Ultrasonics Sonochemistry 19 (2012) 1033–1038

Contents lists available at SciVerse ScienceDirect

Ultrasonics Sonochemistry

journal homepage: www.elsevier.com/locate/ultsonch

Synthesis of 2-(1,5-diaryl-1,4-pentadien-3-ylidene)-hydrazinecarboximidamide hydrochloride catalyzed by *p*-dodecylbenzenesulfonic acid in aqueous media under ultrasound irradiation

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ARTICLE INFO

Article history:
Received 31 August 2011
Received in revised form 8 February 2012
Accepted 24 February 2012
Available online 3 March 2012

Keywords:
1,5-Diaryl-1,4-pentadien-3-one
amidinohydrazone hydrochloride
Synthesis
Ultrasound irradiation
Condensation
Aqueous media

ABSTRACT

Amidinohydrazone compounds are very important synthetic intermediates and can serve as versatile precursors in synthesis of many natural products and drug molecules. The use of ultrasound, *p*-dodecylbenzenesulfonic acid (DBSA) and water as solvent improved the synthesis of different 2-(1,5-diaryl-1,4-pentadien-3-ylidene)-hydrazinecarboximidamide hydrochlorides. The best reaction conditions for the condensation of 1,5-diphenyl-1,4-pentadien-3-one with aminoguanidine hydrochloride were as follows: 1,5-diphenyl-1,4-pentadiene-3-one (1, 1 mmol), aminoguanidine hydrochloride (1.1 mmol), DBSA (0.5 mmol), water 10 mL, reaction temperature 25–27 °C, irradiation frequency 25 kHz. 2a was achieved in 94% yield within 2 h. The other seven amidinohydrazones were obtained in 84–94% yield within 2–3 h under the same conditions. Compared to the method involving catalysis by hydrochloric acid in refluxing EtOH, the advantages of present procedure are milder conditions, shorter reaction times, higher yields, and environmental friendly conditions, which make it a useful strategy for the synthesis of analogues.

1. Introduction

Amidinohydrazone compounds are very important synthetic intermediates and can serve as versatile precursors in synthesis of many natural products and drug molecules [1–5]. These compounds are useful as insecticidal agents [6,7], and anti-tubercular and anti-malarial agents in warm-blooded animals [8,9].

In general, amidinohydrazones are synthesized *via* the condensation of 1,5-diaryl-1,4-pentadien-3-one with aminoguanidine hydrochloride, with water as a by product. The reaction involves nucleophilic addition of aminoguanidine to the carbonyl, followed by elimination of water. Acid catalysis can aid the reaction [10]. Tomcufcik et al. reported that the synthesis of the title compound was carried out in 40–70% yield under refluxing EtOH *via* the condensation of bischalcone with aminoguanidine hydrochloride catalyzed by hydrochloric acid (classical method) [6]. The method suffers from drawbacks such as a longer reaction time (4–16 h), lower yields, and the use of organic solvent. Therefore, the development of simple, efficient and green methodology for the preparation of amidinohydrazone is still desirable.

Organic reactions in aqueous media have currently attracted increasing interest because of environmental issues and the understanding of biochemical processes. Water is an inexpensive, abundant, non-toxic, and environmentally friendly solvent. It exhibits unique reactivity and selectivity, which is different from those in conventional organic solvents [11]. In this respect, the development of water-tolerant catalysts has rapidly become an area of intense research [12]. Also, most organic reactants including catalysts are insoluble in water, and the surfactants, due to their hydrophobic and hydrophilic nature, form micelles and promote the reaction in water. *p*-Dodecylbenzenesulfonic acid (DBSA) as a Brønsted acid-surfactant combined catalyst acts both as an acid catalyst to activate a substrate and as a surfactant to form stable colloidal dispersion with water-insoluble substrates, and thus can facilitate the reaction [13]. DBSA has been successfully used in many organic reactions [14].

