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Synthesis and antimicrobial activity of chalcone containing polystyrene

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Three different 4-propargyloxychalcones have been prepared starting from 4-propargyloxy benzaldehyde and chalcones with proper chemical transformation. Polystyrenes containing biologically active chalcone moiety in their structures have been successfully synthesised by the Click reaction from the 4-propargyloxychalones (terminal alkyne) and azido end-functional polystyrene (PS-N_3). All the desired products have been obtained with good yield and purity. The structure of the 4-propargyloxychalcones and the chalcone containing polystyrenes have been characterized by FT-IR, ^{1}H NMR and UV-Vis spectroscopy. The antibacterial activity of the synthesized 4-propargyloxychalcones their polystyrene derivatives have been evaluated against two bacterial strains, *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative). The results reveal that the tested chalcones and their polystyrene derivatives have moderate antimicrobial activity.

Keywords: Chalcone, 4-propargyloxychalcone, azide end-functional polystyrene, chalcone containing polystyrene, click reaction, antibacterial activity

Over the last few years, synthesis of polymers containing a reactive functional group has attracted much attention to researchers in polymer science in view of the fact that it provides many ways to modify the polymers for necessary applications[1]. Searching for new bio-active molecules with better therapeutic properties and improving biological activities for known drugs by modification of their structures as well as extending the activity in a variety of applications have become a growing concern in current medicinal and pharmaceutical chemistry[2]. ‘Click’ chemistry has been known to an effective technique for modification of polymers and developing new functional polymeric materials and biological applications[3].

Synthetic polymers those have antimicrobial activity are being widely used for the protection of spreading the microorganisms on an external area of materials such as antibiotics, antifouling paints, and in water treatment and soil sterilization[4]. Chalcone exhibits a variety of biological activities such as antifungal, antibacterial, insecticidal, antiprotozoal, anticancer and cytotoxic, *etc*. The presence of the chalcone (PhCH=CHCOPh) provides an advantage in biological activities by accompanying with different compounds in medicinal chemistry[5]. Only a few research has been reported on polymers those contain chalcone unit in their main chain as they are less soluble due to their planar structure and stable rod-like chalcone moiety[6]. Most of the studies have focused polymers containing chalcone unit as a side chain[7].

Microbial contamination of pathogenic microorganisms has a great effect in different fields such as medical devise, equipment for surgery, food packaging and storage, hygienic equipment, water purifying methods, domestic appliances, heal care products, *etc*. Polymeric antimicrobial agents are effective alternative for conventional antimicrobial agents associated with the above problems[8] and can be used in coating for medical instruments, water treatment, medical usages, food packaging and materials related with health care[9]. The polymeric antimicrobial agents also have many advantages because of their poor solubility and more stability. The antimicrobial polymeric agents can reduce the environmental issues associated with the remaining toxicity and can extend their lifetime[10].

Because of the above importance, polymers containing antimicrobial properties have gained growing interest from the view point of industrial and academic aspects. Therefore, in the present work, we have synthesized three different 4-propar-gyloxychalcones with proper chemical transformation. Azide-alkyne coupling reaction between azido terminated polystyrene ($PS-N_3$) and alkyne terminated 4-propargyloxy chalcones was performed in presence of Cu-catalyst to obtain chalcone containing end-functional polystyrene. We have also evaluated their antibacterial activity.

Results and Discussion

Structural characterization of 4-propargyloxybenzaldehyde

To obtain propargyloxychalcones 4-propargyloxy-benzaldehyde was synthesized and used as starting material. In the FT-IR spectrum, the characteristic peak appeared at 2123 and 1682 cm^{-1} indicated the presence of C≡C and carbonyl group (C=O), respectively in its structure. No peak for hydroxyl group (O-H) was appeared, which confirmed that *p*-hydroxybenzaldehyde converted into a new compound (4-propargyloxybenzaldehyde).

The structure of 4-propargyloxybenzaldehyde was also supported by ^{1}H NMR and UV-Vis spectroscopies. In ^{1}H NMR spectrum of 4-propargyloxybenzaldehyde, peaks observed at 2.59 ppm was due to the presence of ≡CH proton. The peak appeared at 7.28 ppm was attributed to the residual protons in $CDCl_3$. The proton of aldehyde group (-CHO) exhibited peak at 9.90 ppm.

UV-Vis spectrum of the 4-propargyloxy-benzaldehyde showed maximum absorption in chloroform solution at wavelength (λ_{max}) 274 nm due to the extension of π system.

Structural characterization of 4-propargyloxy chalcone, 4

In FT-IR spectrum, the peak for C≡C bond was appeared at 2111 cm^{-1}. The bands at 3221 and 1660 cm^{-1} were assigned to C-H (≡C-H) and C=O (carbonyl group) bonds, respectively.

In ^{1}H NMR spectrum of 4-propargyloxychalcone (**4**), a multiplet resonance signals in the range of 7.41-8.02 ppm were attributed to the protons of the aromatic rings. Two doublets located at 7.01 and 7.03 ppm assigned to -CH=CH- protons, suggested the presence of a α,β-unsaturated carbonyl group in the structure. The peak corresponds to the residual protons in $CDCl_3$ was appeared at 7.25 ppm.

