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WATER BATH SONICATOR AS AN ECO-FRIENDLY TECHNIQUE FOR SYNTHESIS OF NEW DIHYDRAZIDE HYDRAZONE DERIVATIVES

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ABSTRACT

In this study, the synthesis of a few dihydrazide hydrazone molecules (A1–A6) employing a green chemistry strategy was accomplished successfully using straightforward, environmentally friendly methods. In a water bath sonicator, succinic dihydrazide (1 equivalent) and a variety of aldehydes (2 equivalents) were combined to quickly and efficiently synthesize the necessary compounds. The synthesized compounds were looked into and verified using IR, 1H-NMR, and 13C-NMR as well as physical properties. It's interesting to note that NMR data revealed that each produced chemical had many tautomeric isomers through proton transfer, as well as asymmetric structures. Actually, it is anticipated that the resultant compounds will have a great ability to form complexes with heavy metals, making them valuable in a variety of significant domains.

KEYWORDS: Green chemistry, ultrasound, succinic dihydrazie, hydrazide hydrzone, tautomeric isomers.

1-INTRODUCTION

Green chemistry, also known as sustainable chemistry, is a branch of chemistry and chemical engineering that focuses on the development of goods and procedures that reduce or completely do away with the usage and production of hazardous compounds.(Economy; O'Neil, Scott, Relph, & Ponnusamy, 2020; Wale, Suryavanshi, Wavare, Phalke, & Sharmale, 2023).The disadvantages of traditional methods for conducting organic synthesis reactions included a long reaction time, unsatisfactory yields, a need for more solvent, toxic or expensive reagent requirements, high temperatures, and, on the other hand, uneconomical products. Depending on the quantity and nature of the phases present, the use of heterogeneous systems might lead to problems with mass transfer resistance.(Avila-Ortiz & Juaristi, 2020).Additionally, it might cause particle agglomeration, which reduces surface area and eventually slows the pace of the reaction. To avoid all of these problems, ultrasound techniques can be used to achieve different reactions with a practical and affordable solutions(Gharat & Rathod, 2020). The term "ultrasound" refers to sound waves with wavelengths between 7.0 and 0.015 cm and frequencies greater than those to which human ears can respond, or more than 16kHz(Pandya, Banerjee, Tiwari, & Chabra, 2010). Any substance with elastic qualities, whether solid, liquid, or gas, can transmit it (Singh, Kaur, Khurana, & Kad, 1998). The use of ultrasonic irradiation in chemical reactions can help meet the objectives of greener chemistry, such as minimizing waste and conserving time and energy (Bharathi et al., 2020). The reaction rate and product yield can both be increased with this method. A variety of chemical processes, including addition, substitution, coupling, condensation, oxidation, reduction, protection/deprotection, photochemical, and polymerization, are facilitated by sonication(Patil et al., 2013). By employing an ultrasonic method, dihydrazide can react with aldehydes or ketones to create dihydrazide hydrazone compounds. These compounds contain two groups of each of carbonyl and hydrazone. The hydrazone compounds have an azomethene group (NH-N=CH-). The compounds knowns as diacylhydrazone (Han, Su, Xu, Khan, & Li, 2020; Yuan, Lv, Wang, &

Zhu, 2015)as well as, It is anticipated. The derivatives of these compounds have a high biological activity and used as medicines and antibacterial(Abo-Bakr, 2013). In addition, their similar derivatives are used to convert different solvents (ethanol, benzene, toluene, ….etc) into gel(Che et al., 2017).Furthermore, Hydrazone and thiosemicarbazide synthesized from malonyldihydrazide are used as inhibitors against the corrosion of carbon steel.(Alarfaji, Ali, Bani-Fwaz, & Bedair, 2021). Another used of the similar these compounds are formation of complexes with metals(Kenie, Satyanarayana, & Shyamala, 2015; Lal et al., 2010). In fact, dihydrazide hydrazone compounds found in tautomeric isomers (Zhang et al., 2002) .Isomers are chemical entities that share the same formula but have distinct structures. Isomerism occurs frequently in natural and synthetic chemistry. Isomer structural changes can result in considerable variances in physical, chemical, and hence biological, and medicinal properties (Wu, Wang, Han, & Yao, 2020). There are three types of isomers: keto-keto, keto-enol, and enol-enol. The keto-keto form is more stable than the others. (Cucinotta, Ruini, Catellani, & Stirling, 2006; El-Saied, Shakdofa, Abdou, Abd-Elzaher, & Morsy, 2017; Mohammed, Sheat, Abood, & Yahya, 2021)