Ultrasound irradiation has been considered as a clean and useful protocol and widely used in organic synthesis in the recent two decades. The most important effect of ultrasound passing through a liquid medium is the generation of cavities. This leads to the development of high temperatures and high pressures within the cavities during their collapse [15]. A large number of organic reactions can be carried out in higher yields, shorter reaction times and milder conditions under ultrasound irradiation [15,16]. Ultrasound has been previously used for the acceleration of condensation, such

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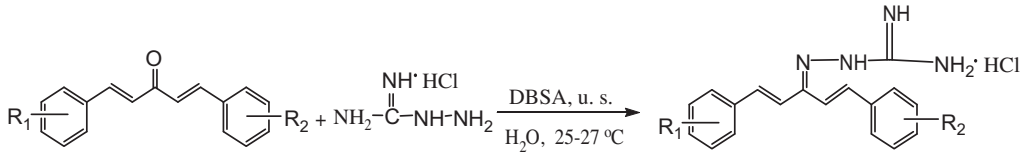
doi:10.1016/j.ultsonch.2012.02.009



Scheme 1. Synthesis of 2-(1,5-diaryl-1,4-pentadien-3-ylidene)-hydrazinecarboximidamide hydrochloride.

as the condensation of carbonyl compounds and hydroxylamine hydrochloride [17], the Knoevenagel condensation of malononitrile with aromatic aldehydes to form arylmethylenemalononitriles [18], the condensation of aromatic aldehydes and barbituric acid [19] and Claisen–Schmidt condensation of acetophenone with aromatic aldehydes [20]. These reactions all involve nucleophilic addition followed by elimination of water. Recently, our laboratory has described the preparation of bis(indolyl)methanes [14b] and 12-aryl-8,9,10,12-tetrahydrobenzo[a]xanthen-11-one derivatives catalyzed by DBSA in aqueous media under ultrasound irradiation [21]. To the best of our knowledge, however, there are no reports on the synthesis of the title compound catalyzed by DBSA under ultrasound irradiation. The aims of this study are to improve the syntheses of amidinohydrazone by the use of ultrasonic irradiation (u.s.) and DBSA (Scheme 1).

2. Experimental

2.1. Apparatus, materials and measurements

All reagents were purchased from Tianjin Reagent Co. (Tianjin, China). Liquid aldehydes and ketones were purified by distillation prior to use. The melting points of the products were uncorrected.

1,5-Diaryl-1,4-pentadien-3-ones were prepared according to reported method in the literature [22]. To a Pyrex flask (50 mL) were added 95% ethanol (4 mL), acetone (2 mmol), aromatic aldehyde (4 mmol) and 1.25 mol/L aqueous potassium hydroxide (4 mL). The mixture was irradiated in the water bath of an ultrasonic cleaner until the aromatic aldehyde disappeared, as indicated by TLC (Thin Layer Chromatography). After completion of the reaction, the mixture was chilled in an ice-water bath. The precipitate was isolated by suction filtration, washed to neutral with cool 95% ethanol and water successively.

MS were determined on Agilent Technologies 6310 Lon Trap LC/MS (the accuracy is the percent) or Bruker apex ultra 7.0 T spectrometer (the accuracy is one ppm). The ^{1}H NMR (600 MHz) and ^{13}C NMR (150 MHz) spectra were recorded on a Bruker AVANCE III 600 spectrometer using TMS as internal standard and DMSO-d6 as solvent. Chemical shifts are expressed in parts per million (ppm), and J values are given in hertz (Hz). Sonication was performed using a Shanghai Branson BUG 25-06 ultrasonic cleaner (Branson Ultrasonics (Shanghai) Co., Ltd, with a frequency of 25 or 40 kHz and a nominal power 250 W. The total acoustic power injected into the sample solution was found to be 0.63 and 1.53 W by calorimetry, respectively [23]).

