Journal of Medicinal and Chemical Sciences 6 (2023) 1065-1076

Journal of Medicinal and Chemical Sciences

Journal homepage: http://www.jmchemsci.com/

Original Article

Organic Synthesis of Some New Compounds Derived from Furfural and Their Evaluation as Antioxidants

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ARTICLE INFO

Article history

Receive: 2022-06-30
Received in revised: 2022-07-17
Accepted: 2022-09-30
Manuscript ID: JMCS-2208-1685
Checked for Plagiarism: **Yes**
Language Editor:
Dr. Fatimah Ramezani
Editor who approved publication:
Dr. Ali H. Jawad Al-Taie

DOI:10.26655/JMCHEMSCI.2023.5.12

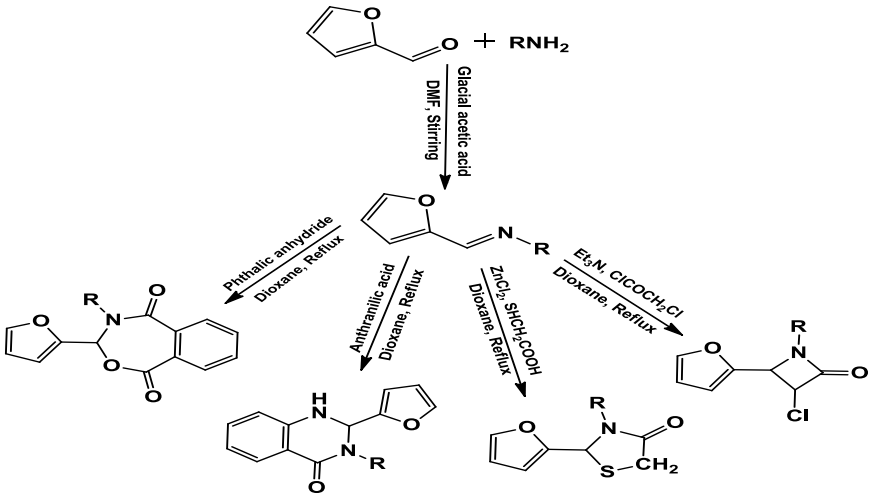
KEYWORDS

Anti-oxidant
DPPH
Furfural
Free radical scavenging

ABSTRACT

Heterogeneous organic compounds play an important role in our daily life as they contribute in many medical and industrial fields and are in continuous development as a result of the preparation of new derivatives with different properties. From this premise, the goal of this work appears, which is preparation of (four, five, six, and seven) membered ring systems derived from furfural, by its reaction with different aromatic aldehydes, and record their antioxidant activity by using free radical scavenging method of DPPH radicals. The new ring systems are synthesized by reacting the prepared Schiff-bases with different ring closure agents (chloroacetyl chloride, mercaptoaceticacid, anthranilic acid, and phthalic anhydride), the prepared compounds were characterized by measuring their melting points and recording their infrared spectra in addition to the NMR spectra for some of them, the recorded results for some derivatives were higher when comparing them with ascorbic acid as a drug because these compounds have electrons that are able to terminate the free radicals that cause the oxidation process.

GRAPHICAL ABSTRACT



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Introduction

Some oxidation processes lead to the formation of free radicals, which can be reduced or eliminated by molecules with the ability to neutralize free radicals, and these molecules are called anti-oxidants [1]. This activity can occur inside living bodies. Therefore, the importance of these molecules appears to protect cells in which oxidation processes occur. These molecules act as drugs that prevent cell damage by free radicals [2]. The DPPH (2,2-Diphenyl-1-picrylhydrazyl) is the most common method among many methods available to measure antioxidants [3], the DPPH solution has a deep purple color absorbed at the wavelength of 517 nm. It is characterized by having free radicals that can be scavenged by antioxidants either by adding an electron or hydrogen atom [4] to turn the color of the solution to yellow, the antioxidants' effectiveness can be determined by measuring the difference in absorbance resulting from the difference in color at the same wavelength. The importance of furfural in comes from being the primary component for any compound that contain a furyl, furfuryl, furoyl, or furfurylidene radical in their structure, furfural as an aldehyde participates in many reactions as acetalization, acylation, aldol and knoevenagel condensations, reduction to alcohols, reductive amination to amines, decarbonylation, oxidation to carboxylic acids, and grignard reactions. Moreover, the effect of withdrawing of electrons in carbonyl group enables furan ring to undergo alkylation, hydrogenation, oxidation, halogenation, and nitration reactions [5, 6]. It can be found in nature in fruit, tea, coffee, cocoa, alcoholic beverages, wood wastes, and whole grain bread. It is considered as artificially flavoring substance and it is dangerous in the case of contact with the skin. Moreover, it is toxic when entering the mouth, irritating to eyes and respiratory system [5]. The use of heterogeneous catalysts in furfural preparation has received the widespread attention in the recent years due to its ability to accelerate the reaction and its selectivity in addition to being environmentally friendly. All these reasons make it the most desirable for practical uses [7]. The purpose of this study is to prepare new derivatives of furfural and evaluate them as antioxidants.

Martials and Methods

All chemicals and solvents which are used in this work were locally purchased from Fluke and BDH and were used directly without any further purification. Melting point were recorded by using Gallenkamp capillary melting point apparatus and where uncorrected, FT-IR spectrum was recorded with Perkin Elmer spectrophotometer by using KBr disk the frequencies were estimated in cm^{-1}, the NMR spectra were recorded on Bruker Avance 600 spectrometer by using DMSO-d_6 as a solvent. The chemical shifts of compounds are expressed by δ (ppm). The reaction time was recorded by using TLC silica gel, solvent used was ethyl acetate: petroleum ether (2:1) and spots were shown by placing the TLC paper in contact with iodine vapor. The antioxidant activity was measured by using spectrophotometer at the wavelength of 517 nm.