UV-Vis spectrum showed maximum absorption in chloroform solution at wavelength (λ_{max}) 335 nm due to extended π system. All the above spectroscopic evidences confirmed the structure of 4-propargyloxychalcone (**4**).

Structural characterization of 4- propargyloxy-2′,4′-dimethoxychalcone, 5

The band for C≡C bond was appeared at 2125 cm^{-1} in IR spectrum of compound **5**. The bands observed at 3250 and1636 cm^{-1} indicated the presence of C-H (≡C-H) and C=O bonds, respectively. The signal observed at 2926 cm^{-1} was assigned for–OCH_3 group.

^{1}H NMR spectrum of 4-propargyloxy-2′,4′-dimethoxychalcone (**5**) showed a multiplet in the range of 7.06 - 8.03 ppm for proton of aromatic rings. Two doublets appeared at 6.70 and 6.74 ppm assigned to -CH=CH- protons of α,β-unsaturated carbonyl group. The peak at 7.28 ppm was assigned to the residual protons in the solvent $CDCl_3$. A singlet peak observed at 1.59 ppm was attributed to-OCH_3 protons.

UV-Vis spectrum of 4-propargyloxy-2′,4′-dimethoxychalcone (**5**) showed maximum absorption at wavelength (λ_{max}) 363 nm. Here, bathochromic shift (red shift) occurred and the UV absorption maxima shifted to the higher wavelength (363 nm) than that of 4-propargyloxychalcone (**4**) (335 nm). This may be because of the methoxy group existing at *para*- and *ortho*-positions of the aromatic ring of the 4-propargyloxy-2′,4′-dimethoxychalcone (**5**).

Structural characterization of 4-propargyloxy-4′-aminochalcone, 6

Similar to compounds **4** and **5**, FT-IR spectrum of 4-propargyloxy-4′-aminochalcone **6** supported its structure.

Similar to compounds **4** and **5**, ^{1}H NMR spectrum of 4-propargyloxy-4′-aminochalcone **6** confirmed its structure. One additional peak appeared at 3.88 ppm was assigned to –NH_2 protons.

UV-Vis spectrum of 4-propargyloxy-4′-aminochalcone **6** showed maximum absorption at wavelength (λ_{max}) 330 nm. Here, hypsochromic shift (blue shift) occurred and the UV absorption maxima of the chalcone **6** shifted to the lower wavelength (330 nm) than that of 4-propargyloxychalcone **4** (335 nm) and this might be due to the presence of the *para*-amino group of the aromatic ring of 4-propargyloxy-4′-aminochalcone **6**.

Structural characterization of chalcone containing polystyrenes, 7

The structure of chalcone containing polystyrene **7** was supported by its FT-IR and ^{1}H NMR spectroscopies. The characteristic band (around 2104 cm^{-1}) for azide group (-N=N=N-) was not appeared in FT-IR spectrum, which suggested that the azide group of azido end-functional polystyrene (PS-N_3) converted into another form (1,2,3-triazole ring). On the other hand, a band appeared at 1638 cm^{-1} attributable for 1,2,3-triazole ring confirmed the click reaction between azido polystyrene and 4-propargyloxy-chalcone **4**, yielding polystyrene derivatives **7**. The presence of absorption band at 3026 cm^{-1} indicated the C-H (str) for triazole ring.

Figure 1 shows ^{1}H NMR spectrum of chalcone containing polystyrene (**7**) and each peak with its corresponding proton is labelled with alphabet letter. All the peaks of the ^{1}H NMR spectrum were supported by the structure of the compound. ^{1}H NMR peaks for azido end-functional polystyrene (PS-N_3) were similar to those reported in our earlier paper [20]. Peaks for all protons of the polymeric benzene ring were appeared in the downfield (6.36-7.22 ppm). Peaks appeared at 1.45 and 1.85 ppm (denoted by j and f) were assigned to the polymeric $-CH_2$ and –CH protons, respectively. Signals for $-CH_2$-O-CO- and $-CH_2$-N (denoted by l and m) protons were appeared at 4.38 and 3.75, respectively. Protons for benzene rings of the chalcone unit (denoted by q, t, u and v) and proton for the triazole ring (denoted by n) exhibited signals in the downfield (7.28-7.72 ppm). Peak appeared at 7.82 and 8.01were ascribed to cis form of -CH=CH-CO (denoted by trans-r,s) protons of the chalcone unit. Peaks for protons of trans form of the same group -CH=CH-CO (denoted by cis-r,s) were supposed to be observed at 8.45 and 8.70 ppm.

The thermal properties of polystyrene derivative (**7**) were evaluated by the thermogravimetric analysis under N_2 atmosphere, and the heating rate was 10 °C/min in the temperature from 30 °C to 500°C. The compound (**7**) lost 5% of its original weight up to 298 °C and was stable up to 320 °C (Table I).