2.2. General procedure for the synthesis of the title compounds

1,5-Diaryl-1,4-pentadiene-3-one (1, 1 mmol), aminoguanidine hydrochloride (121 mg, 1.1 mmol), DBSA (164 mg, 50% mmol) and H_2O (10 mL) were added into a 25 mL round bottomed flask. The reaction flask was placed in the cleaner bath, where the surface of reactants was slightly lower than the level of the water. In the water bath of the ultrasonic cleaner, the reaction mixture was irradiated at 25–27 °C for the period of time as indicated in Table 2. The reaction was monitored by TLC (silica, CH_3OH:CH_2Cl_2 = 1:4, V/V), and the reaction temperature was controlled by removal or addition of water from ultrasonic bath. After the completion of the reaction, the reaction mixture was extracted with CH_2Cl_2 (3 × 10 mL), the combined organic layer was dried over anhydrous Na_2SO_4 and filtered. The solvent was removed by evaporation under reduced pressure to give the crude product, which was further purified by column chromatography on silica (200–300 mesh) and eluted with petroleum ether (b.p. 60–90 °C) or a mixture of CH_3OH and CH_2Cl_2 (1:20, V:V). The authenticity of the products (2b–e) was established by comparing their melting points and ^{1}H NMR with data reported in the literatures [6]. The authenticity of the other samples (2a, 2f–l) was established by their ^{1}H NMR, ^{13}C NMR and MS.

2.2.1. Compound 2a

2-[3-phenyl-1-(2-phenylethenyl)-2-propen-1-ylidene]-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 223–224 °C (223–225 °C) [6]. ^{1}H NMR: δ_H 7.25 (d, J = 16 Hz, 1H, CH), 7.34–7.43 (m, 6H, Ph-H), 7.45 (d, J = 16 Hz, 1H, CH), 7.54 (d, J = 16 Hz, 1H, CH), 7.62 (d, J = 16 Hz, 1H, CH), 7.70 (d, J = 7.4 Hz, 2H, NH_2), 7.90–7.92 (m, 4H, Ph-H), 7.96 (brs, 1H, NH), 12.11 (s, 1H, NH); ^{13}C NMR: δ_C 156.4, 149.1, 139.3, 136.8, 135.4, 130.0, 129.3, 129.2, 129.1, 128.7, 127.8, 122.9, 119.2; HRMS m/z (ESI): calcd for $C_{18}H_{19}N_4$ $[M + H]^+$ 291.1604, found 291.1605.

2.2.2. Compound 2b

2-{3-(2-chlorophenyl)-1-[2-(2-chlorophenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 243–244 °C (243–244 °C) [6]. ^{1}H NMR: δ_H 7.16 (d, J = 16 Hz, 1H, CH), 7.34–7.54 (m, 6H, Ph-H), 7.44 (d, J = 8 Hz, 1H, CH), 7.49 (d, J = 8 Hz, 1H, CH), 7.59 (d, J = 16 Hz, 1H, CH), 7.83 (brs, 2H, NH_2), 7.87–7.88 (m, 2H, Ph-H), 8.29 (s, 1H, NH), 11.83 (s, 1H, NH).

2.2.3. Compound 2c

2-{3-(3-chlorophenyl)-1-[2-(3-chlorophenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 217–219 °C (217–220 °C) [6]. ^{1}H NMR: δ_H 7.29 (d, J = 16 Hz, 1H, CH), 7.36–7.47 (m, 4H, Ph-H), 7.48 (d, J = 16 Hz, 1H, CH), 7.55 (d, J = 16 Hz, 1H, CH), 7.65 (d, J = 16 Hz, 1H, CH), 7.80 (s, 2H, NH_2), 7.86–7.92 (m, 4H, Ph-H), 7.98 (brs, 1H, NH), 12.21 (s, 1H, NH).

2.2.4. Compound 2d

2-{3-(4-chlorophenyl)-1-[2-(4-chlorophenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, 233–234 °C (233–234 °C) [6]. ^{1}H NMR: δ_H 7.24 (d, J = 16 Hz, 1H, CH), 7.45 (d, J = 16 Hz, 1H, CH), 7.46–7.50 (m, 4H, Ph-H), 7.52 (d, J = 16 Hz, 1H, CH), 7.55 (d, J = 16 Hz, 1H, CH), 7.71 (d, J = 8 Hz, 2H, NH_2), 7.78 (brs, 1H, NH), 7.82–7.91 (m, 4H, Ph-H), 11.94 (s, 1H, NH).

