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Research Article

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Copolymerization of N-tert-butylacrylamide with Quinolinylacrylate: Synthesis, Characterization, Monomer reactivity ratios, Mean sequence length and Antimicrobial activity

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ABSTRACT

A novel acrylic monomer Quinolinylacrylate (QA) was synthesized by esterification of 8-Hydroxy quinoline and Acryloyl chloride. The monomer (QA) was characterized by Fourier transform infrared spectroscopy (FT-IR). Copolymers of N-tert-butylacrylamide (NTB) with Quinolinylacrylate (QA) at different feed composition was prepared by free radical polymerization at 60°C using 2,2'-azobisisobutyronitrile (AIBN) as an initiator and methanol/water (3:1) as a solvent. The copolymers compositions were characterized using ^{1}H-NMR data. The monomer reactivity ratios were determined by the application of linearization methods such as Fineman-Ross (r_1= 8.0, r_2= 0.60), Kelen-Tudos (r_1= 8.0 , r_2= 0.61) . Mean sequence lengths of copolymers were estimated from r_1 and r_2 values. Antimicrobial activity of the copolymers was also investigated against various microorganisms like bacteria (Escherichia coli , Pseudomonas aeruginosa and Klebsiella pneumoniae), fungi (Aspergillus flavus , Candida albicans and Cryptococcus) . The activity of copolymers against bacteria and Fungi increases with increasing mole % of QA content.

Keywords: Free radical polymerization, Copolymer composition, reactivity ratios, Mean sequence length, Antimicrobial activity.

INTRODUCTION

Now Functional polymers are synthesized and used not only for their macromolecular properties but also for the properties of the functional groups [1]. In recent years, some comprehensive work has been published on functional monomers and their polymers [2, 3]. Acrylate homopolymers along with their copolymers are used in various fields such as films, fibers, filaments, coating, lithography, lacquers,adhesives, printing inks and binders [4-6].Moreover, the N-substituted acrylamides are used to prepare thermosensitive materials like poly(N-isopropylacrylamide) and copolymers of N-ethylacrylamide and styrene [7]. The thermosensitive polymers present also great potential in application as drug delivery system [8], human gene vectors [9] and biocatalysts [10].Copolymer composition and monomer distribution in the copolymer are dependent on the reactivity ratios. ^{1}H-NMR spectroscopic analysis has been established as a powerful tool for the estimation of copolymer composition [11, 12].The monomer reactivity ratios determined by conventional linearization methods. Antimicrobials gained interest in both academic research and industry due to their potential to provide quality and safety benefits to many materials. Contamination by microorganism is of great concern in several areas such as medical devices, health care products, water purification systems, hospital and dental equipments etc. One possible way to avoid the microbial contamination is to develop antimicrobial agents. Antimicrobial agents are those materials capable of killing pathogenic microorganisms. Antimicrobial agents of low molecular weight are used for the sterilization of water, as antimicrobial drugs, as food

preservatives, and for soil sterilization [13]. The use of antimicrobial polymers offers promise for enhancing the efficacy of some existing antimicrobial agents and minimizing the environmental problems accompanying conventional antimicrobial agents by reducing the residual toxicity of the agents, increasing their efficiency and selectivity, and prolonging the lifetime of the antimicrobial agents.