Synthesis of furan-2-ylmethylene derivatives (C_1-C_3) [8, 9]

Furfural (0.3 mmol, 0.3 mL) was placed in a round flask and mixed with glacial acetic acid (0.3 mmol, 0.25 mL). The mixture was let to stir for 10 minutes at room temperature followed by adding the amine (0.3 mmol) dissolved in DMF (10 mL). The mixture was stirred for 3-5 hours monitored by TLC ethyl acetate: petroleum ether (2:1), the products were cooled filtered, washed with water, and re-crystallized with ethanol. Physical properties of compounds (C_1-C_3) are listed in Table 1.

Synthesis of 3-chloro-4-(furan-2-yl) azetidin-2-one derivatives (C_4-C_6) [10]

Imine group derivatives (0.9 mmol) were mixed with chloroacetyle chloride (0.9 mmol,0.075 mL) with triethylamine (0.9 mmol, 0.13 mL) and all were dissolved in 10 mL dioxane. The mixture was gently heated for 14-19 hours monitored by TLC ethyl acetate: petroleum ether (2:1), and then the products were cooled, filtered, and

recrystallized with ether. The physical properties of compounds (C_4-C_6) are summarized in Table 2.

Synthesis of 2-(furan-2-yl) thiazolidin-4-on derivatives (C_7-C_9) [11, 12]

Imine group derivatives (0.9 mmol) were mixed with thioacetic acid (0.9 mmol, 0.065 mL) with zinc chloride (0.9 mmol, 0.126 g) all dissolved in 10 mL dioxane. The mixture was refluxed for 17-23 hours monitored by TLC ethyl acetate: petroleum ether (2:1), and then the products were cooled, filtered, and re-crystallized with ether. The physical properties of compounds (C_7-C_9) are presented in Table 3.

Table 1: Physical properties of compounds (C_1-C_3)

Compounds	Chemical formula	M.Wt. (g/mol)	M.P(°C)	Time (hrs.)	Color	Yield (%)
C_1	$C_{11}H_8N_2O$	184	160-162	3	Dark-brown	93
C_2	$C_{12}H_7N_2SOBr$	307	204-206	5	Pale-yellow	76
C_3	$C_{12}H_{10}NO_3$	216	182-184	4	White-yellow	61

Table 2: Physical properties of compounds (C_4-C_6)

Compounds	Chemical formula	M.Wt. (g/mol)	M.P. (°C)	Time (h)	Color	Yield (%)
C_4	$C_{13}H_9N_2O_2Cl$	260.6	>360	19	Dark-brown	72
C_5	$C_{14}H_8N_2SO_2BrCl$	383.6	144-146	19	Light-gray	66
C_6	$C_{14}H_{11}NO_4Cl$	292.7	>360	14	Black	67

Table 3: Physical properties of compounds (C_7-C_9)

Compounds	Chemical formula	M.Wt. (g/mol)	M.P. (°C)	Time (h)	Color	Yield (%)
C_7	$C_{13}H_{10}N_2O_2S$	258.3	>360	19	Black	65
C_8	$C_{14}H_9N_2S_2O_2Br$	381.2	155-160	23	Light-gray	97
C_9	$C_{14}H_{12}NO_4S$	290.3	182-184	17	Dark-brown	73

Synthesis of 2-(furan-2-yl)-2,3-dihydroquinazolin-4(1H)-one derivatives (C_{10}-C_{12}) [13]

Imine group derivatives (0.9 mmol) were mixed with anthranilic acid (0.9 mmol, 0.12 g) dissolved in 10 mL dioxane. The mixture was refluxed for 16-30 hours monitored by TLC ethyl acetate: petroleum ether (2:1), and then the products were cooled, filtered, and re-crystallized by ether. The physical properties of compounds (C_{10}-C_{12}) are listed in Table 4.

Synthesis of 3-(furan-2-yl)-3,4dihydrobenzo[e][1,3]oxazepine-1,5-dione derivatives (C_{13}-C_{15}) [14]

Imine group derivatives (2.6 mmol) were mixed with phthalic anhydride (2.6 mmol, 0.4 g) dissolved in 10 mL dioxane. The mixture was refluxed for 8-17 hours, monitored by TLC ethyl acetate: petroleum ether (2:1), the products were cooled, filtered, and re-crystallized with ether. The physical properties of compounds (C_{13}-C_{15}) are presented in Table 5.

Antioxidant assay

Antioxidant activity was measured by using the free radical scavenging method of DPPH by dissolving 1 mg of each sample in 10 mL of DMSO to prepare a concentration of 100 ppm. Then, by taking 1 mL of the solution and dissolving it in 1 mL of DMSO to prepare the concentration of 50 ppm, and finally it was taken from the stock solution of 0.5 mL and dissolved in 1.5 mL of DMSO to prepare the concentration of 25 ppm. Thus, three concentrations were prepared from each sample, the efficacy was measured by taking 1 mL of each concentration and adding it to 1 mL of a 50 ppm DPPH solution in a test tube and leaving the samples in incubator for half an hour in the absence of light, and then it was measured

by using spectrophotometer at the wavelength of 517 nm and compared with the standard ascorbic acid solution. The blank solution was prepared by mixing 1 mL of methanol to 1 mL of DPPH solution 50 ppm dissolved in DMSO [15], IC_{50} for samples was calculated and the results were displayed in Figure 1. The mechanism of free radical scavenging by using (DPPH) is described in Scheme 1.