Table 1
The effect of reaction conditions on the yield of 2a under ultrasound irradiation.[a]

Entry	Frequency, kHz	Substrate/regent, molar ratio	DBSA, mmol	T, °C	Isolated yield, %
1	25	1:1.1	0.1	25–27	26
2	25	1:1.1	0.2	25–27	41
3	25	1:1.1	0.3	25–27	58
4	25	1:1.1	0.4	25–27	75
5	25	1:1.1	0.5	25–27	94
6	25	1:1.1	0.6	25–27	96
7	25	1:1.1	0.5	35–37	90
8	25	1:1.1	0.5	45–47	93
9	25	1:1	0.5	25–27	91
10	25	1:1.2	0.5	25–27	95
11	40	1:1.1	0.5	25–27	92
12	25	1:1.1	–	25–27	–
13	–	1:1.1	0.5	25–27	75

[a] Reaction time: 2 h.

2.2.5. Compound 2e

2-{3-(4-methylphenyl)-1-[2-(4-methylphenyl)ethenyl]-2-propen-1-ylidene}hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 179–180 °C (179.5–180.5 °C) [6]. ^{1}H NMR: δ_H 2.33 (s, 3H, CH_3), 2.35 (s, 3H, CH_3), 7.17 (d, J = 16 Hz, 1H, CH), 7.22–7.28 (m, 4H, Ph-H), 7.29 (d, J = 16 Hz, 1H, CH), 7.40 (d, J = 16 Hz, 1H, CH), 7.49 (d, J = 16 Hz, 1H, CH), 7.57 (d, J = 8 Hz, 2H, NH_2), 7.710–7.75 (m, 4H, Ph-H), 7.85 (brs, 1H, NH), 11.85 (s, 1H, NH).

2.2.6. Compound 2f

2-{3-phenyl-1-[2-(4-methylphenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 183–184 °C. ^{1}H NMR: δ_H 2.33 (s, 3H, CH_3), 7.12 (d, J = 16 Hz, 1H, CH), 7.16–7.26 (m, 5H, Ph-H), 7.28 (d, J = 16 Hz, 1H, CH), 7.32 (d, J = 16 Hz, 1H, CH), 7.37 (d, J = 16 Hz, 1H, CH), 7.40 (d, J = 8 Hz, 2H, NH_2), 7.50–7.62 (m, 4H, Ph-H), 7.65 (brs, 1H, NH), 11.62 (s, 1H, NH). ^{13}C NMR: δ_C 153.4, 147.1, 139.2, 135.8, 129.8, 129.7, 129.1, 129.0, 127.6, 127.5, 127.1, 22.1; HRMS *m/z* (ESI): calcd for $C_{19}H_{21}N_4$ $[M + H]^+$ 305.1761, found 305.1764.

2.2.7. Compound 2g

2-{3-phenyl-1-[2-(4-methoxylphenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid; m.p. 146–148 °C. ^{1}H NMR: δ_H 3.80 (s, 3H, CH_3), 7.24 (d, J = 16 Hz, 1H, CH), 7.31–7.44 (m, 6H, Ph-H), 7.45 (d, J = 16 Hz, 1H, CH), 7.52 (d, J = 8.4 Hz, 1H, CH), 7.63 (d, J = 8.4 Hz, 1H, CH), 7.68 (d, J = 7.5 Hz, 2H, NH_2), 7.78–7.84 (m, 3H, Ph-H), 7.87 (brs, 1H, NH), 11.97 (s, 1H, NH). ^{13}C NMR: δ_C 160.9, 160.2, 156.5, 136.8, 130.2, 129.8, 129.1, 129.0, 128.5, 127.7, 123.1, 114.7, 55.8; HRMS *m/z* (ESI): calcd for $C_{19}H_{21}N_4O$ $[M + H]^+$ 321.1710, found 321.1712.

