water (5 mL) and acetone (5 mL) and then drying at room temperature. It was observed that the recovered biocatalyst could be used at four times without significant loss of activity (Fig. 2).

4 Conclusion

An efficient and environmentally benign method has been developed for the synthesis of 2,3-dihydroquinazolin-4(1*H*)-ones in the presence of a catalytic amount of nano-ovalbumin in ethanol/H_2O under reflux condition. Egg white nano-ovalbumin as an environmentally benign biocatalyst was prepared from egg white by a simple protocol. Simple separation of catalyst, reusability of eco-friendly metal-free biocatalyst and excellent yields are advantages of this protocol.

Table 3 Synthesis of spiro-2,3-dihydroquinazolin-4(1*H*)-ones catalyzed by nano-ovalbumin



Entry	n	Time (h)	Yield (%)	M.P. (°C) Found	M.P. (°C) Reported [Ref.]
1	1	1.5	93	270–275	258–259 [41]
2	2	1	90	227–230	220–221 [41]

Reaction conditions: 2-aminobenzamide (1.0 mmol), ketone (1.25 mmol) and nano-ovalbumin (0.2 g)

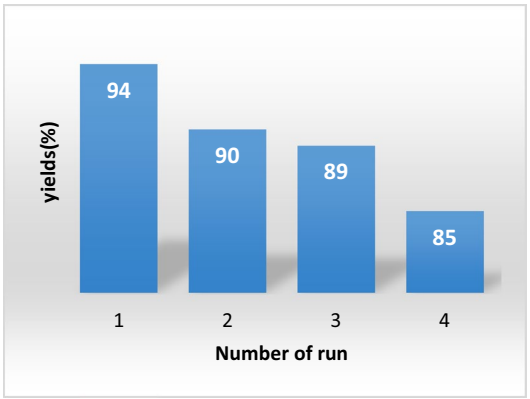


Fig. 2 Recyclability of the catalyst

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Compliance with ethical standards

Conflict of interestConflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Connolly DJ, Cusack D, O'Sullivan TP, Guiry PJ (2005) Synthesis of quinazolinones and quinazolines. Tetrahedron 61:10153–10202. https://doi.org/10.1016/j.tet.2005.07.010
2. Kshirsagar U (2015) Recent developments in the chemistry of quinazolinone alkaloids. Org Biomol Chem 13:9336–9352. https://doi.org/10.1039/C5OB01379H
3. Wolfe JF, Rathman TL, Sleevi MC, Campbell JA, Greenwood TD (1990) Synthesis and anticonvulsant activity of some new 2-substituted 3-aryl-4 (3*H*)-quinazolinones. J Med Chem 33:161–166. https://doi.org/10.1021/jm00163a027
4. Roopan SM, Khan FN, Jin JS, Kumar RS (2011) An efficient one pot–three component cyclocondensation in the synthesis of 2-(2-chloroquinolin-3-yl)-2,3-dihydroquinazolin-4 (1*H*)-ones: potential antitumor agents. Res Chem Intermed 37:919. https://doi.org/10.1007/s11164-011-0301-3
5. Kamal A, Bharathi EV, Reddy JS, Ramaiah MJ, Dastagiri D, Reddy MK, Viswanath A, Reddy TL, Shaik TB, Pushpavalli S (2011) Synthesis and biological evaluation of 3, 5-diaryl isoxazoline/isoxazole linked 2,3-dihydroquinazolinone hybrids as anticancer agents. Eur J Med Chem 46:691–703. https://doi.org/10.1016/j.ejmech.2010.12.004
6. Abdel-Alim A-AM, El-Shorbagi A-NA, El-Gendy MA, El-Shareif HA (1993) Quinazolinone Derivatives of Biological Interest V. Novel 4 (3H)-quinazolinones with sedative-hypnotic, anticonvulsant and antiinflammatory activities. Coll Czech (CC) 58:1963–1968. https://doi.org/10.1135/cccc19931963
7. Bathini PK, Yerrabelly H, Yerrabelly JR (2018) Synthesis and antimicrobial/anti-malarial activity of a new class of chromone-dihydroquinazolinone hybrid heterocycles. J. Org. Chem. 3:212–228. https://doi.org/10.24820/ark.5550190.p010.348
8. Salehi P, Ayyari M, Bararjanian M, Ebrahimi SN, Aliahmadi A (2014) Synthesis, antibacterial and antioxidant activity of novel 2,3-dihydroquinazolin-4 (1*H*)-one derivatives of dehydroabietylamine diterpene. J Iran Chem Soc 11:607–613. https://doi.org/10.1007/s13738-013-0330-5
9. Khodarahmi G, Jafari E, Hakimelahi G, Abedi D, Khajouei MR, Hassanzadeh F (2012) Synthesis of some new quinazolinone derivatives and evaluation of their antimicrobial activities. Iranian J Pharm Res 11:789–797
10. Khodarahmi G, Khajouei MR, Hakimelahi G, Abedi D, Jafari E, Hassanzadeh F (2012) Antibacterial, antifungal and cytotoxic evaluation of some new 2,3-disubstituted 4 (3H)-quinazolinone derivatives. Res Pharm Sci 7:151–158
11. Deshmukh SU, Kharat KR, Kadam GG, Pawar RP (2017) Synthesis of quinazolinones derivatives an antiproliferative agent against human lung carcinoma cells. Chem Eur J 8:317–320. https://doi.org/10.5155/eurjchem.8.3.317-320.1586
12. Wei M, Chai W-M, Wang R, Yang Q, Deng Z, Peng Y (2017) Quinazolinone derivatives: synthesis and comparison of inhibitory mechanisms on α-glucosidase. Bioorg Med Chem 25:1303–1308. https://doi.org/10.1016/j.bmc.2016.09.042
13. Beyki M, Fallah-Mehrjardi M (2018) Silica sulfuric acid-coated Fe_3O_4 nanoparticles as a highly efficient and reusable solid acid catalyst for the green synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones under solvent-free conditions. Lett Org Chem 15:39–44. https://doi.org/10.2174/1570178614666170711144740