Table 4: Physical properties of compounds C_{10}-C_{12}

Compounds	Chemical formula	M.Wt. (g/mol)	M.P (°C)	Time (h)	Color	Yield (%)
C_{10}	$C_{18}H_{13}N_4O_2$	317.3	>360	16	Dark-brown	53
C_{11}	$C_{19}H_{12}N_4SO_2Br$	440.3	205-206	16	Gray	90
C_{12}	$C_{19}H_{15}N_3O_4$	349.3	178-180	30	Brown	65

Table 5: Physical properties of compounds C_{13}-C_{15}

Compounds	Chemical formula	M.Wt. (g/mol)	M.P(°C)	Time (h)	Color	Yield (%)
C_{13}	$C_{19}H_{12}N_2O_3$	316.3	>360	17	Black	98
C_{14}	$C_{20}H_9N_2SO_3Br$	437.2	oily	17	Brown	74
C_{15}	$C_{20}H_{14}NO_6$	364.3	210(d)	8	Black	63

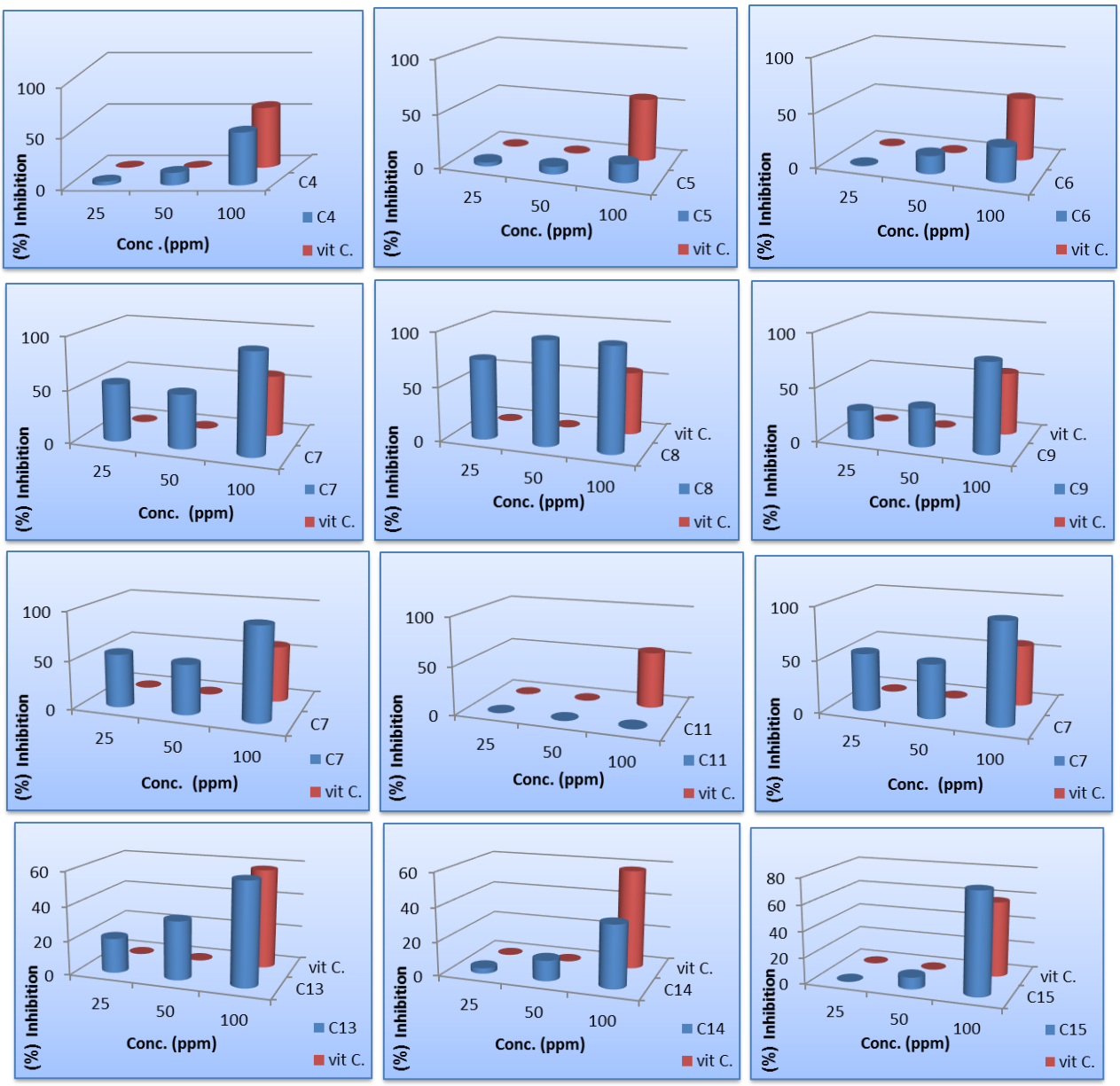
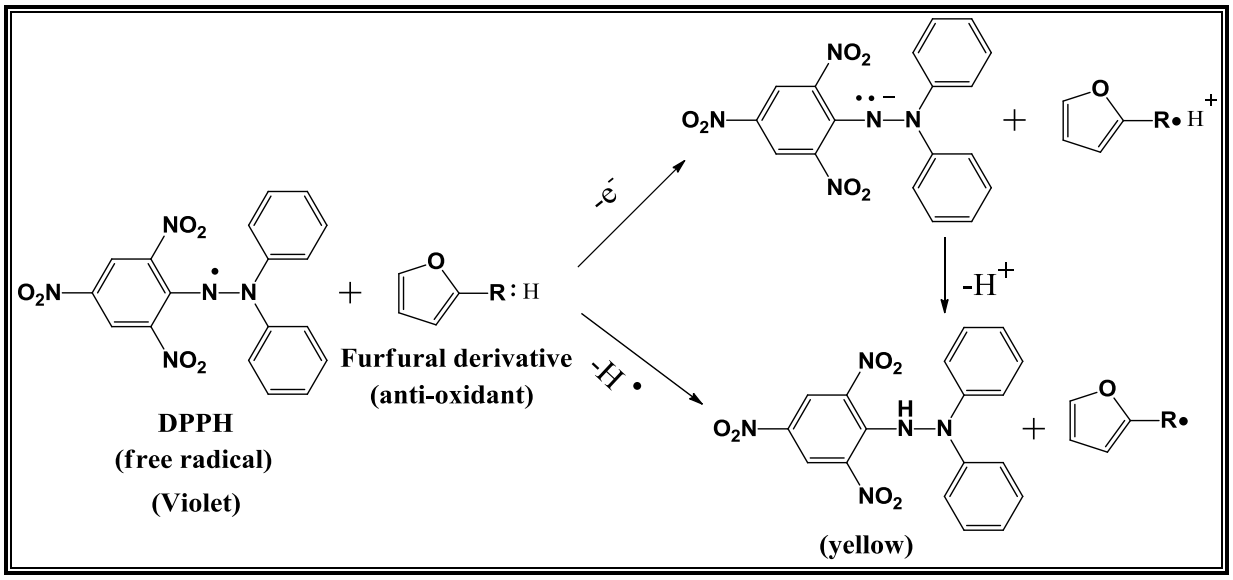