Structural characterization of 2′,4′-dimethoxychalcone, 2, containing polystyrene, 8

Similar to compound **7**, the structure of chalcone containing polystyrene (**8**) was confirmed by FT-IR and ^{1}H NMR spectroscopies. The IR spectrum of this compound (**8**) confirmed the formation of 1,2,3-triazole ring as no signal appeared at around 2104 cm^{-1} for azide group, instead appeared a signal at 1638 cm^{-1} for triazole ring. The absorption band at 3026 cm^{-1} indicated the C-H (str) for triazole ring proton.

The ^{1}H NMR spectrum (Figure 2) of polystyrene derivative (**8**) showed similar peaks as were appeared in compound (**7**). One additional peak appeared at

Table I — Thermogravimetric data for azido end functional polystyrene (PS-N_3) and chalcone containing polystyrenes **7**, **8**, **9**

Compd	Temperature (°C) (5% weight loss)	Temperature (°C) (stability)
PS-N_3	276	300
7	298	320
8	318	330
9	324	335

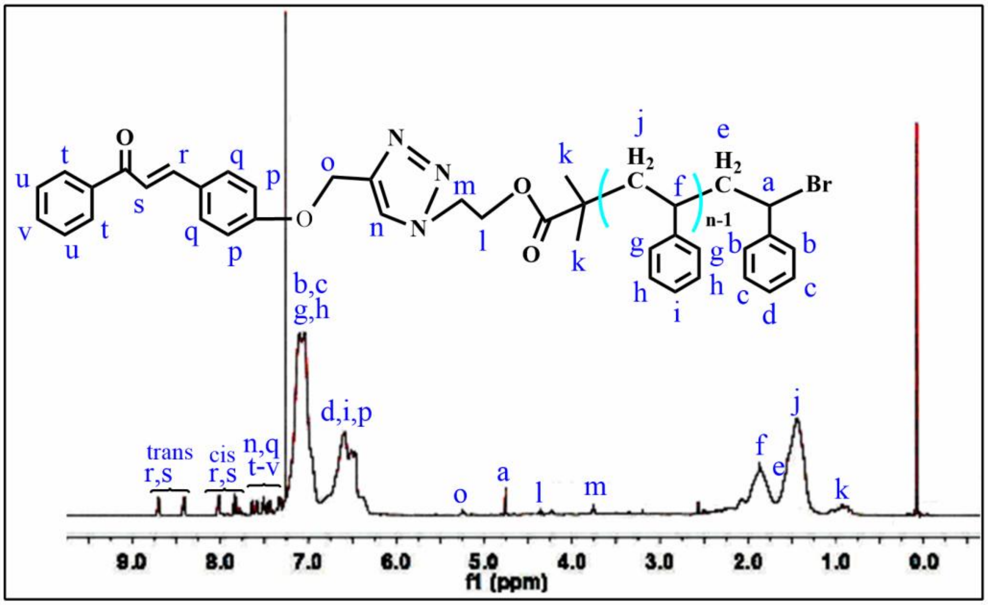


Figure 1 — ^{1}H NMR spectrum of chalcone containing polystyrene **7**. Alphabetic letters indicate the peaks corresponding to the protons of the structure

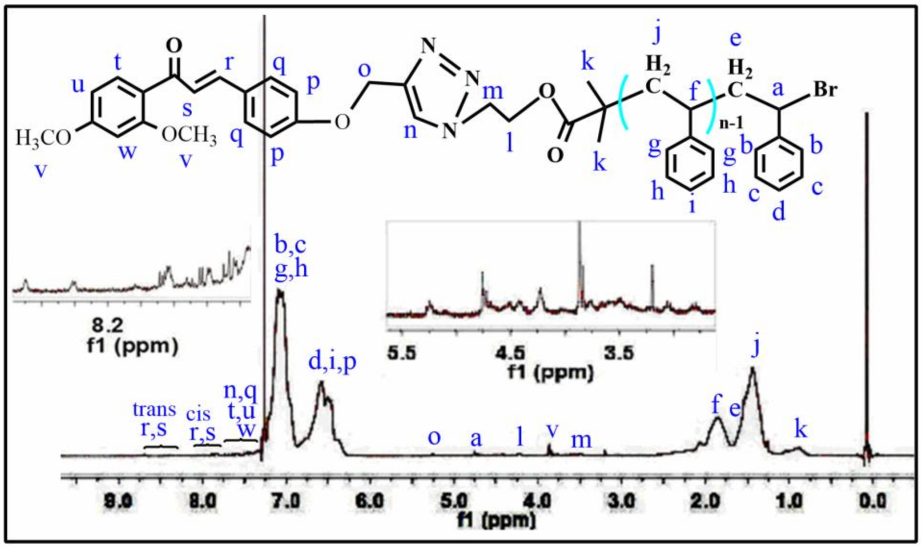


Figure 2 — ^{1}H NMR spectrum of chalcone containing polystyrene **8**. Alphabetic letters indicate the peaks corresponding to the protons of the structure