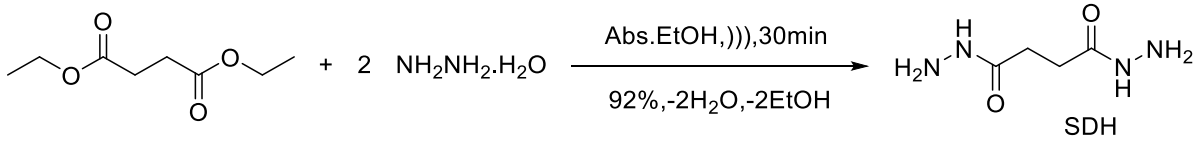
2-EXPERIMENTAL PART

2.1-Materials:

All chemicals and solvents from Aldrich, fluka, BDH, and Scharlau. ^{1}H & ^{13}C – NMR Spectra were scanned on Bruker Ascend 400 MH_Z, 101 MH_Z for ^{13}C NMR, 400 MH_Z for ^{1}H NMR. The chemical shift (δ) measured in ppm downfield from an internal tetramethylsilane (TMS) as an internal standard and DMSO as solvent. Coupling constants (*J*) were reported in hertz (Hz). In addition, spin multiplicities were presented by the following symbols: s-(singlet), d-(doublet), t-(triplet), and m-(multiplate). ^{13}C-NMR information was given in parentheses as C, CH, CH_2, and CH_3.The end point of the reaction were monitored by usig thin later chromatography ((TLC Silica gel 60 F254). The melting point of the compounds determined on an (sturat SPM30). Irradiation of reaction by using water bath ultrasonic ISOLAB (tank 3L, frequency 40 kHz) and to determine the FT-IR of functional group using a Bruker instrument.

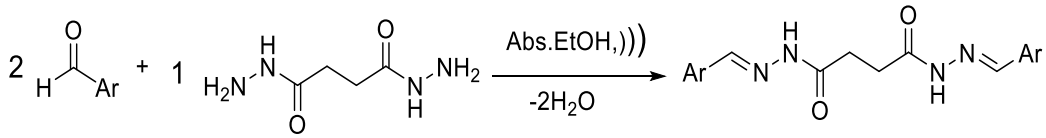
2.2- Methods:

Synthesis of SDH (Succinic dihydrazide**):**



A mixture of diethyl succinate (2.5 ml, 14 mmole) and hydrazine-hydrate 99% (2.5 ml, 50 mmole) in Abs-EtOH (15 ml) was sonicated by using a water bath ultrasound for 30 min (TLC was used to monitor the reaction). The resulted white precipitate was filtered, dried and recrystallized from EtOH to provide the desired compound. And spectral data was in agreement with the published data (Abdullah, 2009)Yield 93%. m.p: 171-173 °C. FT-IR- cm^{-1}: 3287-3197, 3043, 2876, 1625. ^{1}H NMR (400 MHz, DMSO, d_6) δ: 2.25 (s, 4H), 4.14 (s, 4H), 8.98 (s, 2H). ^{13}C NMR (101 MHz, DMSO, d_6) δ: 29.41, 171.2.

General methods for the synthesis of dihyrazide hydrazone compounds (A1-A6):



A warm solution of SDH (7 mmole) in Abs-EtOH (20 ml) was added gradually to a solution of aldehyde (14 mmole) in Abs-EtOH (20 ml) at r.t. Three drobs of conc.HCl was added to the mixture and then the mixture was sonicated. The reaction was controlled by TLC and the resulted compound was filtered with distilled water, dried

and finally recrystallized from DMF to afford the required compound.

Synthesis of (A1): N'1-(4-hydroxybenzylidene)-N'4-(4-hydroxybenzylidene) succinohydrazide:

Reaction time (30 min), yellow color, yield 93%, m.p: 226-229°C. FT-IR-cm^{-1}:3305, 3234, 3066, 1656, 1588. ^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.52 (s, 2H), 2.9 – 2.96 (m, 2H), 6.79 – 6.82 (m, 4H), 7.47 – 7.51 (m, 4H), 7.89 (s, 1H), 8.06 (s, 1H), 9.87 (s, 2H), 11.07 (d, *J* = 7.3 Hz, 1H), 11.25 (d, *J* = 9.4 Hz, 1H, OH). ^{13}C NMR (101 MHz, DMSO, *d6*) δ: 26.75, 27.51, 28.62, 29.29,115.75, 125.39, 125.41, 125.45, 125.47, 128.36, 142.88, 143.08, 146.03, 146.21, 159.06, 159.10, 159.26, 159.30, 167.62, 167.93, 173.14, 173.38.