Figure 1: A comparison between the tested compounds and ascorbic acid in (%I) by using different concentrations



Scheme 1: Mechanism of free radical scavenging

Results and Discussion

Furfural derivatives were synthesized by his reaction with different aromatic amines followed by cyclization reaction to form different ring closure derivatives, as displayed in Scheme 2. Compounds (C_1-C_3) were synthesized by a nucliuphilic addition of different substituted amines to furfural carbonyl group in the presence of glacialacetic acid. The spectral results of the compounds (C_1-C_3) showed clear differences indicating the occurrence of the Schiff base reaction, as the FT-IR spectrum demonstrates the main difference in the groups in terms of the absence of the carbonyl band and the presence of other bands indicating the presence of imine group [8] ν(C=N) at 1662-1614 cm^{-1}, as listed in Table 6. ^{1}H-NMR indicates the appearance signal of imine group C=N at δ 8.51 (1H, s, CH=N) for compound C_1, at δ 8.08 (1H, s, CH=N) for compound C_2, at δ 8.37 (1H, s, CH=N) for compound C_3, in addition to other characteristic groups as the amino group in compound C_1 at δ 6.61 (2H, s, NH_2), and the hydroxyl group of compound C_3 at δ 12.79 (1H, s, OH). ^{13}C-NMR also depicts the presence of imine group (CH=N) at the following chemical shifts at δ 152.52 for compound C_1 and C_2, at δ 150.09 for compound C_3.

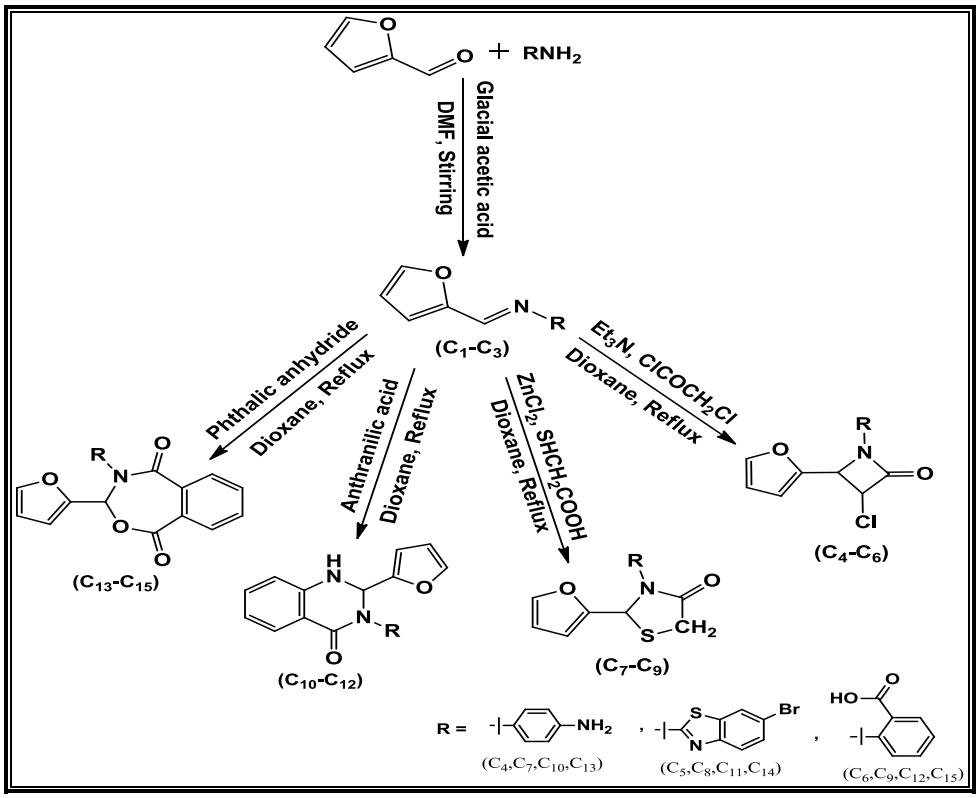
Azetidine-2-one rings were prepared by a nucleophilic addition reaction of chloro acetyle chloride to the imine compound in the presence of trimethylamine. These rings illustrate a significant FT-IR absorption bands indicating the appearance of carbonyl group at 1699-1683 cm^{-1} and ν(C-N) at 1292-1230 cm^{-1} resulting from the nucleophilic attack on the double bond of imine group. ^{1}H-NMR for compound C_5 indicates the presence of significant chemical shift at δ 4.29-4.23 (1H, d, CH-N), as in ^{13}C-NMR for compound C_5 shows a chemical shift at δ 42.98 (CH-N), at δ 167.72 (C=O).