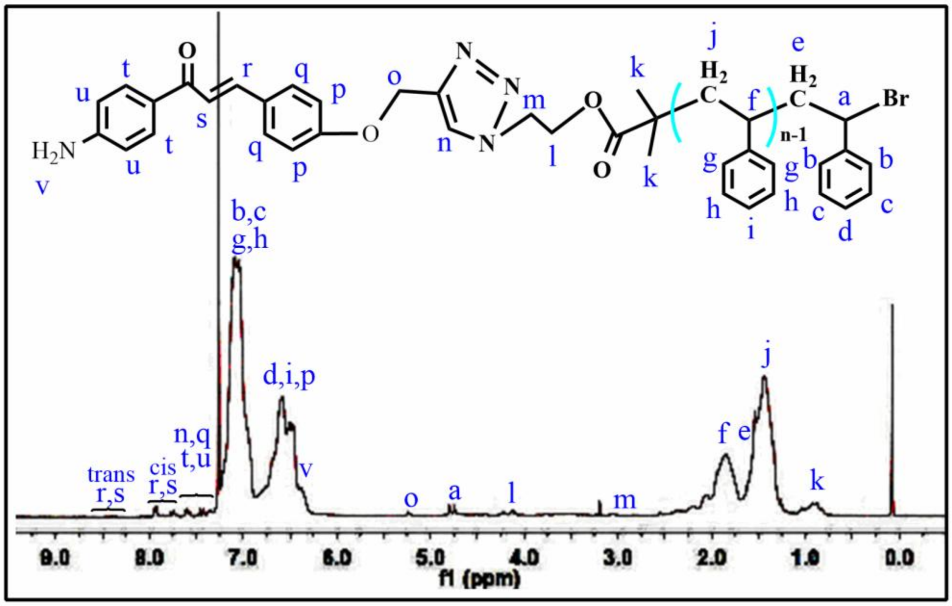


Figure 3 — ^{1}H NMR spectrum of chalcone containing polystyrene **9**. Alphabetic letters indicate the peaks corresponding to the protons of the structure

3.92 ppm was assigned to the $–OCH_3$ protons (denoted by v).

Thermo gravimetric analysis (TGA) of the compound (**8**) showed 5% weight loss up to 318 °C and found to be stable up to 330 °C.

Structural characterization of 4′-aminochalcone, 3, containing polystyrenes, 9

The structure of chalcone containing polystyrene (**9**) was also supported by FT-IR and ^{1}H NMR spectroscopies. The IR spectrum of this compound (**9**) showed a band at 1636 cm^{-1} assigned to 1,2,3-triazole ring and no band was appeared at around 2104 cm^{-1} indicated the successful click reaction between azido polystyrene and 4-propargyloxy-4′-aminochalcone (**6**). Absorption band C-H (str) for triazole ring proton was appeared at 3026 cm^{-1}.

The structure of chalcone containing polystyrene (**9**) and its ^{1}H NMR spectrum are shown in Figure 3. Similar to compounds **7** and **8** the structure of compound (**9**) was supported by its ^{1}H NMR spectrum. All the peaks in the spectrum and their corresponding

Table II — Antibacterial activity of 4-propargylxoychalcones **4**, **5**, **6** and chalcone containing polystyrenes **7**, **8**, **9** against Gram-positive and Gram-negative bacteria

Types of organism	Name of organisms	Zone of inhibition at 250 μg/disc						Zone of inhibition at 500 μg/disc						K (30 μg/ disc)
		P1	P2	P3	Ch1	Ch2	Ch3	P1	P2	P3	Ch1	Ch2	Ch3	
Gram-positive Bacteria	*Staphylococcus aureus*	19	16	12	27	15	19	21	22	19	30	19	23	21
Gram-negative Bacteria	*Escherichia coli*	12	13	10	20	22	19	20	20	15	22	25	22	22

Note: ch1, ch2 and ch3 denote chalcone **4**, **5** and **6**, respectively. P1, P2 and P3 denote polystyrene derivative **7**, **8** and **9**, respectively.