Synthesis of (A2): N'1-(4-hydroxy-3-methoxybenzylidene)-N'4-(4-hydroxy-3-methoxybenzylidene) succinohydrazide:

Reaction time (15 min), white color, yield 84%, m.p:217-220 °C. FT-IR-cm^{-1}: 3537, 3516, 3038, 1670, 1646, 1603. ^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.52 (s, 2H), 2.92 – 2.96 (s, 2H), 3.79 – 381 (m, 6H), 6.80 (d, *J* = 8.1 Hz, 2H), 7.05 (td, *J* = 7.9, 1.9 Hz, 2H), 7.20 – 7.26 (m, 2H), 7.88 (s, 1H), 8.04 (s, 1H), 9.47 (s, 2H), 11.09 (s, 1H), 11.26 (d, *J* = 9.9 Hz, 1H). ^{13}C NMR (101 MHz, DMSO, *d6*) δ: 27.13, 27.92, 29.04, 29.75,56.02, 109.85, 115.86, 116.03, 126.24, 126.30, 143.44, 143.64, 146.59, 146.81, 148.40, 148.96, 149.01, 149.20, 149.25, 168.02, 168.34, 173.58, 173.81.

Synthesis of (A3): N'-(3-nitrobenzylidene)-5-((3-nitrobenzylidene) amino)-4-oxopentanehydrazide:

Reaction time (30 min), white color, yield 88.5%, m.p: 278-281°C. FT-IR-cm^{-1}: 3186, 3074, 1663, 1619, 1603, 1525. ^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.57 – 2.89 (m, 2H), 3.01 (s, 2H), 7.67 – 7.75 (m, 2H), 8.09 – 8.25 (m, 6H), 8.45 – 8.5 (m, 2H), 11.56 (s, 1H), 11.74 (d, *J* = 7.9 Hz, 1H).^{13}C NMR (101 MHz, DMSO, *d6*) δ: 27.09, 27.7,28.92,31.25121.04, 121.37, 124.31, 130.88, 133.33, 136.66, 148.68, 174.30.

Synthesis of (A4): N'1-(benzo [d][1,3] dioxol-5-ylmethylene)-N'4-(benzo[d][1,3]dioxol-5-ylmethylene) succinohydrazide:

Reaction time (15 min), brown color, yield 87%, m.p:253-356 °C. FT-IR-cm^{-1}: 3230, 3068, 1660, 1627, 1591, 926. ^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.73 – 2.94 (m, 4H), 6.06 – 6.07 (m, 4H), 7.08 – 7.13 (m, 2H), 7.06 – 7.16 (m, 2H), 7.23 – 7.26 (m, 2H), 7.90 (s, 1H), 8.07 (d, *J* = 3.6 Hz, 1H), 11.18 (d, *J* = 5.9 Hz, 1H), 11.33 (s, 1H, OH).^{13}C NMR (101 MHz, DMSO, *d6*) δ: 27.14, 27.87, 29.03, 36.25, 101.93, 105.52, 108.88, 123.08, 129.25, 129.30, 145.81, 146.00, 148.39, 149.14, 168.38, 173.92.

Synthesis of (A5): N'1-((Z)-furan-2-ylmethylene)-N'4-(furan-2-ylmethylene) succinohydrazide:

Reaction time (20 min), light brown color, yield 85,5%, m.p:242-245 °C. FT-IR-cm^{-1}: 3182, 3084, 1671, 1646, 1619, 939. ^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.51– 2.9 (m, 4H), 6.61 (dt, *J* = 3.7, 1.9 Hz, 2H), 6.81 – 6.89 (m, 2H), 7.77 – 7.83 (m, 2H), 7.88 (s, 1H), 8.06 (d, *J* = 3.8 Hz, 1H), 11.24 (d, *J* = 8.0 Hz, 1H), 11.39 (d, *J* = 10.9 Hz, 1H). ^{13}C NMR (101 MHz, DMSO, *d6*) δ: 26.87, 27.62, 28.84, 29.54, 112.50, 113.29, 136.00, 136.18, 145.15, 149.76, 149.96, 168.48, 173.92.

