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Research Article

The Reaction of Aldehydes with Aryl Acetonitriles and their Microbial Evaluations

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Abstract: In this study ten different asymmetric olefins, with very good yield 77-92% were afforded using Knoevenagel condensation reaction between different aldehydes such as benzaldehyde, p-methoxybenzaldehyde, p-chlorobenzaldehyde, p-nitrobenzaldehyde and cinnamaldehyde and substrates containing active methylene groups such as 2-(4-bromophenyl) acetonitrile and 2-(naphthalen-2-yl) acetonitrile in ethanol at room temperature, in the presence of potassium hydroxide as a catalyst. All the synthesized compounds were identified on the basis of melting point, TLC and NMR spectra. In addition, these compounds were tested against microorganisms such as gram-positive bacteria and gram-negative bacteria in comparison with different antibiotics and the results were shown activity against gram-positive bacteria and gram-negative bacteria where compounds (V) and (X) exhibited higher activity than others against all selected microorganisms.

Keywords: Aryl acetonitriles, asymmetric olefin, benzaldehyde, cinnamaldehyde, knoevenagel condensation

INTRODUCTION

In past decades, many carbon-carbon bond-forming reactions have been detected and their applications in organic chemistry have also been well confirmed in the literature (Sammelson and Kurth, 2001) (Rupainwar *et al*., 2019). Base-catalyzed synthesis were frequently used, both on a small scale as well as large scale in organic synthesis, for example, in Aldol (Tang *et al*., 2005), Knoevenagel (Asiri, 1999), Henry (Ballini and Bosica, 1997) and Michael (Chi and Gellman, 2005) reactions. The Knoevenagel reaction is one of the most beneficial reactions in synthetic organic chemistry. Synthetically, the Knoevenagel reaction is a facile and versatile method for the formation of carbon-carbon bonds. A Hantzsch pyridine synthesis, the Gewald reaction and the Feist-Bénary furan synthesis all contain a Knoevenagel reaction step. It is named after Emil Knoevenagel, a German chemist (18 June 1865-11 August 1921) (Knoevenagel, 1898; Ryabukhin *et al*., 2007). It is a nucleophilic addition between aldehydes or ketones and an active methylene compound, using weakly bases as catalysts in organic solvents, followed by elimination of water afforded an α, β-unsaturated compound (Fig. 1). The methylene activity is induced by either X or Y groups which are a strong electron withdrawing group such as -CN, -COOR, or $-NO_2$, in order to facilitate the deprotonation to give the enolate anion. If a strong base was used as a catalyst, the

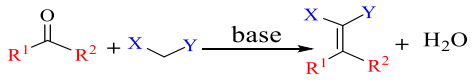

Fig. 1:

aldehyde or ketone may undergo self-condensation. Classical reaction conditions involve the reaction of an aldehyde (ketones can also be used but react much more slowly) with an activated methylene compound in a polar aprotic solvent such as DMF in the presence of a catalyst, usually a primary, secondary or tertiary amine or their ammonium salts. Alternative catalysts have included group 1 fluoride salts (Apsimon *et al*., 1970; Shi *et al*., 2002) titanium tetrachloride coupled with a tertiary amine (The Lehnert modification) (Lehnert, 1970; Lehnert, 1974) and to heterogeneous methods such as dry alumina (Foucaud modification) (Texierboullet and Foucaud, 1980). montmorillonite and xonolite treated with potassium tert-butoxide and zinc acetate (Siebenhaar *et al*., 2001). Polymer-supported amine catalysts (Simpson *et al*., 1999) have been used in condensation. Similarly, other useful modifications such as microwave irradiation (Balalaie and Nemati, 2000), ultrasound techniques (McNulty *et al*., 1998), solvent-free conditions (Ren *et al*., 2009) and ionic liquids (Li *et al*., 2003; Su *et al*., 2003) have all been utilized.

Knoevenagel reaction finds application in many fields, including therapeutic drugs (Kraus and Krolski,

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1986), perfumes, cosmetics (Bigi *et al*., 1999; Yu *et al*., 2000), herbicides, insecticides, polymers (Liang *et al*., 2005), etc. The Knoevenagel reaction has been used as the key step in the synthesis of antimalarial drug lumefantrine (a component of Coartem) (Beutler *et al*., 2007).

However, some of these procedures have drawbacks like harsh reaction conditions, low yield, long reaction time and use of organic solvents which cause environmental waste and pollution. Thus they are against the currently popular 'green' methodologies and are unfavored. Also, the catalysts have to be applied in stoichiometric amounts or even in large excess for complete conversion of the substrate. Thus, there still exists a need for the development of new and mild methods to obtain these products under green chemistry or easy work-up procedures.