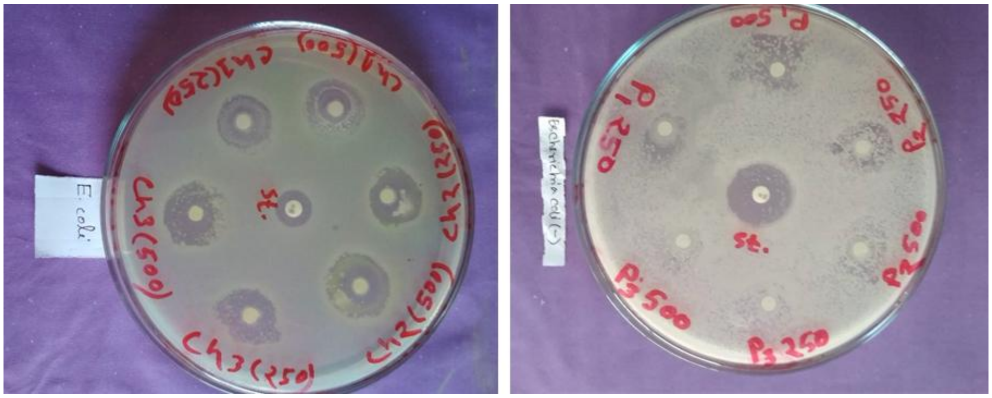


Figure 4 — Zone inhibition test for 4-propargylxoychalcones (**4**, **5**, **6**, denoted as Ch1, Ch2, Ch3) and chaconne containing polystyrenes (**7**, **8**, **9**, denoted as P1, P2, P3) compared to Gram-negative (*Escherichia coli*)

protons of the compound (**9**) are labelled with alphabet letters and shown in Figure 3. All the peaks are also listed in the experimental section.

The TGA thermogram of polystyrene derivative (**9**) showed 5% weight loss up to 324°C and obtained to be stable up to 335°C (Table I).

Antibacterial activity of 4-propargyloxychalcones, 4,5,6 and chalcone containing polystyrenes, 7,8,9

The antibacterial potential of three 4-propargylxoychalcones (**4,5,6)** and their polystyrenes derivatives **(7,8,9)** was evaluated on the basis of inhibition zone diameter against two pathogenic bacteria *viz*. *Escherichia coli* and *Staphylococcus aureus.* Then, these effects (inhibition zone diameter) were compared with that of the standard kanamycin (30 μg/disc). The results revealed that all the polystyrene derivatives (**7,8,9)** and 4-propargylxoychalcones (**4,5,6)** showed potential antibacterial activity against *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative) bacteria, but their potential activity was comparatively higher against the Gram-positive (*Staphylococcus aureus*) than that of the Gram-negative (*Escherichia coli*) bacteria. A noticeable growth in the inhibitory zone was observed with an increase of concentration for all the tested chalcones (**4,5,6**) and their polystyrene derivatives (**7,8,9**). All the compounds showed an increased activity at 500μg/disc than that of 250 μg/disc (Table II). Among the 4-propargylxoychalcones (**4,5,6)** and polystyrenes (**7,8,9)**, 4-propargylxoychalcones (**4)** and its corresponding polystyrene derivatives (**7**) exhibited higher antibacterial activity for Gram-positive (*Staphylococcus aureus*) bacterial strain. On the other hand, 4-propargylxoychalcones (**5)** and its corresponding polystyrene derivatives (**8**) exhibited higher antibacterial activity for the Gram-negative (*Escherichia coli*) bacterial strain than other chalcones (**4,6**) and polystyrene derivatives (**7,9**). Photographic representations of zone inhibition for 4-propargylxoychalcones (**4,5,6)** and their polystyrene derivatives (**7,8,9**) are shown in Figure 4 and Figure 5.

Materials and Methods

Materials

4-hydroxybenzaldehyde, 2,4-dimethoxyacetophenone and 4-aminoacetophenone were purchased from Loba Chemie and used without further purification. Methanol, ethanol and DMF were purified by distillation and used $CaCl_2$ while refluxing for 12 h. Propargyl bromide was purchased from Sigma

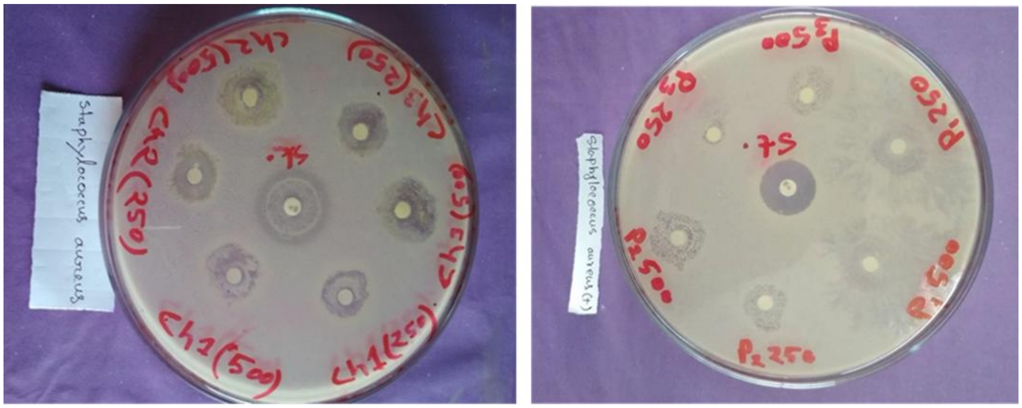
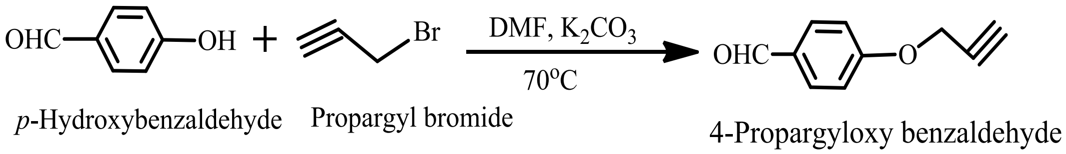