Thiazolin-4-one rings undergoes addition mechanism also including two steps of nucleophilic attack of thio acetic acid in the presence of zinc chloride**,** in this type of five-membered ring systems appears as similar the ones to those of the aforementioned ring systems, new bands are observed in the FT-IR spectrum, such as ν(C=O) at 1701-1685 cm^{-1} and ν(C-N) at 1394-1215 cm^{-1}, as well as ν(CH_2) aliphatic at 3137-3004 cm^{-1} and ν(C-S) at 686-648 cm^{-1}. ^{1}H-NMR for compound C_8 illustrates a characteristic chemical shift at δ 3.68 (1H, s, CH), as the ^{13}C-NMR spectrum for compound C_8 at δ 66.83 for CH-N group.

Quinazolin-4-one rings were prepared by reaction of Schiff base derivatives with anthranilic acid, the absorption bands of FT-IR shows distinct peaks in the six-membered rings formed as the carbonyl group at 1681-1631 cm^{-1} as well as ν(N-H) at 3317-3083 cm^{-1}. ^{1}H-NMR spectrum for compound C_{12} shows the

appearance of significant chemical shifts at δ 4.56-4.53 (1H, d, NH) and δ 4.96 (1H, d, CH), as in ^{13}C-NMR for compound C_{12} at δ 65.29 for CH-N group.

1,3-Oxazepane compounds were prepared from the addition reaction of imine compounds to phthalic anhydride, FT-IR spectra indicates the appearance of carbonyl groups at 1731-1699 cm^{-1} and ester group at 1373-1139 cm^{-1}. All data are listed in Tables 7, 8, and 9.



Scheme 2: Preparation of furfural derivatives

Table 6: FT-IR spectral data of compounds (C_1-C_3)

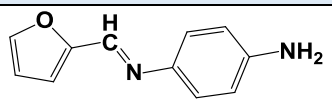
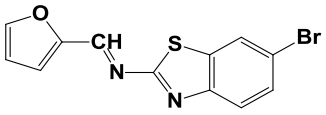
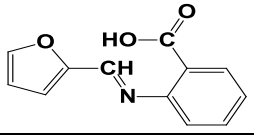
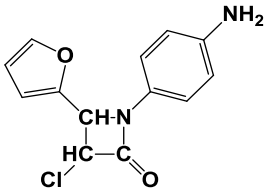
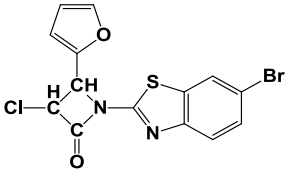
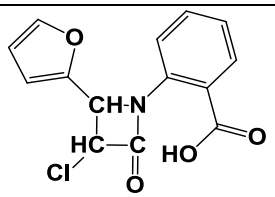
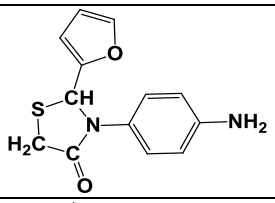
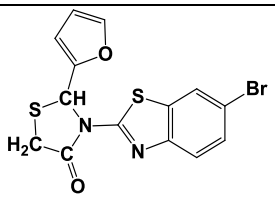
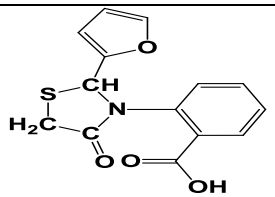
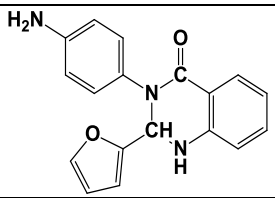
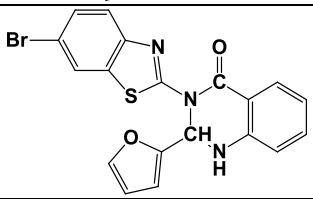
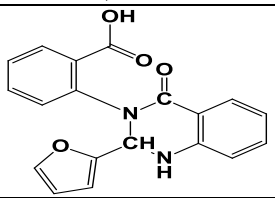
Symbol of Compund	Structure	FT-IR spectral data		
		V(C=N)	V(C=C) aromatic	Others
C_1		1614	1510	v(NH_2) 3521-3433
C_2		1631	1527	v(C-S) 651
C_3		1602	1577	v(O-H) acidic 3074-2565, v(C=O) 1731

Table 7: FT-IR spectral data of compounds (C_4-C_{15})