MATERIALS AND METHODS

Materials: All chemicals were purchased from Sigma-Aldrich (St. Louis, Mo, USA) and were used as received. Reactions were monitored on TLC (ethylacetate/pet.ether). All spectroscopic analysis of prepared compounds were conducted in Micro-Analytical Unit at Research Center of the Faculty of Science of Sohag University. ^{1}H NMR spectra were carried out on Bruker 400 MHz with chemical shift (δ) expressed in ppm downfield from tetramethylsilane as an internal stander (δ MS = 0) using CDCl3 as a solvent. The multiplicity of the signal is as following: s (Singlet), d (Doublet), t(Triplet), q(Quartet), m(Multiplet).^{13}C-NMR were measured on Bruker 100 MHz with internal reference TMS δ = 0. Infrared spectra were recorded on Maltson 5000 FT IR spectrometer on Perkin Elmer model spectrum100, where the positions of absorptions have been expressed in wave number units (cm^{-1}). Melting points (m.p) of the synthesized compounds were measured in capillary tubes using Stuart scientific apparatus and are uncorrected.

Disc diffusion method: Disc diffusion method was carried out in Benghazi Children's Hospital lab. Bacterial was grown on Mueller Hinton agar (MHA-HiMedia, India). It is the commonly used agar to be used in the Kirby Bauer method.

Synthetic procedure: An equimolar mixture of the aldehyde (5 mmol) and 2-(4-bromophenyl) acetonitrile or 2-(naphthalen-2-yl) acetonitrile (5 mmol) was dissolved in absolute ethanol (10 mL). The solution was then added dropwise to a stirred solution (2 mmol) of potassium hydroxide10% in absolute ethanol (10 mL). After the addition was completed, the mixture was stirred at room temperature for 1 h. The precipitate formed was filtered off, washed with absolute ethanol and recrystallized from absolute ethanol.

The sensitivity test of the synthesized compounds (I-X): Putting 0.2 g of chemical compounds in 2 mL of the Suitable solvent (chloroform) then standardized filter papers were impregnated in antibacterial (synthesized compounds) for 15 min to allow absorption of antibacterial by filter papers. Filter papers are inserted into the Mueller Hinton agar (five in each agar plate) and one in center impregnated in The appropriate solvent (chloroform) by the use of sterile forceps. The top of the Petri dish is shut then put in an incubator with 37°c for 24 h.

Antibiotic: Antibiotic carried out using the agar diffusion technique containing the gram-negative bacteria such as Klebsiella pneumoniae, Pseudomonas aeruginosa, Escherichia coli, Acinetobacter baumannii, Bacillus megaterium (S), Serratia odorifera, Enterobacter asburiae and gram-positive bacteria such as Staphylococcus aureus and Streptococcus viridians.

RESULTS AND DISCUSSION

Results:

Spectral data of compounds (I-X): (*Z*)-*2*-(*4-bromophenyl*)-*3-phenylacrylonitrile* (*I*)**:**IR (KBr) : ν = 3053.43 (C–H), 2215.46 (C≡N), 1590.79 (C=C), 816.19, 748.17, 677.21 (para and mono substituted aromatic), 777.25 (C–H of trisubstituted alkene), 509.08 (C–Br) cm^{-1} .^{1}H-NMR ($CDCl_3$) :δ = 7.46 (m, 3H), 7.51 (s, 1H), 7.54 (d, 4H), 7.89 (dd, 2H).^{13}C-NMR ($CDCl_3$) : δ = 110.50 (1C), 117.62 (1C), 123.44 (1C), 127.49 (2C), 129.05 (2C), 129.39 (2C), 130.85 (1C), 132.23 (2C), 133.46 (2C), 142.56 (1C).

*(Z)-2-(4-bromophenyl)-3-(4-methoxyphenyl) acrylonitrile (II):*IR (KBr) : ν = 3055.12, 3011.67, 2972.61, 2932.17, 2898.50 (C–H), 2211.69 (C≡N), 1582.57 (C=C), 1170.95 (C–O), 821.50 (para substituted aromatic), 722.56 (C–H of trisubstituted alkene), 524.92 (C–Br) cm^{-1} .^{1}H-NMR ($CDCl_3$) : δ = 3.85 (s, 3H), 6.96 (d, 2H), 7.41 (s, 1H), 7.50 (m, 4H), 7.86 (d, 2H).^{13}C-NMR ($CDCl_3$) : δ = 55.44 (1C), 107.33 (1C), 114.48 (2C), 118.14 (1C), 122.80 (1C), 126.21 (1C), 127.20 (2C), 131.33 (2C), 132.11 (2C), 133.80 (1C), 142.11 (1C), 161.68 (1C).