Figure 5 — Zone inhibition test for 4-propargylxoychalcones (**4**, **5**, **6**, denoted as Ch1, Ch2, Ch3) and chaconne containing polystyrenes (**7**, **8**, **9**, denoted as P1, P2, P3) compared to Gram-positive bacteria (*Staphylococcus aureus*)



Scheme I — Reaction scheme for synthesis of 4-propargyloxybenzaldehyde

Aldrich. Potassium hydroxide was purchased from Thomas Baker and purified by reduced pressure distillation. Copper (1) bromide was purified by recrystallization in MeOH and washed with ether. Bipyridine was purchased from Sigma Aldrich. Azido end functional polystyrene (PS-N_3) was synthesized as described in our earlier article[11]. Other reagents were used as received. All solvent were purified by distillation followed by refluxed with Na.

Analytical procedures

All melting points were recorded on an electrical melting point apparatus by an open capillary method and were uncorrected. Fourier Transform Infrared (FT-IR) spectra were measured on a PerkinElmer Spectrum 100, FT-IR Spectrometer and KBr pellets technique was used. ^{1}H NMR spectra were recorded at room temperature and used 400 MHz BRUKER Spectrometer operated in pulse Flourier Transform mode. $CDCl_3$ was used as solvent and the internal reference peak was at 7.26 ppm. Shimadzu UV-1650PC, UV–Visible Spectrophotometer was used to record UV spectra for the compounds. The progress of the reactions and compound's purity were checked by thin layer chromatography. The spots on the TLC were developed into iodine vapor and identified under UV light. Thermal stability of the chalcone containing polystyrenes was observed by Thermo gravimetric Analysis (TGA) measured on Perkin-Elmer, Simultaneous Thermal Analyzer, STA 8000.

Experimental Section

Synthesis of 4-propargyloxybenzaldehyde

In 60 mL DMF, 41 mmol of 4-hydroxy-benzaldehyde and 45 mmol of K_2CO_3 were dissolved at RT and stirred constantly for 1 h. Then, 41 mmol of propargyl bromide was added to the reaction mixture and heated to 70°C. The progress of the reaction was followed by using thin layer chromatography [n-hexane : acetone; 2:1, $\boldsymbol{R}_{\mathbf{f(}\boldsymbol{p}\textbf{-HB)}}$= 0.43, $\boldsymbol{R}_{\textbf{f(product)}}$=0.56]. When the reaction was completed, it was decanted into cold water. A precipitation was obtained as yellowish color which was separated by filtration and finally the product was washed with cold water. The desired product was purified by crystallization from methanol and obtained 44.7 g as yellowish crystal, yield 82.5%, m.p. 74-76°C. IR (KBr): 3210 (C-H), 2123 (C≡C), 1682 (C=O), 1248 (Ar-O), 1174 cm^{-1} (O-CH_2); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.90 (s, 1H, CHO), 7.89 (d, 2H, aromatic protons), 7.12 (d, 2H, aromatic protons), 4.80 (s, 2H, OCH_2), 2.59 (s, 1H, ≡CH); UV-Vis (λ_{max}): 274 nm. The reaction scheme is illustrated in Scheme I.

Synthesis of 4-propargyloxychalcones, 4,5,6

To an ethanolic solution of KOH (10 mL, 3%), acetophenones (**1**,**2**,**3**) (0.625 mmol) and 4-propargyloxybenzaldehyde (0.625 mmol) were added, and the mixture was stirred with magnetic stirrer for overnight at RT. The reaction scheme is shown in Scheme II. The completion of the reaction was checked by TLC [petroleum ether : acetone; 3:1]. Then, 10% HCl was added to the reaction mixture to make the *p*H 9 and extracted using ethyl acetate. Finally, the reaction mixture was washed with brine solution and dried *in vacuo*. The resulting products were 4-propargyloxychalcones **4, 5** and **6** with off white, yellow and yellow-reddish color, respectively.

Compound **4** was recrystallized from ethanol to afford pure product, yield 75%, m.p. 67-68°C. IR (KBr): 3221 (≡C-H), 2111 (C≡C), 1660 (C=O), 1575 (C=C), 1217 ((Ar-O), 1172 cm^{-1} (O-CH_2); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.41-8.02 (m, 7H, aromatic protons), 7.03 (d, 1H, β CH=CH), 7.01 (d, 1H, α CH=CH), 4.74 (s, 2H, OCH_2), 2.54 (s, 1H, ≡CH); UV-Vis (λ_{max}): 335 nm.