The literature survey reveals that M. Bankova et al[14] synthesized copolymerization of 5-chloro-8-quinolinyl acrylate (AQ) and 5-chloro-8-quinolinyl methacrylate (MQ) . The obtained monomers and polymers were characterized by spectroscopic methods (IR , ^{1}H and ^{13}C-NMR), gel-permeation chromatography (GPC) and differential scanning calorimetry (DSC). Rajni T. Patel et al [15] synthesized and characterized a new functional acrylic monomer , 8-quinolinyl acrylate (8-QA) and copolymerized it with methyl methacrylate (MMA) and studied their thermal behavior.W.S. Kim and co-workers [16] reported radical copolymerization of 8-quinolinyl acrylate (QA) with acrylamide (AM) was carried out in dimethyl sulfoxide at 70°C in order to synthesize hydrophilic polymers which are able to release 8-Hydroxyquinoline (HQ). From the composition of poly(QA-co- AM) , the monomer reactivity ratios were determined to be 1.97 for QA and 0.34 for AM. From the hydrolysis of the polymers, it was shown that the release of HQ increased with increasing contents of the hydrophilic AM in the copolymer and with increasing pH of the release medium. M. Bankova and co-workers[17] prepared new copolymers of 5-chloro-8-quinolinyl acrylate (AQ) and acrylamide (AM) of various composition by radical polymerization. The obtained polymers were characterized by spectroscopic methods (IR, ^{1}H and ^{13}C NMR) and differential scanning calorimetry (DSC). The product of the reactivity ratios is near unity and the monomer pair exhibits a random tendency in copolymerization. The antimicrobial activity of some AM-AQ copolymers was tested on Gram-positive and Gram-negative bacteria and the minimum inhibitory concentrations were determined. The tested compounds exhibit comparatively high antibacterial activity. R.Chitra et al. [18] prepared copolymers of N-cyclohexylacrylamide(NCA) and 8-Quinolinylacrylate(QA) .The resulted copolymers were characterized by ^{1}H-NMR . Copolymerization, reactivity ratios, thermal behavior and antimicrobial activity were also computed.

The present work describe the synthesis and characterization of poly (NTB-co-8QA). Copolymer composition was obtained from ^{1}HNMR data .The determination of monomer reactivity ratio of the monomers,mean sequence length and antimicrobial activity of the copolymers were also reported.

EXPERIMENTAL SECTION

Materials

Acrylonitrile was first washed with 5% NaOH solution in water to remove the inhibitor and then with 3% Orthophosphoric acid solution in water to remove basic impurities. Then the Acrylonitrile was washed with double distilled water and dried over anhydrous $CaCl_2$. The Acrylonitrile was then distilled in an atmosphere of nitrogen and reduced pressure. It was then collected in a clean dry amber colored bottle and kept in the refrigerator at 5^{o}C.AIBN was recrystallized from chloroform. All the solvents were purified by distillation prior to their use.

Preparation of N-tert-butylacrylamide(NTB)

The Monomer N-tert-butylacrylamide was prepared by the reaction of t-butyl alcohol with acrylonitrile[19]. N-tert-butylacrylamide was recrystallized in warm dry benzene. The white crystals have a mp. 94^{o}C and the yield was 87 %. The monomer was confirmed by both ^{1}H-NMR and ^{13}C-NMR spectroscopy.

^{1}H-NMR Spectroscopy $CDCl_3$, δ(PPM)

The ^{1}H-NMR spectra of monomers and copolymers were recorded on the GSX-400 spectrometer (JEOL, Tokyo, Japan) operating at 400 MHz respectively in $CDCl_3$. The following peaks appear in NTB spectrum; at 1.42 ppm for tert-butyl protons, at 5.59-6.28 ppm for vinyl protons and at 7.27 ppm for N-H proton.

^{13}C-NMR($CDCl_3$), δ(ppm): δ 164.80(CH_2 = C(H)-<u>CO</u>-NH..); δ 132.93(CH_2 =<u>C</u>(H)-CO-NH…); δ 122.82(<u>CH_2</u>=C(H)-CO-NH..) ; δ 51.37(-<u>C</u>$(CH_3)_3$; δ 28.77 (-C (<u>C</u>$H_3)_3$

Preparation of 8-Quinolinylacrylate (QA)

Acryloyl chloride was prepared by reacting acrylic acid with benzoyl chloride. The 8-Quinolinyl acrylate (QA) comonomer was prepared by esterification of 8-Hydroxy quinoline and acryloyl chloride. IR spectral analysis confirmed the monomer formation.

IR (KBr, cm^{-1}) : 1741 for C=O of ester group, 1634 for olefinic (C=C) stretching, 3066 C-H vibration of aromatic ring and 894 for –C-H bending mode of vinyl group.