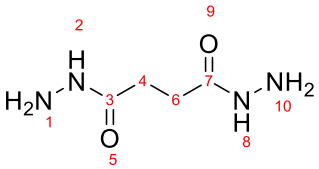
Synthesis of (A6): N'1-(4-bromobenzylidene)-N'4-(4-bromobenzylidene) succinohydrazide:

Reaction time (30 min), white color, yield (93%), m.p: 277-280°C. FT-IR-cm^{-1}: 3199, 3055, 1651, 1605, 1587. ^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.51 – 2.57 (m, 2H), 2.95 (s, 2H), 7.60 – 7.66 (m, 8H), 7.97 (s, 1H), 8.14 (s, 1H), 11.37 (d, *J* = 4.8 Hz, 1H), 11.52 (d, *J* = 9.1 Hz, 1H, OH). ^{13}C NMR (101 MHz, DMSO, *d6*) δ: 27.06, 27.77, 28.94, 123.24, 129.02, 129.25, 132.25, 141.93, 144.76, 168.62, 174.10.

3-RESULT AND DISCUSSION

The synthesized compound (SDH) was prepared from a reaction of diethyl succinate with hydrazine hydrated in Abs.-EtOH as a solvent by using an ultrasound technique. The compound was confirmed by IR, ^{1}H-NMR, and ^{13}C-NMR spectra. The IR spectrum showed two bands at 3287 & 3197 related to the (NH_2) group. Also, a band at 3043 to (N-H) group, as well as, a band at 1625 to (C=O) group. The ^{1}H-NMR spectrum showed a single signal at 2.25 ppm related to the (CH_2) group. In addition, a single signal at 4.14 ppm related to the (NH_2) group. Furthermore, the spectrum showed a single signal at 8.98 ppm related to the (N-H) group. ^{13}C-NMR gave only two signals, one of them at 29.41 ppm related to two (CH_2) groups, while another signal which is at 171.2 ppm was related to two of (C=O) groups.

Table (1): structure and chemical shift ^{1}H & ^{13}C NMR for compound SDH

Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, d_6) δ: 2.25 (s, 4H, H4H6), 4.14 (s, 4H, H1H10), 8.98 (s, 2H, H2H8).
13C NMR	^{13}C NMR (101 MHz, DMSO, d_6) δ: (29.41) C4C6, (171.25) C3C7.

The prepared compound (SDH) was used in a second step to produce the required dihydrazide hydrazone compounds by using a water bath sonicator. SDH compound (1 equivalent) was reacted with different aldehydes (2 equivalent) in a presence of some drops of (conc. HCl) in-EtOH as a solvent. The resulted compounds were confirmed by their physical and spectroscopic data.

Table (2): The chemical formula, yield, and physical properties for (A1-A6) compounds.

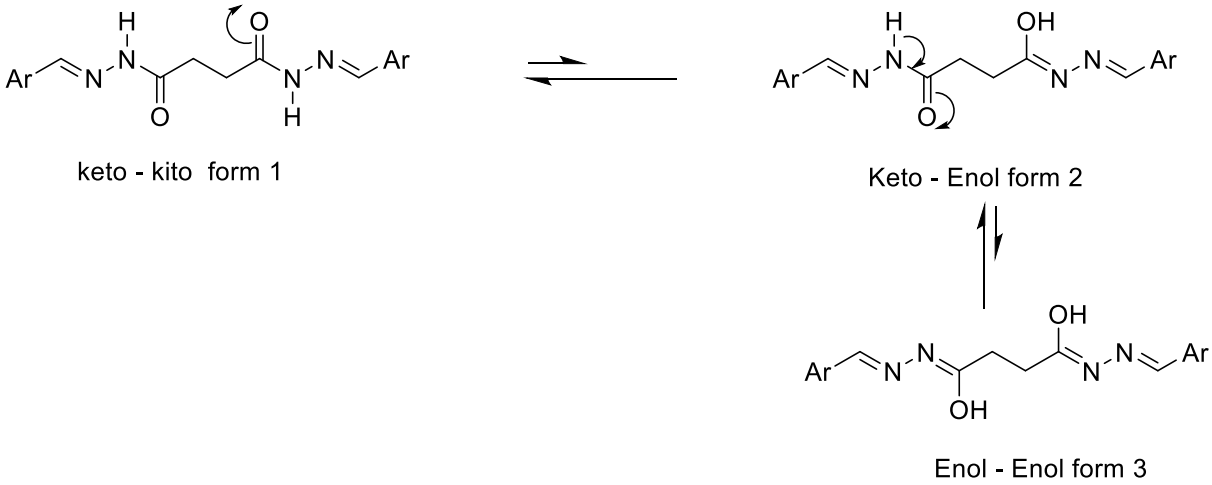
Compounds	Chemical formula	% Yield	M.p.	Color of precipitate
SDH	$C_4H_{10}N_4O_2$	93%	171-173 °C	Crystal-white
A1	$C_{18}H_{18}N_4O_4$	93%	226-229 °C	yellow
A2	$C_{20}H_{22}N_4O_6$	84%	217-220 °C	white
A3	$C_{18}H_{16}N_6O_6$	88.5%	278-281 °C	white
A4	$C_{20}H_{18}N_4O_6$	87%	250-253 °C	brown
A5	$C_{14}H_{14}N_4O_4$	85.5%	242-245 °C	light brown
A6	$C_{18}H_{16}Br_2N_4O_2$	93%	277-280 °C	white