2.2.8. Compound 2h

2-{3-(4-methoxyphenyl)-1-[2-(4-methoxyphenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 208–209 °C. ^{1}H NMR: δ_H 3.81 (s, 6H, CH_3), 6.96–7.01 (m, 4H, Ph-H), 7.08 (d, J = 16 Hz, 1H, CH), 7.38 (d, J = 16 Hz, 1H, CH), 7.42 (d, J = 16 Hz, 1H, CH), 7.46 (d, J = 16 Hz, 1H, CH), 7.63 (d, J = 8.6 Hz, 2H, NH_2), 7.70 (brs, 1H, NH), 7.76–7.86 (m, 4H, Ph-H), 11.83 (s, 1H, NH); ^{13}C NMR: δ_C 160.9, 160.2, 156.0, 150.7, 139.2, 134.9, 130.2, 129.5, 129.2, 128.9, 120.6, 116.9, 114.6, 55.7, 55.8; HRMS *m/z* (ESI): calcd for $C_{20}H_{23}N_4O_2$ $[M + H]^+$ 351.1816, found 351.1818.

2.2.9. Compound 2i

2-{3-(3,4-dioxanemethylphenyl)-1-[2-(3,4-dioxanemethylphenyl) ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 234–235 °C. ^{1}H NMR: δ_H 6.06 (s, 2H, CH_2), 6.08 (s, 2H, CH_2), 6.95 (d, J = 8 Hz, 1H, CH), 6.98–7.07 (m, 2H, Ph-H), 7.08 (d, J = 8 Hz, 1H, CH), 7.25 (d, J = 8 Hz, 1H, CH), 7.31 (d, J = 8 Hz, 1H, CH), 7.38 (s, 2H, NH_2), 7.42–7.70 (m, 4H, Ph-H), 7.75 (brs, 1H, NH), 11.67 (s, 1H, NH); ^{13}C NMR: δ_C 156.4, 149.1, 148.4, 148.3, 148.2, 139.9, 135.4, 131.2, 130.6, 125.2, 123.5, 121.0, 116.2, 108.9, 106.9, 106.3, 101.9, 101.5; HRMS *m/z* (ESI): calcd for $C_{20}H_{19}N_4O_4$ $[M + H]^+$ 379.1401, found 379.1401.

2.2.10. Compound 2j

2-{3-(2,4-dichlorophenyl)-1-[2-(2,4-dichlorophenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 187–188 °C. ^{1}H NMR: δ_H 7.17 (d, J = 16 Hz, 1H, CH), 7.42 (d, J = 16 Hz, 1H, CH), 7.46–7.53 (m, 4H, PH-h), 7.66 (s, 2H, NH_2), 7.75–7.81(m, 2H, PH-h), 7.83 (brs, 1H, NH), 7.87 (d, J = 8 Hz, 1H, CH), 8.29 (d, J = 8 Hz, 1H, CH), 11.97 (s, 1H, NH); ^{13}C NMR: δ_C 134.6, 133.9, 133.8, 133.5, 132.9, 132.5, 129.6, 129.3, 129.2, 128.0, 127.9, 127.9, 121.3. *m/z* (EI): 429.1 $[M + H]^+$.

2.2.11. Compound 2k

2-{3-(3,4-dichlorophenyl)-1-[2-(3,4-dichlorophenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 237–239 °C. ^{1}H NMR: δ_H 7.33 (d, J = 16 Hz, 1H, CH), 7.50 (d, J = 16 Hz, 1H, CH), 7.57 (d, J = 16 Hz, 1H, CH), 7.67–7.70 (m, 3H, Ph-H), 7.72 (d, J = 16 Hz, 1H, CH), 7.88 (d, J = 8 Hz, 2H, NH_2), 7.92 (brs, 1H, NH), 8.0–8.2 (m, 3H, Ph-H), 10.48 (s, 1H, NH); ^{13}C NMR: δ_C 137.8, 137.2, 132.3, 132.2, 131.1, 130.2, 129.3, 129.2, 128.4, 127.8, 120.3; *m/z* (EI): 429.1 $[M + H]^+$.