14. Rostami A, Tahmasbi B, Gholami H, Taymorian H (2013) Supported N-propylsulfamic acid on magnetic nanoparticles used as recoverable and recyclable catalyst for the synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones in water. Chin Chem Lett 2:211–214. https://doi.org/10.1016/j.cclet.2013.01.032
15. Rao AD, Vykunteswararao B, Bhaskarkumar T, Jogdand NR, Kalita D, Lilakar JKD, Siddaiah V, Sanasi PD, Raghunadh A (2015) Sulfonic acid functionalized Wang resin (Wang-OSO_3H) as polymeric acidic catalyst for the eco-friendly synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones. Tetrahedron Lett 56:4714–4717. https://doi.org/10.1016/j.tetlet.2015.06.004
16. Labade VB, Shinde PV, Shingare MS (2013) A facile and rapid access towards the synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones. Tetrahedron Lett 54:5778–5780. https://doi.org/10.1016/j.tetlet.2013.08.037
17. Zolfigol MA, Ghaderi H, Baghery S, Mohammadi L (2017) Nanometasilica disulfuric acid (NMSDSA) and nanometasilica monosulfuric acid sodium salt (NMSMSA) as two novel nanostructured catalysts: applications in the synthesis of Biginelli-type, polyhydroquinoline and 2,3-dihydroquinazolin-4 (1H)-one derivatives. J Iran Chem Soc 14:121–134. https://doi.org/10.1007/s13738-016-0964-1
18. Ghorbani-Choghamarani A, Norouzi M (2014) Synthesis of copper (II)-supported magnetic nanoparticle and study of its catalytic activity for the synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones. J Mol Catal A Chem 395:172–179. https://doi.org/10.1016/j.molcata.2014.08.013
19. Chen J, Su W, Wu H, Liu M, Jin C (2007) Eco-friendly synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones in ionic liquids or ionic liquid–water without additional catalyst. Green Chem 9:972–975. https://doi.org/10.1039/B700957G
20. Mirjalili BBF, Bamoniri A, Azad S (2017) Synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones catalyzed by nano-Fe_3O_4/$TiCl_2$/cellulose as a bio-based magnetic catalyst. J Iran Chem Soc 14:47–55. https://doi.org/10.1007/s13738-016-0956-1
21. Davoodnia A, Allameh S, Fakhari A, Tavakoli-Hoseini N (2010) Highly efficient solvent-free synthesis of quinazolin-4 (3H)-ones and 2,3-dihydroquinazolin-4 (1*H*)-ones using tetrabutylammonium bromide as novel ionic liquid catalyst. Chin Chem Lett 21:550–553. https://doi.org/10.1016/j.cclet.2010.01.032
22. Shaabani A, Maleki A, Mofakham H (2008) Click Reaction: highly efficient synthesis of 2,3-dihydroquinazolin-4 (1 H)-ones. Synth Commun 38:3751–3759. https://doi.org/10.1080/00397910802213802
23. Rostami A, Tavakoli A (2011) Sulfamic acid as a reusable and green catalyst for efficient and simple synthesis of 2-substituted-2,3-dihydroquinazolin-4 (1*H*)-ones in water or methanol. Chin Chem Lett 22:1317–1320. https://doi.org/10.1016/j.cclet.2011.06.008
24. Alleoni ACC (2006) Albumen protein and functional properties of gelation and foaming. Sci Agric 63:291–298. https://doi.org/10.1590/S0103-90162006000300013
25. Tankrathok A, Daduang S, Patramanon R, Araki T, Thammasirirak S (2009) Purification process for the preparation and characterizations of hen egg white ovalbumin, lysozyme, ovotransferrin, and ovomucoid. Prep Biochem Biotechnol 39:380–399. https://doi.org/10.1080/10826060903209646
26. Akazawa T, Ogawa M, Hayakawa S, Hirata M, Niwa T (2018) Structural change of ovalbumin-related protein X by alkali treatment. Poult Sci J 97:1730–1737. https://doi.org/10.3382/ps/pey024
27. Geng F, Xie Y, Wang J, Li S, Jin Y, Ma M (2018) Large-scale purification of ovalbumin using polyethylene glycol precipitation and isoelectric precipitation. Poult Sci J 98:1545–1550. https://doi.org/10.3382/ps/pey402