Infrared spectroscopy is a very useful method for determining whether or not organic molecules contain functional groups. Table 3 lists some of the A1–A6 compounds' typical IR designations as well as SDH

Table (3): analysis of FT-IR-cm^{-1} spectroscopy for compounds SAD & **(A1-A6)**

Com.	N-H	C-H (Ar.)	C=O	C=N	C=C	Other
SDH	3043	-	1625	-	-	NH_2 3287-3197
A1	3234	3066	1625	1606	1588	O-H 3305
A2	3516	3038	1670	1646	1603	O-H 3537
A3	3186	3074	1663	1619	1603	N=O 1525
A4	3230	3068	1660	1625	1591	C-O 926
A5	3182	3084	1671	1646	1619	C-O 939
A6	3199	3055	1651	1605	1587	-

^{1}H-NMR spectra showed that the resulted compounds have asymmetric structures because of lack of a plane of symmetry. In addition, the ^{1}H-NMR data showed that the resulted compounds have more than one isomers, which was confirmed by a clear signal appeared at around (11 ppm) which was related to (OH) group resulted by the tautomerism phenomenon Consequently, each compound can be found in three tautomeric isomers as explained in the following scheme 1 (Alarfaji, et al., 2021).



Schem 1: tautomeric isomers phenomenon of the compounds A1-A6

As well as, ^{13}C-NMR supported the ^{1}H-NMR data and gave additional evidence that the compounds were successfully prepared. The chemical shifts of the ^{13}C-NMR & ^{1}H-NMR spectra of (A1-A6) compounds are show in table (4 – 8). In fact, proton of CH_2 groups (C2 & C3) were appeared at rang δ (2.52 – 3.0 ppm) as the compounds (A1 – A6) were asymmetrical (with no plan of symmetry). While the aromatic protons were showed at rang δ (6.89 – 8.25 ppm). In additional the proton of the two imine groups (CH=N) gave signals at rang δ (7.88 – 98.50 ppm), where the two groups were asymmetric so they showed different chemical shifts> the protons of the substituted groups showed the right explained in tables (4 – 8). While ^{13}C NMR showed chemical shifts that indicated the carbon of the prepared compounds

and consequently confirmed their structures. It is worth to be mentioned that (CH_2) groups gave four signals at rang δ (26.75 – 36.25) indicated three tautomeric isomers, as it was mentioned above.

Table (4): structure and chemical shift ^{1}H & ^{13}C NMR for compound A1

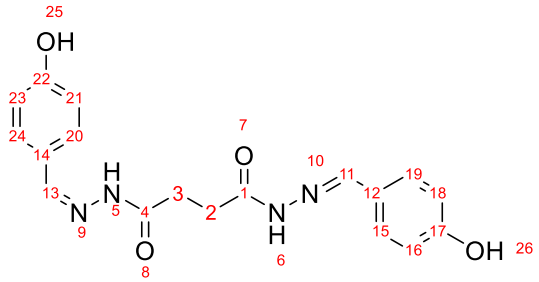
Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.52 (s, 2H, H2 or H3), 2.9 – 2.96 (m, 2H, H2 or H3), 6.79 – 6.82 (m, 4H, H16H18H21H23), 7.47 – 7.51 (m, 4H, H15H19H20H24), 7.89 (s, 1H, H13), 8.06 (s, 1H, H11), 9.87 (s, 2H, H25H26), 11.07 (d, *J* = 7.3 Hz, 1H, H5 or H6), 11.25 (d, *J* = 9.4 Hz, 1H, OH, tautomeric isomers).
13C NMR	^{13}C NMR (101 MHz, DMSO, *d6*) δ: (26.75, 27.51, 28.62, 29.29,) C2C3, (115.75) C16C18C21C23, (125.39, 125.41, 125.45, 125.47) C12C14, (128.36) C15C19C20C24, (142.88, 143.08, 146.03, 146.21) C13C11, (159.06, 159.10, 159.26, 159.30) C11C13, (167.62, 167.93, 173.14, 173.38) C1C4.