Symbol of Compound	Structure	FT-IR spectral data		
		V(C=O)	V(C-H) aliphatic	Others
C_4		1683	2887, 2950	v(NH_2) 3452-3421
C_5		1699	2947, 2991	v(C-S) 682
C_6		1699	2848, 2918	v(O-H) acidic 3444-3425, v(C=O) 1699
C_7		1701	2823, 2893	v(NH_2) 3564-3477, v(CH_2) aliphatic 2893-2823
C_8		1699	2918, 2975	v(C-S) 688, v(CH_2) aliphatic 2975-2850
C_9		1685	2910, 2950	v(O-H) acidic 3481-3386, v(C=O) 1768 v(CH_2) aliphatic 2910-2794
C_{10}		1681	2848, 2904	v(NH_2) 3456-3427, v(NH) 3126
C_{11}		1701	2852, 2918	v(C-S) 694, v(NH) 3083
C_{12}		1664	2893, 2950	v(O-H) acidic 3074-2854, v(C=O) 1730, v(NH) 3317

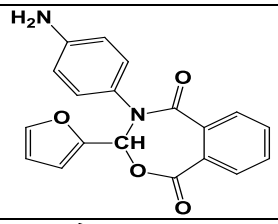
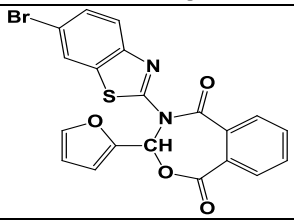
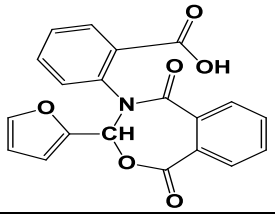
C_{13}		1714	2884, 2920	ν(NH_2) 3444-3421
C_{14}		1731	2923, 2956	ν(C-S) 719
C_{15}		1699	2893, 2947	ν(O-H) acidic 3438-3429, ν(C=O) 1787

Table 8: ^{1}H-NMR spectral data for some prepared compounds C_1-C_{15}

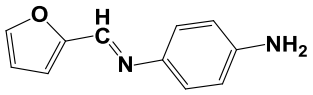
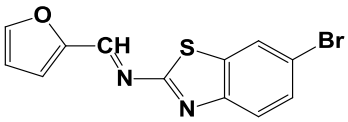
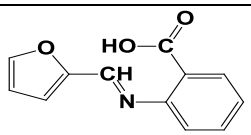
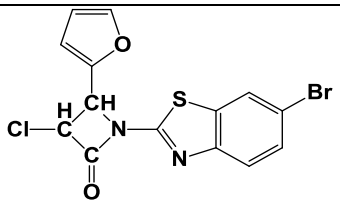
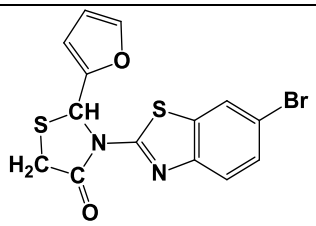
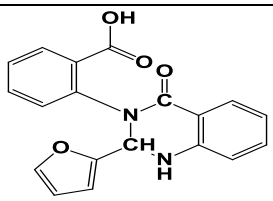
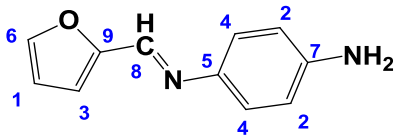
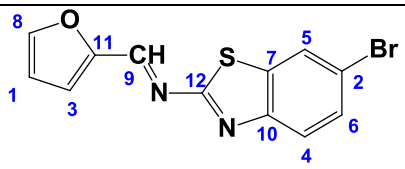
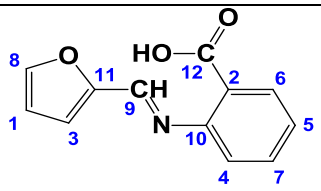
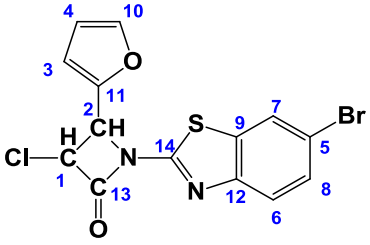
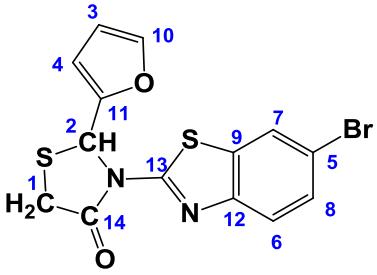
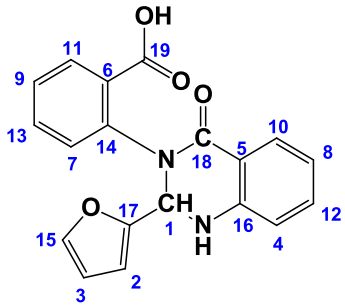
Symbol of Compound	Structures	^{1}H-NMR spectral data (δ ppm)
C_1		6.61 (2H, s, NH_2), 7.97-6.66 (7H, m, H aromatic), 8.51 (1H, s, CH)
C_2		7.88-7.25 (6H, m, H aromatic), 8.08 (1H, s, CH)
C_3		8.35-6.50 (7H, m, H aromatic), 8.37 (1H, s, CH), 12.79 (1H, s, OH)
C_5		4.29-4.23 (1H, d, CH-N), 4.49 (1H, d, CH-Cl), 8.36-7.25 (6H, m, H aromatic)
C_8		3.68 (2H, s, CH_2), 7.25 (1H, s, CH), 7.90-7.28 (6H, m, H aromatic)
C_{12}		4.56-4.53 (1H, d, NH), 4.96 (1H, d, CH), 8.38-6.49 (11H, m, H aromatic), 12.79 (1H, s, OH)

Table 9: ^{13}C-NMR spectral data (δ ppm) for some of the prepared compounds (C_1-C_{15})