(Z)-2-(4-bromophenyl)-3-(4-chlorophenyl) acrylonitrile (III): IR (KBr) : ν = 3046.54, 2904.63 (C–H), 2219.21 (C≡N), 1584.61 (C=C), 819.58 (para substituted aromatic), 775.10 (C–H of trisubstituted alkene), 1074.07 (C–Cl), 515.93 (C–Br) cm^{-1} .

^{1}H-NMR ($CDCl_3$) : δ = 7.30 (d, 2H), 7.33 (s, 1H), 7.39 (d, 2H), 7.44 (d, 2H), 7.68 (d, 2H).^{13}C-NMR ($CDCl_3$) : δ = 111.16 (1C), 117.32 (1C), 123.72 (1C), 127.45 (2C), 129.32 (2C), 130.53 (2C), 131.89 (1C), 132.30 (2C), 133.11 (1C), 136.79 (1C), 140.90 (1C).

(Z)-2-(4-bromophenyl)-3-(4-nitrophenyl) acrylonitrile (IV): IR (KBr) : ν = 3070.12, 2972.04, 2910.68 (C–H), 2217.44 (C≡N), 1577.53 (C=C),

1507.19, 1334.84 (N–O), 845.32 (C–H of trisubstituted alkene), 814.98 (para substituted aromatic), 505.54 (C–Br) cm^{-1}. ^{1}H-NMR ($CDCl_3$) : δ = 7.48 (s, 1H), 7.50 (d, 4H), 7.92 (d, 2H), 8.19 (d, 2H). ^{13}C-NMR ($CDCl_3$) : δ = 114.90 (1C), 116.68 (1C), 124.16 (2C), 124.68 (1C), 127.73 (2C), 129.98 (2C), 132.50 (2C), 132.50 (1C), 139.21 (1C), 139.36 (1C), 148.40 (1C).

2-(4-bromophenyl)-5-phenylpenta-2,4-dienenitrile (V): IR (KBr) : ν = 3052.52, 3024.70, 2993.51, 2906.46 (C–H), 2213.97 (C≡N), 1604.27, 1572.67 (C=C), 967.68 (trans C–H), 854.55 (C–H of trisubstituted alkene), 817.98, 743.01, 681.60 (para and mono substituted aromatic), 475.84 (C–Br) cm^{-1}. ^{1}H-NMR ($CDCl_3$) : δ = 6.90 (dd, 1H), 7.24 (m, 5H), 7.34 (d, 2H), 7.41(d, 4H). ^{13}C($CDCl_3$) : δ = 112.02 (1C), 116.55 (1C), 123.27 (1C), 124.93 (1C), 127.04 (2C), 127.63 (2C), 128.99 (2C), 129.77 (1C), 132.24 (2C), 132.24 (1C), 135.65 (1C), 141.97 (2C).

(Z)-2-(naphthalen-2-yl)-3-phenylacrylonitrile (VI): IR (KBr) : ν = 3035.77, 2967.91 (C–H), 2222.58 (C≡N), 1593.06 (C=C), 857.32 (C–H of trisubstituted alkene), 733.52, 688 (mono substituted aromatic) cm^{-1}. ^{1}H-NMR ($CDCl_3$) : δ = 7.53 (m, 5H), 7.65 (s, 1H), 7.75 (dd, 1H), 7.88 (dd, 2H)(d, 1H), 7.96 (d, 2H), 8.18 (s, 1H). ^{13}C-NMR ($CDCl_3$) : δ = 111.72 (1C), 118.11 (1C), 122.53 (1C), 126.28 (1C), 127 (1C), 127.09 (1C), 127.75 (1C), 128.53 (1C), 128.94 (1C), 129.01 (2C), 129.40 (2C), 130.58 (1C), 131.67 (1C), 133.34 (1C), 133.46 (1C), 133.86 (1C), 142.12 (1C).

*(Z)-3-(4-methoxyphenyl)-2-(naphthalen-2-yl)acrylonitrile(VII):*IR (KBr): ν = 3060.27, 2963.49, 2908.42, 2839.73 (C–H), 2209.26 (C≡N), 1592.63 (C=C), 1176.03 (C–O), 867.19 (C–H of trisubstituted alkene), 814.44 (para substituted aromatic) cm^{-1}. ^{1}H-NMR ($CDCl_3$) : δ = 3.85 (s, 3H), 6.99 (d, 2H), 7.54 (d, 2H), 7.58 (s, 1H), 7.71 (d, 1H), 7.89 (m, 5H), 8.12 (s, 1H). ^{13}C-NMR ($CDCl_3$) **:** δ = 55.40 (1C), 108.60 (1C), 114.44 (2C), 118.64 (1C), 122.51 (1C), 125.72 (1C), 126.61 (1C), 126.83 (1C), 126.87 (1C), 127.71 (1C), 128.41 (1C), 128.81 (1C), 131.29 (2C), 132.04 (1C), 133.23 (1C), 133.38 (1C), 141.76 (1C), 161.49 (1C).