Table (5): structure and chemical shift ^{1}H & ^{13}C NMR for compound A2

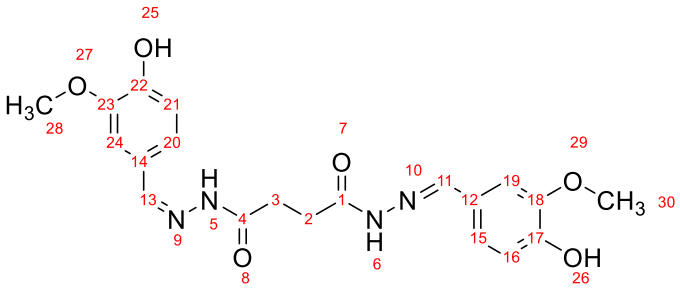
Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.52 (s, 2H, H2 or H3), 2.92 – 2.96 (s, 2H, H2 or H3), 3.79 – 381 (m, 6H, H28H30), 6.80 (d, *J* = 8.1 Hz, 2H, H19H24), 7.05 (td, *J* = 7.9, 1.9 Hz, 2H, H15H20), 7.20 – 7.26 (m, 2H, H16H21), 7.88 (s, 1H, H13), 8.04 (s, 1H, H11), 9.47 (s, 2H, H25H26), 11.09 (s, 1H, H5 or H6), 11.26 (d, *J* = 9.9 Hz, 1H, OH tautomeric isomers).
13C NMR	^{13}C NMR (101 MHz, DMSO, *d6*) δ: (27.13, 27.92, 29.04, 29.75) C2C3, (56.02) C28C30, (109.85) C19C24, (115.86) C16C21, (116.03) C15C20, (126.24, 126.30, 143.44, 143.64) C12C14, (146.59, 146.81,) C13(148.40) C18C23, (148.96, 149.01, 149.20, 149.25) C11C13, (168.02, 168.34, 173.58, 173.81) C1C4.

Table (6): structure and chemical shift ^{1}H & ^{13}C NMR for compound A3

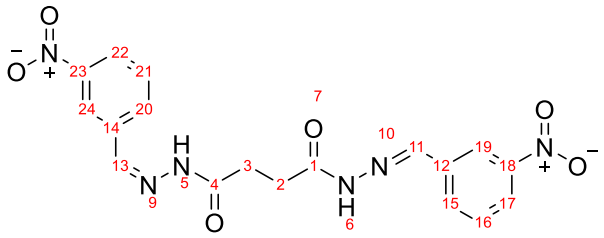
Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.57 – 2.89 (m, 2H, H2 or H3), 3.01 (s, 2H, H2 or H3), 7.67 – 7.75 (m, 2H, H16H21), 8.09 – 8.25 (m, 6H, H15H16H17H20H21H22), 8.45 – 8.5 (m, 2H, H11H13), 11.56 (s, 1H, H5 or H6), 11.74 (d, *J* = 7.9 Hz, 1H, OH tautomeric isomers).
13C NMR	^{13}C NMR (101 MHz, DMSO, *d6*) δ: (27.09, 27.7,28.92,31.25) C2C3, (121.37) C19C24, (124.31) C17C22, (130.88) C16C21, (133.33) C15C20, (136.66) C11C12C13C14, (148.68) C18C23, (174.30) C1C4.