5: Yield 72%, m.p. 80-82°C. IR (KBr): 3250 (≡C-H), 2926 (O-CH_3), 2125 (C≡C), 1636 ((C=O), 1582 (C=C), 1222 (Ar-O), 1177 cm^{-1} (O-CH_2); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.06-8.03 (m, 7H, aromatic protons), 6.74 (d, 1H, β CH=CH), 6.70 (d, 1H, α CH=CH), 4.81 (s, 2H, OCH_2), 2.58 (s, 1H, ≡C-H), 1.59 (s, 6H, 2×OCH_3); UV-Vis (λ_{max}): 363 nm.

6: Yield 70%, m.p. 72-72°C. IR (KBr): 3408 (N-H_2), 3257 (≡C-H), 2116 (C≡C), 1640 (C=O), 1583 (C=C), 1220 (Ar-O), 1172 cm^{-1} (O-CH_2); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.03-7.90 (m, 7H, aromatic protons), 6.52 (d, 1H, β CH=CH), 6.50 (d, 1H, α CH=CH), 4.78 (s, 2H, OCH_2), 3.88 (s, 2H, NH_2), 2.59 (s, 1H, ≡C-H); UV-Vis (λ_{max}): 330 nm.

Synthesis of azido end-functional polystyrene (PS-N_3)

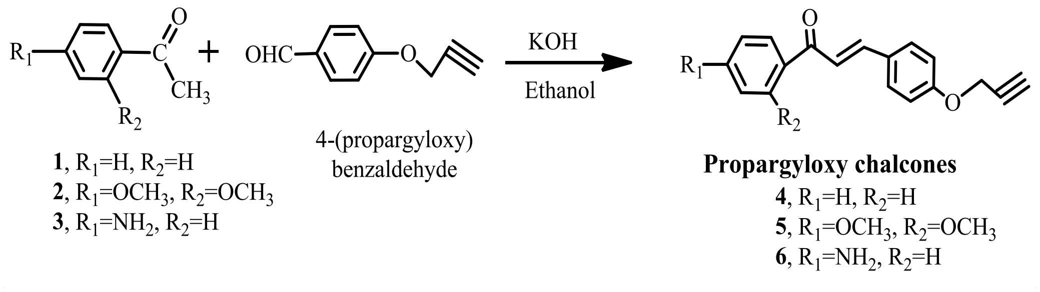
The azide (N_3) end-functional polystyrene (PS-N_3) was prepared by ATRP method starting from 2-bromoethanol and sodium azide. Synthetic procedure and characterization of this polystyrene was reported in our earlier paper[11]. To purify this polymer, it was dissolved in $CHCl_3$ and passed through an alumina column. It was then dried and precipitated in MeOH.

Synthesis of chalcone containing polystyrenes (7,8,9) by click reaction

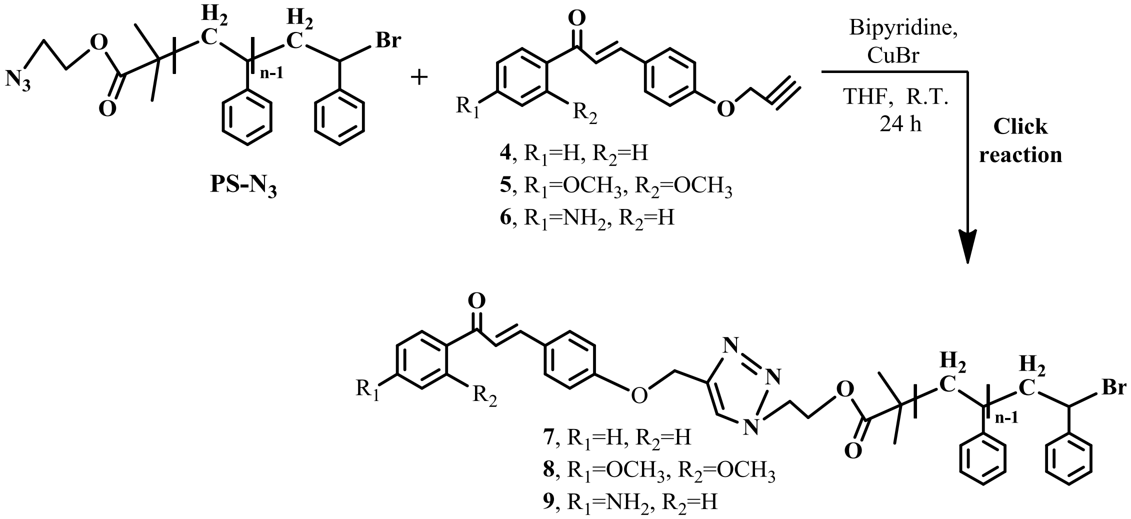
In a Schlenk flask, azido end-functional polystyrene (PS-N_3, Mn = 3363, Mw/Mn = 1.56) (0.0297 mmol), 4-propargyloxychalcones **(4,5,6)** (0.0125 mmol), bipyridine (0.2376 mmol) and THF (5 mL) were added. To make the solution purging, nitrogen gas was used and freeze-pump-thaw degassing was carried out. Then, 0.0297 mmol of CuBr was added which changed it as a reddish brown homogeneous solution. The solution was stirred for 24 h on an oil bath at 35°C, then it was diluted with THF and eliminated the copper catalyst using an alumina column. Using a rotary evaporator, the solvents were concentrated and a complete precipitation of the polymer was obtained in MeOH while stirring overnight. The polymer was washed with MeOH (2.50 mL), filtered and dried at 60°C for 6 h under vacuum. The reaction scheme is shown in Scheme III.