(Z)-3-(4-chlorophenyl)-2-(naphthalen-2-yl)acrylonitrile (VIII): IR (KBr) : ν = 3054.64, 2967.87, 2904.07 (C–H), 2221.86 (C≡N), 1580.93 (C=C), 861.09 (C–H of trisubstituted alkene), 823.65 (para substituted aromatic), 1126.57 (C–Cl) cm^{-1}. ^{1}H-NMR ($CDCl_3$) **:** δ = 7.46 (d, 2H), 7.55 (m, 2H), 7.60 (s, 1H), 7.74 (dd, 1H), 7.88 (d, 2H)(d, 1H)(dd, 2H), 8.17 (s, 1H). ^{13}C-NMR ($CDCl_3$) : δ = 112.35 (1C), 117.80 (1C), 122.37 (1C), 126.41 (1C), 127.20 (2C), 127.73 (1C), 128.53 (1C), 129.01 (1C), 129.26 (2C), 130.52 (2C), 131.34 (1C), 132.27 (1C), 133.29 (1C), 133.51 (1C), 136.48 (1C), 140.47 (1C).

(Z)-2-(naphthalen-2-yl)-3-(4-nitrophenyl) acrylonitrile (IX): IR (KBr) : ν = 3106.14, 3057.91, 2973.66, 2901.96 (C–H), 2218.07 (C≡N), 1589.55 (C=C), 1513.07, 1339.71 (N–O), 867.41 (C–H of trisubstituted alkene), 815.40 (para substituted aromatic) cm^{-1} . ^{1}H-NMR ($CDCl_3$) **:** δ = 7.48 (m, 2H), 7.62 (s, 1H), 7.68 (dd, 1H), 7.79 (m, 2H), 7.84 (d, 1H), 7.97 (d, 2H), 8.13 (s, 1H), 8.23 (d, 2H). ^{13}C-NMR ($CDCl_3$) **:** δ = 113.69 (1C), 114.75 (1C), 119.81 (1C), 121.77 (2C), 124.82 (1C), 124.92 (1C), 125.33 (1C), 125.41 (1C), 126.31 (1C), 126.88 (1C), 127.55 (2C), 128.30 (1C), 130.83 (1C), 131.49 (1C), 136.26 (1C), 137.35 (1C), 145.92 (1C).

2-(naphthalen-2-yl)-5-phenylpenta-2,4-dienenitrile (X): IR (KBr) : ν = 3051.18, 3022.10, 2979.30, 2907.09 (C–H), 2213.94 (C≡N), 1597.78, 1570.30 (C=C), 965.82 (trans C–H), 743.24, 685.07 (mono substituted aromatic), 854.24 (C–H of trisubstituted alkene) cm^{-1} . ^{1}H-NMR ($CDCl_3$) **:** δ = 6.96 (dd, 1H), 7.29 (m, 4H), 7.44 (m, 6H), 7.61 (d, 1H), 7.76 (m, 2H), 8.02 (s, 1H). ^{13}C-NMR ($CDCl_3$) **:** δ = 113.34 (1C), 117.01 (1C), 122.05 (1C), 125.31 (1C), 126.05 (1C), 127 (2C), 127.56 (2C), 127.71 (1C), 128.46 (1C), 128.95 (4C), 129.56 (1C), 130.63 (1C), 133.38 (C), 135.87 (1C), 141.26 (1C), 141.52 (1C).

Discussion: Knoevenagel condensation is one of the most important and widely employed methods for carbon-carbon double bond formation in synthetic chemistry. It has been used for the preparation of a wide range of substituted electrophilic alkenes (Al-Omran *et al*., 2011). The Knoevenagel reaction is considered to be a modification of the aldol reaction; the main difference between these approaches is the higher acidity of the active methylene hydrogen when compared to α-carbonyl hydrogen. The Knoevenagel reaction, like the aldol, has been carried out diastereoselectively and enantioselectively (Tortora *et al*., 1986). This study concerns the use of the Knoevenagel condensation for the synthesis of several substituted asymmetrical alkenes and dienes containing the powerful electron-withdrawing cyano group, using the simple and efficient route shown in Fig. 2.