Table (7): structure and chemical shift ^{1}H & ^{13}C NMR for compound A4

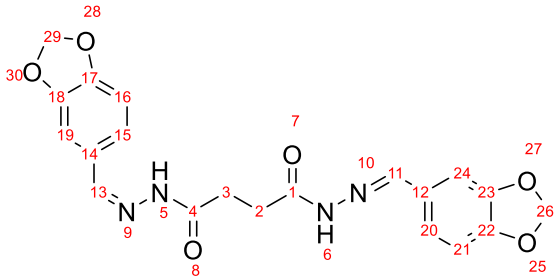
Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.73 – 2.94 (m, 4H, H2H3), 6.06 – 6.07 (m, 4H, H26H29), 7.08 – 7.13 (m, 2H, H16H21), 7.06 – 7.16 (m, 2H, H15H20), 7.23 – 7.26 (m, 2H, H19H24), 7.90 (s, 1HH13), 8.07 (d, *J* = 3.6 Hz, 1H, H11), 11.18 (d, *J* = 5.9 Hz, 1H, H5 or H6), 11.33 (s, 1H, OH tautomeric isomers).
13C NMR	^{13}C NMR (101 MHz, DMSO, *d6*) δ: (27.14, 27.87, 29.03, 36.25) C2C3, (101.93) C26C29, (105.52) C19C24, (108.88) C16C21, (123.08) C15C20, (129.25) C14, (129.30) C12, (145.81) C13, (146.00) C11, (148.39) C18C23, (149.14) C17C22, (168.38, 173.92) C1C4.

Table (8): structure and chemical shift ^{1}H & ^{13}C NMR for compound A5

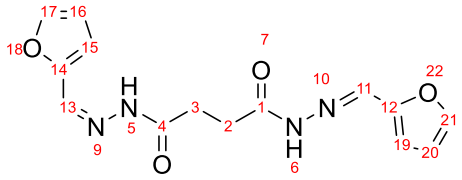
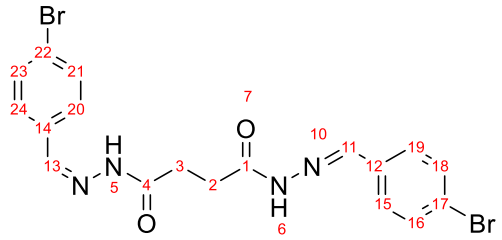
Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.51– 2.9 (m, 4H, H2H3), 6.61 (dt, *J* = 3.7, 1.9 Hz, 2H, H16H20), 6.81 – 6.89 (m, 2H, H15H19), 7.77 – 7.83 (m, 2H, H17H21), 7.88 (s, 1H, H13), 8.06 (d, *J* = 3.8 Hz, 1H, H11), 11.24 (d, *J* = 8.0 Hz, 1H, H5 or H6), 11.39 (d, *J* = 10.9 Hz, 1H, OH tautomeric isomers).
13C NMR	^{13}C NMR (101 MHz, DMSO, *d6*) δ: (26.87, 27.62, 28.84, 29.54) C2C3, (112.50) C16C20, (113.29) C15C19, (136.00) C13, (136.18) C13, (145.15) C17C21, (149.76) C14, (149.96) C12, (168.48, 173.92) C1C4.

Table (8): structure and chemical shift ^{1}H & ^{13}C NMR for compound A6

Structure	
1H NMR	^{1}H NMR (400 MHz, DMSO, *d6*) δ: 2.51 – 2.57 (m, 2H, H2 or H3), 2.95 (s, 2H, H2 or H3), 7.60 – 7.66 (m, 8H, H15H16H18H19H20H21H23H24), 7.97 (s, 1H, H13), 8.14 (s, 1H, H11), 11.37 (d, *J* = 4.8 Hz, 1H, H5 or H6), 11.52 (d, *J* = 9.1 Hz, 1H, OH tautomeric isomers).
13C NMR	^{13}C NMR (101 MHz, DMSO, *d6*) δ: 27.06, 27.77, 28.94 (C2C3), 123.24 (C17C22), 129.02 (C12), 129.25 (C14), 132.25 (C15C16C18C19C20C21C23C24), 141.93 (C13), 144.76 (C11), 168.62 (C1C4), 174.10 (C1C4).

4-CONCLUTION

A simple and environmentally friendly method can be used to produce dihydrazide hydrazine molecules. The easy reaction of succinic dihydrazide (SDH) with various aldehydes (2 equivalents) resulted in the synthesis of the necessary dihydrazide hydrazone compounds with high yield and in a short period. The resultant compounds possessed more than one isomer due to the tautomerism phenomenon; also, their structures were asymmetrical, as proven by H and C NMR spectra. As a result, the water bath sonicator can be employed successfully for the production of dihydrazide hydrazone molecules (A1-A6).

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