Synthesis of Poly (NTB-co-QA)

A total feed of 5gm of monomers N-tert-butylacrylamide, 8-Quinolinylacrylate and 50 mg of AIBN initiator were dissolved in 25ml of methanol/water (3:1) placed in a standard reaction tube to obtain a homogenous solution. The

mixture was flushed with oxygen free dry nitrogen gas. The inlet and outlet of the reaction tube were closed by means of rubber tubing's and pinch cock. The reaction vessel is then immersed in a thermostatic water bath maintained at 60°c. The copolymerization reaction was allowed to proceed for an appropriate duration (6 hr) that would give a conversion below 10%. After the reaction vessel was removed from the thermostat and cooled under the tap. The solution poured in ice cold water to precipitate the co-polymer and the copolymer washed with methanol. It was then dried in vacuum oven for 24 hours.

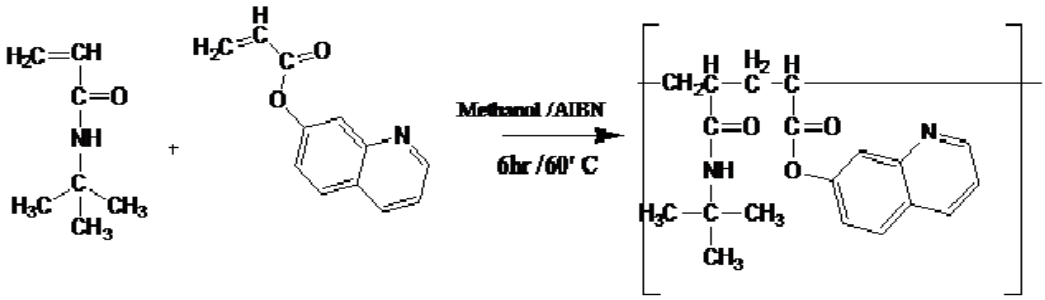
Antimicrobial Studies

The synthesized compounds in the present investigation have been tested for antimicrobial activity by well diffusion method. The organisms selected for the antibacterial activity was carried out by using *Escherichia coli* , *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The organisms selected for the antifungal activity was carried out by using *Aspergillus flavus, Candida albicans and Cryptococcus*. Antimicrobial activity was evaluated by measuring the zone of inhibition in mm against the test microorganisms. DMSO was used as solvent control. Ciprofloxacin was used as reference antibacterial agent. Ketoconazole was used as reference antifungal agent. The plates are prepared as per the standard methods [20].

RESULTS AND DISCUSSION

Copolymerization

A series of copolymers of N-tert-butylacrylamide(NTB) and 8-Quinolinylacrylate (QA) were prepared by free radical polymerization in methanol at 60°C using AIBN as initiator. The schematic representation of the copolymer is given below:



Characterization

^{1}H -NMR Spectroscopy

The ^{1}H-NMR spectrum of copolymer, N-tert-butylacrylamide(NTB) and 8-Quinolinylacrylate(QA) (0.5 :0.5) is shown in Figure 1 . The following peaks appear in the copolymer spectrum: at 0.9 ppm for CH_3 group, at 1.1 - 1.4 ppm for tert-butyl group, at 1.5 – 2.5 ppm and 2.9 ppm for CH and CH_2 backbone group, at 7.0 -7.7 ppm due to aromatic protons and at 8.0 - 8.1 ppm for N-H proton (Figure- 1).

Determination of copolymer composition

The copolymer composition was determined by ^{1}H-NMR spectral analysis of the copolymer. The Assignment of the resonance peaks in the ^{1}H-NMR spectrum allows the accurate evaluation of the content of each kind of monomer incorporated in to the copolymer chain.

The QA peak area is used to determine the copolymer composition. Resonance signals at 7.0 -7.7 ppm corresponds to aromatic proton, and their integrated intensity of this peak was compared to the total intensities of all the peaks in the copolymer spectrum, which is a measure of their relative areas. The copolymer compositions can be obtained using

$$X_{(QA)} = \frac{13\,A(\text{Quinolinyl})}{6A_{total}+4A(\text{Quinolinyl})} \qquad (1)$$

Where X= mole fraction and A=peak area. Table 1 gives the values of the corresponding mole fraction in the copolymers. The kinetic behavior was determined by plotting the mole fraction of QA in the comonomer feed (M_2) against that in the copolymer feed (m_2) (Figure- 2).