The Knoevenagel condensation between aldehydes and substrates with active methylene groups was applied to synthesize a series of 2-aryl-3-(4-substituted phenyl) acrylonitriles (aryl = 4-bromophenyl or 2-naphthyl). (phenyl), (methoxy, chloro, or nitro-substituted phenyls) or (styrenyl) and a cyano group attached to the double bond of acrylonitrile were studied. Structures were confirmed by m.p, TLC, IR and NMR spectral data. Melting points, yields and colors for compounds as shown in Table 1.

These reactions were carried out under mild conditions, e.g., room temperature and in absolute ethanol as the solvent, with good yields. The explanation of this reaction is a nucleophilic attack of the active methylene of 2-(4-bromophenyl)acetonitrile or 2-(naphthalen-2-yl)acetonitrile on the aldehyde

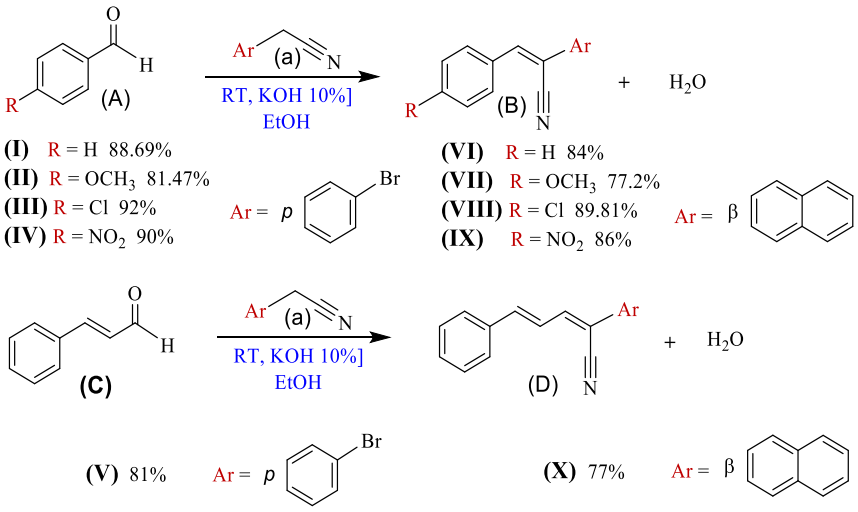

Fig. 2:

Table 1:

Comp. No.	m.p.(°C)	Yield %	Colour
(I)	112	88.69	Colorless
(II)	134-134.5	81.47	Light yellow
(III)	126	92	Colorless
(IV)	159-160	90	Yellow
(V)	149-150	81	Yellow
(VI)	127-127.5	84	Colorless
(VII)	127.5-128	77.2	Light yellow
(VIII)	162	89.81	Colorless
(IX)	166-166.5	86	Yellow
(X)	163-164	77	Yellow

substrate creating a vinylic bond afforded the desired compound. It is only considered as Knoevenagel-type condensation involving deprotonation of the acidic methylene groups and will readily react with electron-rich aromatic aldehydes. The resonance-stabilized carbanion is able to attack the electropositive carbon atom of the aldehyde in a nucleophilic reaction. Thus, a new C-C bond with an alkoxide functionality will be formed which further protonated by the solvent. Hence, protic solvents are Advantageous for this kind of reaction. Finally, the β-hydroxy compound (carbon atom attached with the cyano group designated as α) undergoes dehydration via the elimination of one molecule of water afforded the unsaturated product. The mechanism can be proved by the isolation of the β-hydroxy intermediate. In reactions between compound (a) and aldehydes in the presence of KOH (10%) as a base, we could not find any evidence for the formation of such a β-hydroxy intermediate. However, the initial step is the deprotonation of the CH-acidic methylene of compound (a), a base like potassium hydroxide (10%) can be used for this purpose. The corresponding anion (b), formed from (a) by deprotonation, subsequently this carbanion attacks the carbonyl substrate (c) or (f) to give the corresponding β-hydroxy intermediate (d) or (g) respectively. Loss of water from intermediate (d) or (g) leads to an α β-unsaturated condensation product (e) or (h). The general mechanism as shown in Fig. 3 and 4.

Knoevenagel condensation in absolute ethanol at room temperature of various aldehydes, including aromatic aldehydes with an electron- donating group (methoxy) or electron-withdrawing groups (chloro, nitro), reacted rapidly with one mole equivalent of compounds containing active methylene groups at 25°C in the presence of KOH (10%) afforded the corresponding products with good yields. Compounds (I), (II), (III), (IV), (V), (VI), (VII), (VIII), (IX) and (X) were obtained when carbanion is able to attack the electropositive carbon atom of benzaldehyde, 4-methoxybenzaldehyde, 4-chloro- benzaldehyde, 4-nitrobenzaldehyde or cinnamaldehyde in a nucleophilic reaction afforded the desired compounds.