Symbol of Compound	Structures	^{13}C-NMR spectral data
C_1		112.73 (C1),113.05-114.72 (C2), 117.45 (C3),122.50,122.84 (C4), 142.91,1146.89 (C5),148.15,148.53 (C6), 149.51,149.68 (C7), 152.52 (C8),153.22 (C9)
C_2		112.60 (C1),112.56 (C2),123.72 (C3), 125.30 (C4),125.72 (C5),128.76(C6), 130.87 (C7),133.59 (C8),152.52 (C9), 152.11 (C10),167.67 (C11), 169.27 (C12)
C_3		111.34, 111.43 (C1), 112.55, 112.82 (C2), 115.81, 115.97 (C3), 132.14 (C4), 132.30 (C5), 132.85 (C6), 134.65 (C7), 134.98 (C8), 150.09 (C9), 150.68 (C10), 161.21 (C11), 170.34, 170.46 (C12)
C_5		41.97 (C1), 42.98 (C2), 112.70 (C3), 119.34 (C4), 122.82 (C5), 123.83 (C6), 124.86 (C7), 128.84 (C8), 133.30 (C9), 148.09 (C10), 151.97 (C11), 158.88 (C12), 167.72 (C13), 169.09 (C14)
C_8		41.07 (C1), 66.83 (C2), 112.67 (C3, C4), 119.47 (C5, C6), 123.80 (C7), 128.82 (C8), 133.37 (C9, C10), 152.13 (C11, C12), 167.70 (C13), 170.99 (C14)
C_{12}		65.29 (C1), 111.36 (C2), 111.45 (C3), 112.55 (C4), 115.82 (C5, C6), 115.98 (C7, C8), 132.15 (C9), 132.32 (C10), 132.85 (C11), 134.56 (C12, 13), 134.97 (C14), 150.09 (C15), 150.68 (C16), 161.17 (C17), 170.35 (C18), 170.74 (C19)

Antioxidant activity

The effectiveness of some of the prepareded derivatives (C_1-C_{15}) as antioxidants was measured by free radicals scavenging [9] by using DPPH method [10]. Several concentrations of the derivatives were prepared and the strength in inhibiting free radicals of DPPH was tested by coupling with their own free radicals, ascorbic acid was used as a standard when measuring the absorption for its high effectiveness as an antioxidant due to its possession of a number of hydroxyl groups that can be stable free radicals capable of capturing free radicals of DPPH. The

compounds absorbance after mixing them with DPPH was measured by using spectral methods at wavelength 517 nm, taking into account the provision of a dark environment during work because the DPPH are affected by light, which may cause the radicals to duplicate.

The percentage of inhibition (%I) was measured according to Equation (1).

$$\%I \frac{\text{blank abs.} - \text{sample abs.}}{\text{blank abs.}} \times 100$$

It denotes the amount of substance required to inhibit 50% of the DPPH radicals with IC_{50}, where the greater the strength of the substance inhibition of free radicals the less IC_{50}. All the results are summarized in Table 10.

Table 10: Inhibition percentage and IC_{50} of some prepared compounds C_1-C_{15}

Symbol of compound	Concentration (ppm)	% I	IC_{50}	Symbol of compound	Concentration (ppm)	% I	IC_{50}
C_4	25	3.669725	112.6	C_{11}	25	0	29.4
	50	12.15596			50	0	
	100	51.31086			100	0.229358	
C_5	25	3.669725	312.7	C_{12}	25	60	39.8
	50	7.110092			50	100	
	100	16.51376			100	100	
C_6	25	0	166.3	C_{13}	25	20.18349	80.6
	50	16.51376			50	33.94495	
	100	31.19266			100	59.40367	
C_7	25	54.68164	49	C_{14}	25	3.211009	153.6
	50	50.94007			50	11.92661	
	100	94.75655			100	36.23853	
C_8	25	73.78277	40.7	C_{15}	25	0	80.7
	50	95.50562			50	8.988764	
	10	95			100	76.77903	
C_9	25	27.34082	61.5	Vit c	25	0	113.3
	50	35.58052			50	0	
	100	82.02247			100	57.94506	
C_{10}	25	44.19476	57.9				
	50	68.53933					
	100	68.04869					

Conclusion

In general, the activity of the measured compounds increased with the substance concentration as a result of increasing the percentage of free radicals captured by DPPH, the effectiveness is weak in the four memberd ring derivatives (C_4, C_5, and C_6) due to the absence of groups that have the ability to form free radicals, while, in five membered rings derivatives (C_7, C_8, and C_9), the activity is higher due to the presence of the sulfur atom that can be stable free radicals, and also shows the good activity in the six-membered rings derivatives (C_{10}, C_{11}, and C_{12}) because they have two groups of carbonyls, as is the case in the seven-membered rings derivatives (C_{13}, C_{14}, and C_{15}). On the other hand, all the derivatives prepared from 1,4-phenylenediamine (C_4, C_7, C_{10}, and C_{13}) have good efficacy due to the presence of the terminal amine group. In contrast, it is noted that the effectiveness of the prepared derivatives from 6-bromo-2-aminobenzothiazole (C_5, C_8, C_{11}, and C_{14}) is low because the nitrogen atom is bounded by three bonds and it is not able to form free radicals, as for the prepared derivatives from anthranilic acid have a good efficacy due to the presence of the alcohol group. From these conclusions and from the results summerized in the Table (1.10), the compounds (C_4, C_{14}, C_6, and C_5) appear in sequence weak activity. As for the compounds (C_9, C_{13}, and C_{15}), respectively, shows the medium-strength activity, and the compounds (C_8, C_7, and C_{10}) in sequence show a high activity, were the highest activity compound is (C_{12}) due

to its containment of many heterogeneous atoms that are capable of formation of free radicals, the compound (C_{11}) indicated the least activity among all the compounds.