2.2.12. Compound 2l

2-{3-phenyl-1-[2-(4-chlorophenyl)ethenyl]-2-propen-1-ylidene}-hydrazinecarboximidamide hydrochloride: yellow solid, m.p. 209–210 °C. ^{1}H NMR: δ_H 7.27 (d, J = 16 Hz, 1H, CH), 7.33–7.45 (m, 5H, Ph-H), 7.48 (d, J = 16 Hz, 1H, CH), 7.54 (d, J = 16 Hz, 1H, CH), 7.68 (d, J = 16 Hz, 1H, CH), 7.72 (d, J = 8 Hz, 2H, NH_2), 7.81 (brs, 1H, NH), 7.86–7.92 (m, 4H, Ph-H), 11.95 (s, 1H, NH). ^{13}C NMR: δ_C 156.3, 139.2, 136.8, 136.4, 135.7, 135.4, 134.5, 133.5, 130.5, 130.1, 129.5, 129.2, 128.5, 127.7, 119.0, 118.0; HRMS *m/z* (ESI): calcd for $C_{18}H_{18}ClN_4$ $[M + H]^+$ 325.1214, found 325.1217.

3. Results and discussion

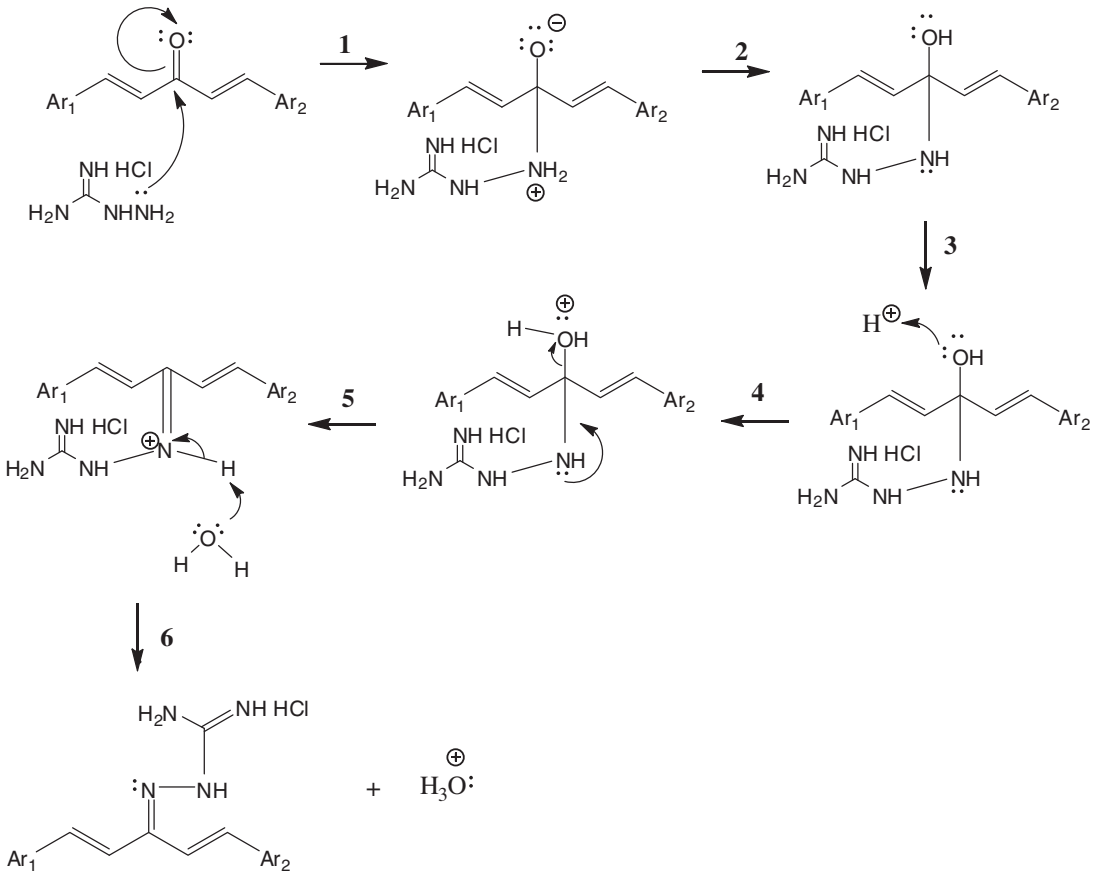
To optimize the reaction conditions, the condensation of 1,5-diphenyl-1,4-pentadien-3-one (1a) and aminoguanidine hydrochloride was selected as the model under ultrasound irradiation (Table 1).