Reactivity ratios

From the monomer feed ratios and the resultant copolymer compositions, the reactivity ratios of monomer 1 (NTB) and monomer 2 (QA) were evaluated by the methods of Fineman –Ross (F-R) Kelen-Tudos (K-T).The significant parameters of F-R and K-T and equation are presented in Table- 2 .The reactivity ratios for NTB (r_1) and QA(r_2) from the F-R plot (Figure 3) and K-T plot(Figure 4) were shown in the Table-3 respectively.

The values of r_1 is greater than 1 and r_2 is less than 1.r_1 shows that NTB favors homo-propagation as opposed to cross propagation and r_2 shows that QA favors cross propagation over homo-propagation. The r_1 and r_2 together showed that the NTB is generally more reactive than QA , hence the copolymer contains a higher proportion of NTB units.

Mean sequence length

The mean sequence length was determined using the pertinent equation:

$$l_1 = r_1 \left(\frac{M_1}{M_2}\right) + 1 \qquad \text{---------- (2)}$$

$$l_2 = r_2 \left(\frac{M_2}{M_1}\right) + 1 \qquad \text{---------- (3)}$$

Where r_1 and r_2 are the reactivity ratios and $[M_1]$ and $[M_2]$ represents the concentration of NTB and QA respectively, in the monomer feed. The mean sequence lengths of copolymer are given in Table 4.It is significant to note that from the Table -4, the QA units decreases in a linear fashion in the polymer chain as the concentration of QA decreases in the monomer feed. In other words the NTB units increases in a linear fashion in the polymer chain as the concentration of NTB increases in the monomer feed. This suggests that the copolymers are weakly order with predominantly a random distribution of monomeric unit in the polymer chain.

Antimicrobial Activity

The synthesized compounds in the present investigation have been tested for antimicrobial activity by well diffusion method. The organisms selected for the antibacterial activity was carried out by using *Escherichia coli* , *Pseudomonas aeruginosa* and *Klebsiella pneumonia* as mentioned in Table 5. The organisms selected for the antifungal activity was carried out by using *Aspergillus flavus , Candida albicans and Cryptococcus* as shown in Table 5. From the table 5 it noticed that the activity of polymers against bacteria and fungi is increases as the QA content in the copolymer increases.

Table - 1: Composition data for free radical polymerization of NTB with QA

Mole fraction of NTB in feed (M_1)	Mole fraction of QA in feed (M_2)	Mole fraction of NTB in copolymer(m_1)	Mole fraction of QA in copolymer(m_2)	$F=M_1/M_2$	$f=m_1/m_2$
0.2	0.8	0.4519	0.5481	0.2500	0.8245
0.3	0.7	0.6637	0.3363	0.4286	1.9735
0.4	0.6	0.7425	0.2575	0.6667	2.8835
0.5	0.5	0.8438	0.1562	1.0000	5.4021
0.6	0.4	0.9146	0.0854	1.5000	10.7096
0.7	0.3	0.9439	0.0561	2.3333	16.8253
0.8	0.2	0.9642	0.0358	4.0000	26.9330

Table -2 : Fineman–Ross and Kelen- Tudos parameters for the copolymers of Poly(N-tert- butylacrylamide-co-Quinolinylacrylate)

$G = F(f-1)/f$	$H=F^2/f$	$\eta = G/\alpha + H$	$\varepsilon = H/\alpha + H$
-0.0532	0.0758	-0.1847	0.2632
0.2114	0.0931	0.6924	0.3050
0.4355	0.1542	1.1886	0.4209
0.8149	0.1851	2.0512	0.4659
1.3599	0.2101	3.2202	0.4975
2.1946	0.3236	4.0959	0.6040
3.8515	0.5941	4.7768	0.7368

$\alpha = (H_{max} \times H_{min})^{1/2} = 0.2122$

Table - 3 : Copolymerization parameter , for the NTB (r_1) and QA (r_2) copolymer