28. Mirjalili BF, Hashemi MM, Sadeghi B, Emtiazi H (2009) $SnCl_4$/SiO_2: an efficient heterogeneous alternative for one-pot synthesis of β-acetamidoketones. J Chin Chem Soc 56:386–391. https://doi.org/10.1590/S0103-50532005000500031
29. Mirjalili BF, Zolfigol MA, Bamoniri A, Hazar A (2005) Al $(HSO_4)_3$ as an efficient catalyst for acetalization of carbonyl compounds under heterogeneous or solvent-free conditions. J Braz Chem Soc 16:877–880. https://doi.org/10.1002/jccs.200900056
30. Mirjalili BF, Zolfigol MA, Bamoniri A, Sheikhan N (2006) Solvent-free preparation of 1, 1-diacetates from aldehydes mediated by zirconium hydrogen sulfate at room temperature. J Chin Chem Soc 53:955–959. https://doi.org/10.1002/jccs.200600127
31. Salehi N, Mirjalili BBF (2018) Nano-ovalbumin: a green biocatalyst for biomimetic synthesis of tetrahydrodipyrazolo pyridines in water. Res Chem Intermed 44:7065–7077. https://doi.org/10.1007/s11164-018-3542-6
32. Salehi N, Mirjalili BF (2018) Biomimetic synthesis of 1-aryl-2, 5-dimethyl pyrroles using egg white nano-ovalbumin at room temperature under solvent-free conditions. Iran J Catal 9:185–192
33. Bharate SB, Mupparapu N, Manda S, Bharate JB, Mudududdla R, Yadav RR, Vishwakarma RA (2012) Efficient synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones using heterogeneous solid acid catalysts: unexpected formation of. Arkivoc 8:308–318. https://doi.org/10.3998/ark.5550190.0013.826
34. Fakhri A, Naghipour A, Ghasemi ZH (2018) Catalytic performance of tannic acid-SO_3H supported on Fe_3O_4@SiO_2 nanoparticles for synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones. Solid State Sci 83:107–114. https://doi.org/10.1016/j.solidstatesciences.2018.07.010
35. Nikoorazm M, Ghorbani-Choghamarani A, Khanmoradi M (2017) Synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones, disulfides and sulfoxides catalyzed by a zinc complex immobilized onto functionalized mesoporous MCM-41 as a mild and efficient catalyst. J Iran Chem Soc 14:1215–1225. https://doi.org/10.1007/s13738-017-1072-6
36. Jazinizadeh T, Maghsoodlou MT, Heydari R (2018) Synthesis of 2-aryl-2,3-dihydroquinazolin-4 (1H)-one derivatives using lactic acid as a green, natural and inexpensive catalyst in water. J. Sci. Technol Trans A Sci 42:1929–1933. https://doi.org/10.1007/s40995-017-0362-2
37. Dabiri M, Salehi P, Baghbanzadeh M, Zolfigol MA, Agheb M, Heydari S (2008) Silica sulfuric acid: an efficient reusable heterogeneous catalyst for the synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones in water and under solvent-free conditions. Catal Commun 9:785–788. https://doi.org/10.1016/j.catcom.2007.08.019
38. Zhang J, Ren D, Ma Y, Wang W, Wu H (2014) CuO nanoparticles catalyzed simple and efficient synthesis of 2,3-dihydroquinazolin-4 (1*H*)-ones and quinazolin-4 (3H)-ones under ultrasound irradiation in aqueous ethanol under ultrasound irradiation in aqueous ethanol. Tetrahedron 70:5274–5282. https://doi.org/10.1016/j.tet.2014.05.059
39. Prakash M, Jayakumar S, Kesavan V (2013) Investigation of the enantioselective synthesis of 2,3-dihydroquinazolinones using Sc (III)–inda-pybox. Synthesis 45:2265–2272. https://doi.org/10.1055/s-0033-1339288
40. Khatri CK, Patil MS, Chaturbhuj GU (2017) Sulfated polyborate: mild, efficient and eco-friendly catalyst for the synthesis of 2,3-dihydroquinazolin-4 (1H)-ones. J Iran Chem Soc 14:1683–1689. https://doi.org/10.1007/s13738-017-1109-x
41. Wu J, Du X, Ma J, Zhang Y, Shi Q, Luo L, Song B, Yang S, Hu D (2014) Preparation of 2,3-dihydroquinazolin-4 (1*H*)-one derivatives in aqueous media with β-cyclodextrin-SO_3H as a recyclable catalyst. Green Chem 16:3210–3217. https://doi.org/10.1039/C3GC42400F