Several structural isomers in the reaction of cinnamaldehyde with 2-(naphthalen-2-yl) acetonitrile and 2-(4-bromophenyl) acetonitrile, the presence of a trans C-H peak (Mistry, 2009; Pavia *et al*., 2001) is a probability for formation two isomers as a result of elimination to occur. It was not possible to separate these isomers on Thin Layer Chromatography (TLC). The structural isomers as shown in Fig. 5.

Infrared spectra of synthesized compounds have shown many similar and repeated bands. Where the spectrum of C-H aromatic ring appeared at about (3035.77-3106.14 cm^{-1}) as well as bands located between (2901.96-2993.51 cm^{-1}) belong to C-H double bond. Sharp bands at (2209.26-2221.86 cm^{-1}) are corresponding to conjugated cyano groups. Other absorptions at (1570.30-1604.27 cm^{-1}) for C = C of an alkene**.** The C-Cl stretching vibration was also detected at 1170.95, 1176.03 for compounds (III) and (VIII). Also, C–O (1114.39,1126.57) are clearly visible in the spectra of compounds (II) and (VII). the Special characteristic peaks at, 1507.19,1334.84,1513.07 and

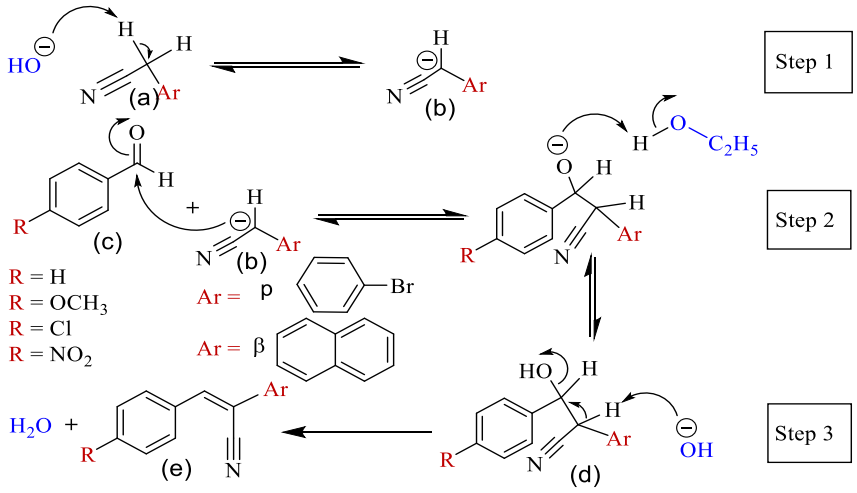

Fig. 3:

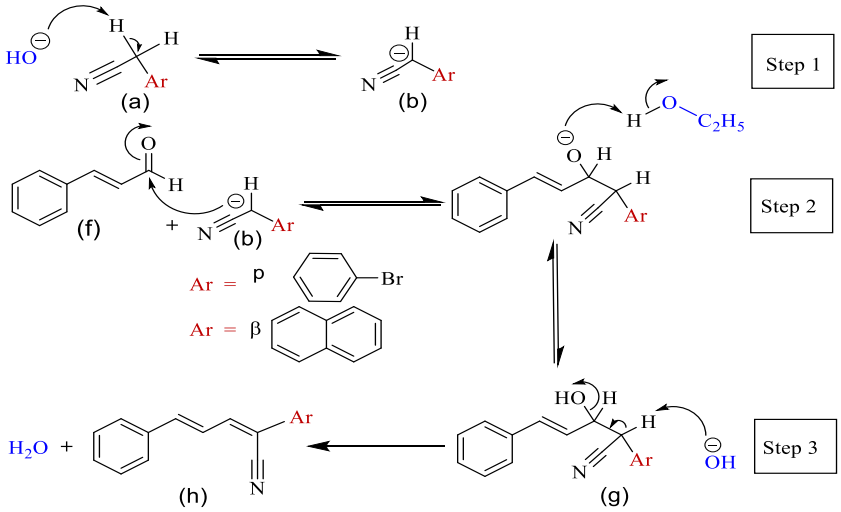

Fig. 4:

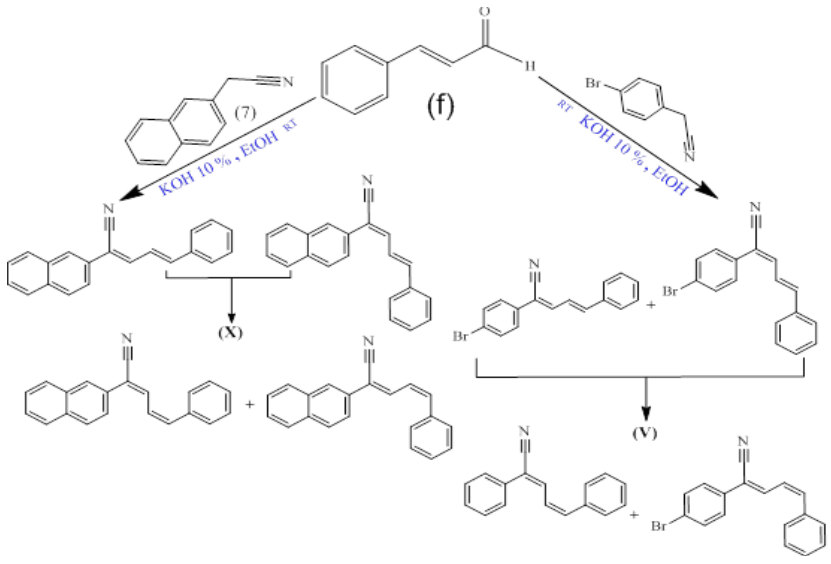

Fig. 5:

1339.71 due to nitrouso group (NO) which appeared as strong and medium bands for compounds (VII) and (IX), respectively.

The synthesized compounds were verified by ^{1}H and ^{13}C NMR spectroscopy. The nuclear magnetic resonance spectral data gave additional support for the composition of the compound. The observed changes are evidence of the reaction that occurred because the chemical shift of a compound is deeply depending on its electronic environment. ^{1}H NMR spectrum of the compound (I) showed a three proton multiplet between 7.45 and 7.47 ppm is corresponding to the three protons of a phenyl ring, one proton singlet at 7.51 ppm is representing a proton of a double bond, a four-proton doublet signal at 7.53 and 7.54 ppm is corresponding to the four aromatic protons derived from the two phenyl rings and a two proton doublet of doublet at 7.88 and 7.90 ppm included two protons of a 4-bromophenyl ring. The singlet beak related to C=C-H, which was observed at 7.51 ppm. In addition, ^{1}H NMR spectrum confirmed the presence of 10 hydrogens atom in the compound, which indicates that the compound (I) was prepared successfully.

There is no significant difference between ^{1}H-NMR spectra of compound (I) and ^{1}H- NMR spectra of compounds (II), (III) and (IV). The difference only appeared in the presence of singlet at 3.85 ppm due to the three protons of a methoxy group as well as appearance of a proton signal of double bonds at about 7.41, 7.33 and 7.48 ppm of compound (II), (III) and (IV), respectively that differ from C = C-H signal of compound (I) which appear at 7.51 ppm due to the effect of substitution on para-position. Furthermore, aromatic hydrogens were detected as a doublet signals at about (6.96,7.86 ppm) of compound II, (7.39, 7.68 ppm) of compound III and (8.19,7.92 ppm) of compound IV, while these hydrogens were observed as multiplet and doublet signals at (7.46, 7.54ppm) for compound (I) this is because phenyl ring is a monosubstituted ring.

^{1}H-NMR spectra of compound (V), show twelve different types of protons the most important signals between of them doublet of doublet signal at 6.88 and 6.92 ppm due to a proton on a double bond between the two aromatic rings, a proton split by two adjacent hydrogens, it split by the hydrogens on either side. A two proton doublet appeared at 7.33 and 7.35 ppm included the single two protons on both double bonds and each being split by the hydrogen atom in the middle.

(Z)-2-(naphthalen-2-yl)-3-phenylacrylonitrile (VI) was obtained when carbanion produced from 2-(naphthalen-2-yl)acetonitrile is able to attack the electropositive carbon atom of benzaldehyde in a nucleophilic reaction afforded the desired compound as colorless crystals. The ^{1}H-NMR spectrum of (VI) showed a five proton multiplet between 7.48 and 7.57 ppm exhibited the five aromatic protons of aromatic rings (the three protons of a phenyl ring and two protons of a naphthyl ring), one proton singlet at 7.65 ppm is representing a proton of a double bond, one proton doublet of doublet signal at 7.74 and 7.77 ppm included an aromatic proton of a naphthyl ring, a three proton doublet of doublet and doublet signal at 7.85 and 7.92 ppm indicated to the three aromatic protons of aromatic rings (the two protons of a phenyl ring and one proton of a naphthyl ring), a two proton doublet signal at 7.96 and 7.97 ppm due to the two aromatic protons of a naphthyl ring and one proton singlet at 8.18 ppm included an aromatic proton of a naphthyl ring.