The effect of the amount of DBSA on the reaction was observed. When the amount of DBSA was 0.1 mmol, 0.2 mmol, 0.3 mmol,

Table 2
Synthesis of 2a–l in aqueous media with or without ultrasound irradiation.

Entry	R_1	R_2	Product	Ultrasound		Stir.[a] (Lit.)	
				Time (h)	Isolated yield (%)	Time (h)	Isolated yield (%)
a	H	H	2a	2	94	8 (16)	91 (69) [6]
b	2-Cl	2-Cl	2b	2	87	2 (6.5)	55 (70) [6]
c	3-Cl	3-Cl	2c	2	84	2 (7)	72 (40) [6]
d	4-Cl	4-Cl	2d	2	85	2 (4)	51 (58) [6]
e	$4\text{-}CH_3$	$4\text{-}CH_3$	2e	2	87	6	65
f	H	$4\text{-}CH_3$	2f	2.5	95	8	72
g	H	$4\text{-}OCH_3$	2 g	2	90	2	45
h	$4\text{-}OCH_3$	$4\text{-}OCH_3$	2 h	2	91	5	80
i	$3,4\text{-}(OCH_2O)$	$3,4\text{-}(OCH_2O)$	2i	2.5	92	2.5	63
j	$2,4\text{-}Cl_2$	$2,4\text{-}Cl_2$	2j	3	88	3	75
k	$3,4\text{-}Cl_2$	$3,4\text{-}Cl_2$	2 k	3	89	3	78
l	H	4-Cl	2 l	2.5	94	2.5	67

[a] Stirring alone without ultrasound, reaction temperature 25–27 °C.



Scheme 2. Formation of 2a–l.

0.4 mmol and 0.5 mmol, the yield of 2a was 26%, 41%, 58%, 75% and 94%, respectively (Entries 1–5). When the amount of DBSA was 0.6 mmol, the yield of 2a increased to 96%, but the improvement from entry 5 is slight (Entry 6). In the absence of DBSA, we also did the experiment for the reaction of 1a with aminoguanidine hydrochloride, the reaction was not taken place at all (Entry 12). It seems that DBSA plays an important catalytic role in the reaction.

The following sequence of reactions appears to afford a satisfactory explanation of the mode of formation of products 2a–l for the condensation of 1,5-diary-1,4-pentadien-3-one with aminoguanidine hydrochloride [10] (Scheme 2).

As shown in Scheme 2, the reaction involves nucleophilic addition of the amino group followed by elimination of water. The nitrogen, with a lone pair electron, is a good nucleophile. It is sufficiently nucleophilic to attach the carbonyl group without the need for acid catalysis. DBSA catalysis is important in creating a good leaving group (Scheme 2, step 4). If protonation did not occur, the leaving group would have to be the hydroxide ion, which is a more reactive molecule and a poorer leaving group. In addition, the condensation of 1a and aminoguanidine hydrochloride was performed in a solid–liquid system in which the emulsification of BDSA could also facilitate the reaction.

As shown in Table 1, we also examined the effect of reaction temperature. When the temperature was 25–27 °C, 35–37 °C and 45–47 °C, the yield was 94% (Entry 5), 90% (Entry 7) and 93% (Entry 8), respectively. Consequently, the reaction temperature had little effect on the reaction.