Acknowledgments

The authors would like to Thank to the Service Laboratory in Department of Chemistry, University of Baghdad, for providing the necessary devices to measure FT-IR, UV-visible, and melting point.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

We have no conflicts of interest to disclose.

References

[1]. Nimse S.B., Pal D., Free radicals, natural antioxidants, and their reaction mechanisms, *RSC advances*, 2015, **5**:27986 [Crossref], [Google Scholar], [Publisher]

[2]. Gurning K., "Identification of Secondary Metabolic and Test of Activity Ethyl Acetate Fraction of Bangun-Bangun (Coleus amboinicus lour.) Leaves as Antioxidant", *Biolink,* 2020, **7**:117 [Crossref], [Google Scholar], [Publisher]

[3]. Alam M.N., Bristi N.J., Rafiquzzaman M., Review on in vivo and in vitro methods evaluation of antioxidant activity, *Saudi pharmaceutical journal*, 2013, **21**:143 [Crossref], [Google Scholar], [Publisher]

[4]. Barbuceanu S.F., Ilies D.C., Saramet G., Uivarosi V., Draghici C., Radulescu V., Synthesis and antioxidant activity evaluation of new compounds from hydrazinecarbothioamide and 1, 2, 4-triazole class containing diarylsulfone and 2, 4-difluorophenyl moieties, *International Journal of Molecular Sciences*, 2014, **15**:10908 [Crossref], [Google Scholar], [Publisher]

[5]. Tarazanov S., Grigoreva K., Shipitcyna A., Repina O., Ershov M., Kuznetsova S., Nikulshin P., "Assessment of the chemical stability of furfural derivatives and the mixtures as fuel components", *Fuel*, 2020, **271**:117594 [Crossref], [Google Scholar], [Publisher]

[6]. Dalvanda K., Rubina J., Gunukulab S., Wheelerb M.C., Hunt G., "Economics of biofuels: Market potential of furfural and its derivatives", *Biomass and Bioenergy*, 2018, **115**:56 [Crossref], [Google Scholar], [Publisher]

[7]. Wang Y., Len T., Huang Y., Diego Taboada A., Boa A.N., Ceballos C., Delbecq F., Mackenzie G., Len C., Sulfonated sporopollenin as an efficient and recyclable heterogeneous catalyst for dehydration of d-xylose and xylan into furfural, *ACS Sustainable Chemistry & Engineering*, 2017, **5**:392 [Crossref], [Google Scholar], [Publisher].

[8]. Ali O.A., El-Medani S.M., Serea M.R.A., Sayed A.S., Unsymmetrical Schiff base (ON) ligand on complexation with some transition metal ions: Synthesis, spectral characterization, antibacterial, fluorescence and thermal studies, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 2015, **136**:651 [Crossref], [Google Scholar], [Publisher]

[9]. Sen S., De B., TS E., AS N., Maurya S., "Cyclization of Microbiological active 4-(furan-2-yl)-1-(pyridine-4-yl)-azetidine-2-one derivatives", International *Journal of Research in Pharmaceutical Sciences*, 2011, **2**:183 [Google Scholar], [Publisher].

[10]. Chatrabhuji P.M., Vyas K.B., Nimavat K.S., Undavia N.K., Synthesis and antimicrobial activity of some 4-oxo–thiazolidines-5-acetic acids, *Organic Chemistry*, 2013, **54**:12781 [Crossref], [Google Scholar], [Publisher].

[11]. Balaji P.N., Ranganayakulu D., Reddy G.S., Synthesis, evaluation for anthelmintic and antimicrobial activity for the novel in vitro thiazolidine-4-one incorporate substituted chloro-quinoline, *Asian Journal of Pharmacy and Pharmacology*, 2017, **3**:9 [Google Scholar], [Publisher] http://ajpp.in/uploaded/p48.pdf.

[12]. AL-Hazimi H.M., Al-Alshaikh M.A., Microwave assisted synthesis of substituted furan-2-carboxaldehydes and their reactions, *Journal of Saudi Chemical Society*, 2010, **14**:373 [Crossref], [Google Scholar], [Publisher]

[13]. Abid O.H., Tawfeeq H.M., Muslim R.F., Synthesis and Characterization of Novel 1, 3-oxazepin-5 (1H)-one Derivatives via Reaction of Imine Compounds with Isobenzofuran-1 (3H)-one, *ACTA Pharmaceutica Sciencia*, 2017, **55**:43 [Crossref], [Google Scholar], [Publisher]

[14]. Kontham V., Ippakayala B., Madhu D., Synthesis of β-carboline fatty alcohol hybrid molecules and characterization of their biological and antioxidant activities, *Arabian Journal of Chemistry*, 2021, **14**:103163 [Crossref], [Google Scholar], [Publisher].

[15]. Liang N., Kitts D.D., Antioxidant property of coffee components: assessment of methods that define mechanisms of action, *Molecules*, 2014, **19**:19180 [Crossref], [Google Scholar], [Publisher]

HOW TO CITE THIS ARTICLE
Andy N. S. shamaya, Oday H. R. Al-Jeilawi. Organic Synthesis of Some New Compounds Derived from Furfural and Their Evaluation as Antioxidants. *J. Med. Chem. Sci*., 2023, 6(5) 1065-1076
https://doi.org/10.26655/JMCHEMSCI.2023.5.12
URL: http://www.jmchemsci.com/article_159554.html