The ^{1}H-NMR spectrum of compound (VII) did not much change compared to the ^{1}H-NMR spectrum of compound (II) and compound (VI). Aromatic hydrogens of methoxy ring noted as a doublet signals at 6.99 ppm and multiple signals at 7.89 ppm overlapping with the other three aromatic hydrogens belonged to naphthalene ring which appeared at the same site in compound (II). In addition, singlet signal of three hydrogens of methoxy group maintained exactly at 3.85 ppm as seen previously in compound (II). On the other hand, the proton signals of the double bond appeared at 7.58, 7.60 and 7.62 ppm for compounds (VII), (VIII) and (IX) respectively, which is lower than the value in compound (VI) which detected at about 7.65 ppm because of the deshielding by withdrawing groups in para position.

The reaction of cinnamaldehyde with 2-(naphthalen-2-yl) acetonitrile afforded 2-(naphthalen-2-yl)-5-phenylpenta-2,4-dienenitrile (X). The ^{1}H-NMR spectrum showed six types of protons. One proton doublet signal at 6.94 and 6.98 ppm is corresponding to a proton on a double bond between the two aromatic rings, a proton split by two adjacent hydrogens, a four proton multiplet between 7.22 and 7.33 ppm due to the four protons (one proton of a double bond, three aromatic protons of a phenyl ring), a six proton multiplet between 7.36 and 7.49 ppm represented the six protons (one proton of a double bond, a three aromatic protons of a naphthyl ring and two aromatic protons of a phenyl ring), one proton doublet at 7.60 and 7.62 ppm indicated to an aromatic proton of a naphthyl ring, a two proton multiplet between 7.73 and 7.80 ppm included two aromatic protons of a naphthyl ring and one proton singlet at 8.02 ppm is representing a proton of a naphthyl ring.

The ^{13}C NMR spectra of synthesized compounds confirmed the presence of 15 carbon atom in compounds (I), (III) and (IV), 16 carbon atom in compound (II) because of the addition of methoxy carbon and 17 carbon atom belonged to cinnamaldehyde carbons which indicates that the target compounds were prepared successfully. Whereas, The number of carbon atoms in compounds (VI), (VIII) and (IX) increased by 4 carbon atoms from the number of carbon atoms in compounds (I), (III) and (IV) due to the replacement of 4-bromophenyl ring with naphthalene ring.

Antibacterial activities of the synthesized compounds were examined in *vitro* by the known agar

Table 2:

Bacteria	I	II	III	IV	V	VI	VII	VIII	IX	X
Staphylococcus aureus (S)	S	S	S	R	R	S	S	S	R	S
Staphylococcus aureus (R)	S	R	S	R	R	S	S	R	R	S
Streptococcus viridans	S	R	R	R	R	S	S	R	R	R
Klebsiella pneumoniae (S)	S	S	S	R	R	S	S	S	S	R
Klebsiella pneumoniae (R)	S	S	R	R	R	S	S	R	R	R
Pseudomonas aeruginosa (S)	S	R	S	R	S	S	R	S	R	S
Escherichia coli (S)	S	S	S	R	R	S	R	S	R	S
Acinetobacter baumannii (R)	S	R	R	S	S	S	R	S	R	R
Bacillus megaterium (S)	S	R	R	R	S	S	R	S	S	R
Serratia odorifera (S)	S	S	R	R	R	S	S	S	S	R
Enterobacter asburiae (S)	S	R	R	S	S	S	S	S	S	R
Enterobacter asburiae (R)	S	S	R	R	R	S	R	S	R	R

Where: S = Sensitive; R = Resist

diffusion technique. All compounds were tested for activity against gram-positive bacteria and gram-negative bacteria as shown in Table 2.

All compounds were showed activity against gram-positive bacteria and gram-negative bacteria. Compounds (V) and (X) exhibited very high activity than others against all selected microorganisms. It was observed that compound (III) showed higher activity against bacteria, compounds (IV), (VIII) and (IX) showed moderate activity against bacteria, compounds (I), (II) and (VI) showed less from moderate activity against bacteria, while compound (VII) displayed weaker activity against all microbes under investigation.

CONCLUSION

Ten novel compounds were prepared during this work research with good yields (77-92)%, all products were characterized by IR, ^{1}H NMR and ^{13}C NMR, these reactions were usually stereoselective with the predominate products being the *Z*-configuration, for most of the compounds studied in this work the condensation products detected were the corresponding one isomer *Z* by ^{1}H-NMR (27). It observed that compounds (V) and (X) showed very high activity against all selected microorganisms whereas the remaining compounds showed different activity ranging between higher to low.

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