7: IR (KBr): 3026 (C-H triazole ring), 2924 (aromatic C-H), 1638 (1,2,3-triazole ring), 1600 (C=O), 1493 (C=C alkene), 1452 (C=C aromatic) 1261 ((Ar-O), 1173 cm^{-1} (O-CH_2); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.70, 8.45(d, 1H, cis CH=CH), 8.01, 7.82(d, 1H, trans CH=CH), 7.28-7.72 (m, 8H, aromatic and triazole rings protons), 6.90-7.22 (m, 8H, aromatic protons of polymeric and adjacent benzenes), 6.30-6.75 (m, 4H, aromatic protons), 5.25 (s, 2H, CH_2-triazole ring), 4.75 (m, 1H, CH-Br), 4.38 (m, 2H, CH_2-O), 3.75 (m, 2H, CH_2-N), 1.85 (m, 1H, CH-polymeric benzene), 1.45 (d, 2H, CH_2-polymeric unit), 0.85 (s, 6H, 2CH_3).

8: IR (KBr): 3026 (CH triazole ring), 2923 (aromatic C-H), 1638 ((1,2,3-triazole ring) 1602 (C=O), 1493 (C=C alkene), 1452 cm^{-1} (C=C aromatic); ^{1}H NMR



Scheme II — Reaction scheme for synthesis of 4-propargyloxychalcones



Scheme III — Reaction scheme for the synthesis of chalcone containing polystyrenes

($CDCl_3$, 400 MHz): δ 8.70, 8.40 (d, 1H, cis CH=CH), 8.10, 7.85 (d, 1H, trans CH=CH), 7.35-7.70 (m, 6H, aromatic and triazole rings protons), 6.90-7.25 (m, 8H, aromatic protons of polymeric and adjacent benzenes), 6.40-6.75 (m, 4H, aromatic protons), 5.25 (s, 2H, CH_2-triazole ring), 4.75 (m, 1H, CH-Br), 4.25 (m, 2H, CH_2-O), 3.92 (s, 6H, 2×OCH_3), 3.50 (m, 2H, CH_2-N), 1.75-2.00 (m, 1H, CH-polymeric benzene), 1.50 (d, 2H, CH_2-polymeric unit), 0.85 (s, 6H, 2CH_3).

9: IR (KBr): 3458 (NH_2), 3026 (CH triazole ring), 2924 (aromatic C-H), 1636 (1,2,3-triazole ring), 1600 (C=O), 1493 (C=C alkene), 1452 cm^{-1} (C=C aromatic); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.65, 8.30(d, 1H, cis CH=CH), 7.95, 7.75 (d, 1H, trans CH=CH), 7.30-7.65 (m, 7H, aromatic and triazole rings protons), 6.95-7.25 (m, 8H, protons of polymeric aromatic and adjacent benzenes), 6.50-6.80 (m, 4H, aromatic protons), 6.35 (s, 2H, NH_2), 5.20 (s, 2H, CH_2-triazole ring), 4.75 (m, 1H, CH-Br), 4.15 (m, 2H, CH_2-O), 3.10 (m, 2H, CH_2-N), 1.70-2.00(m, 1H, CH-polymeric benzene), 1.45 (d, 2H, CH_2-polymeric unit), 0.85 (s, 6H, 2CH_3).

Conclusion

Three 4-propargylxoychalcones **4,5,6** have been synthesized from 4-propargyloxybenzaldehyde and acetophenones. Subsequently, alkyne-azide click reaction was carried out successfully between the 4-propargyloxychalcones **4,5,6** and azide end-functional polystyrene (PS-N_3) to obtain chalcone containing polystyrenes **7,8,9**. All the structures of the products **4-9** have been characterized by FT-IR, ^{1}H NMR and UV-Vis spectroscopies. Thermal properties of the polystyrene derivatives **7,8,9** have also been evaluated by TGA, which showed that azide end-functional polystyrene (PS-N_3) was stable up to 300 °C. The polystyrene derivatives **7,8,9** were observed to be stable up to 320°, 330° and 335°C, respectively. We have tested the antibacterial activity of the 4-propargyloxychalcones **4,5,6** and their polystyrene derivatives **7,8,9** against Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*) bacteria. The results showed that all the tested compounds have moderate antibacterial activity which increased with an increase of concentration. The results also revealed that 4-propargylxoychalcone **4** and its corresponding polystyrene derivatives **7** exhibited higher antibacterial activity for Gram-positive (*Staphylococcus aureus*), and 4-propargylxoychalcone **5** and its corresponding polystyrene derivatives **8** exhibited higher activity for Gram-negative (*Escherichia coli*) bacterial strain.

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