The influence of the molar ratio of 1a to aminoguanidine hydrochloride on the reaction was investigated. When the molar ratio was 1:1, 2a was obtained in 91% yield (Entry 9). Increasing the molar ratio to 1:1.1 and 1:1.2, the yield of 2a was 94% (Entry 5) and 95% (Entry 10) respectively.

The effect of frequency of ultrasound irradiation on the reaction was also observed. When the frequency was 25 kHz, the molar ratio of substrate to aminoguanidine hydrochloride was 1:1.1, the condensation of 1a and aminoguanidine hydrochloride catalyzed by DBSA (0.5 mmol) at 25–27 °C resulted in the desired product in 94% yield within 2 h, while with 40 kHz irradiation under otherwise the same reaction conditions, the yield was 92%. Thus, the irradiation frequency had little effect on the reaction.

We also did the experiments using stirring without ultrasound irradiation. Compound 2a was obtained in 75% (Entry 13) yield in 2 h, whereas under ultrasound irradiation the yield of 2a was 94% (Entry 5). It is apparent that ultrasound irradiation can accelerate the reaction significantly to give better yield. The reason may be the phenomenon of cavitation produced by ultrasound. The effects of ultrasound observed during organic reactions are due to cavitation which can induce instantaneous high local temperatures and pressures. In addition, ultrasound is known to generate extremely fine emulsions from mixtures of immiscible phases. On closer inspection this disturbance can be seen as a large number of tiny 'explosions' at the interface, effectively sending small jets of liquid from one phase into the other. One of the main consequences of these emulsions is the dramatic increase in the interfacial contact area between the immiscible phases, i.e. an increase in the region over which any reaction between species dissolved in the different phases can take place [24,15a,16a].

From the results above, the reaction conditions we chose were as follows: 1,5-diaryl-1,4-pentadiene-3-one (1, 1 mmol), aminoguanidine hydrochloride (1.1 mmol), DBSA (0.5 mmol), water 10 mL, reaction temperature 25–27 °C, irradiation frequency 25 kHz. Using this reaction system, a series of experiments for the condensation of 1,5-diaryl-1,4-pentadien-3-one and aminoguanidine hydrochloride were completed under ultrasound irradiation or silent conditions. The results are summarized in Table 2.

As shown in Table 2, the condensation of various 1,5-diaryl-1,4-pentadiene-3-one and aminoguanidine hydrochloride was carried out in good yields catalyzed by DBSA in aqueous media under ultrasound irradiation. From these results, we can deduce that the yields are, in general, similar or higher than those described in literatures. The dramatic improvements were the short reaction times and high yields. According to the method catalyzed by hydrochloric acid in the literature [6], the time and yield of 2a were 16 h and 69% respectively under refluxing EtOH, for the condensation of 1,5-diphenyl-1,4-pentadiene-3-one and aminoguanidine hydrochloride. The present procedure gave a 94% yield within 2 h (Table 2, Entry a) at 25–27 °C. Other reactions can be completed in 2–3 h instead of 4–16 h to give the products in 84–94% instead of 40–70% yields (Table 2 2a–d) with no requirement of an organic solvent.

In the presence procedure, 1,5-diaryl-1,4-pentadiene-3-ones carrying either electron-donating or electron-withdrawing substituents on the benzene ring all reacted very well. It seems that the effect of electronic factors on the yield was not obvious. The condensation of 1a and aminoguanidine hydrochloride was slightly easier and the yield was slightly higher than that of others. It may be that the steric hindrance around the carbonyl inhibited the attack of aminoguanidine hydrochloride to carbonyl.

4. Conclusion

In conclusion, we have found an efficient and practical procedure for the synthesis of the title compound via the condensation of 1,5-diaryl-1,4-pentadiene-3-one with aminoguanidine hydrochloride catalyzed by DBSA under ultrasound irradiation in the presence of water. Compared to the classical method, the advantages of present procedure are milder conditions, shorter reaction times, higher yields and environmental friendly reaction conditions.

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