Methods	r_1	r_2	r_1r_2
Fineman-Ross method	8.0	0.60	4.80
Kelen-Tudos method	8.0	0.61	4.88

Table - 4: Mean sequence lengths in copolymers of Poly(N-tert-butylacrylamide-co–Quinolinyl acrylate) [a]

QA in feed M_2 (mol %)	l_1	l_2	l_1: l_2	Distribution [b]
0.8	3.0	3.4	3:3	NNNQQQNNN
0.7	4.43	2.4	4:2	NNNNQQNNNN
0.6	6.33	1.9	6:2	NNNNNNQQNNNNNN
0.5	9.0	1.6	9:2	$(N)_9QQ(N)_9$
0.4	13.0	1.4	13:1	$(N)_{13}Q(N)_{13}$
0.3	19.67	1.26	20:1	$(N)_{20}Q(N)_{20}$
0.2	33.0	1.15	33:1	$(N)_{33}Q(N)_{33}$

[a] *r_1 = 8.0 and r_2 = 0.6 ;* [b] *(N=NTB ; Q=QA)*

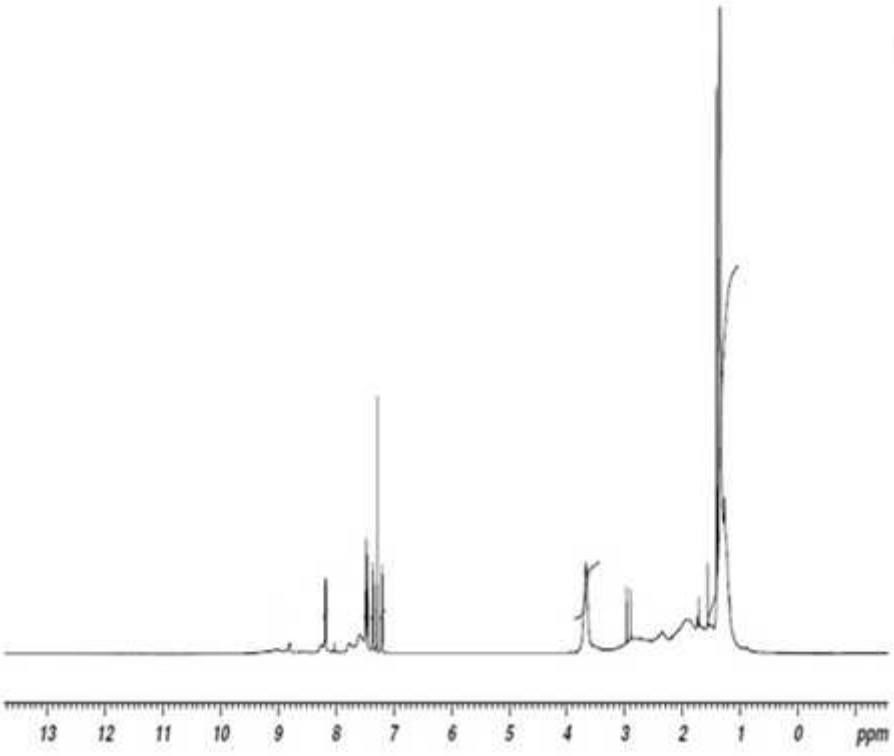


Figure-1: ^{1}H-NMR Spectra of Poly(N-tert-butylacrylamide-co–Quinolinylacrylate)(0:5 , 0:5)

Table - 5 : Antimicrobial Activity of copolymers

S.No	Organisms (Bacteria)	Zone of Inhibition (mm)			
		CONTROL (DMSO)	QA-NTB (0.3:0.7)	QA-NTB (0.5:0.5)	QA-NTB (0.7:0.3)
1.	*Escherichia coli*	No zone	18	20	40
2.	*Pseudomonas aeruginosa*	No zone	18	18	20
3.	*Klebsiella pneumonia*	No zone	25	28	50
Organisms (Fungi)					
1.	*Aspergillus flavus*	No zone	20	33	45
2.	*Candida albicans*	No zone	35	35	50
3.	*Cryptococcus*	No zone	30	31	55

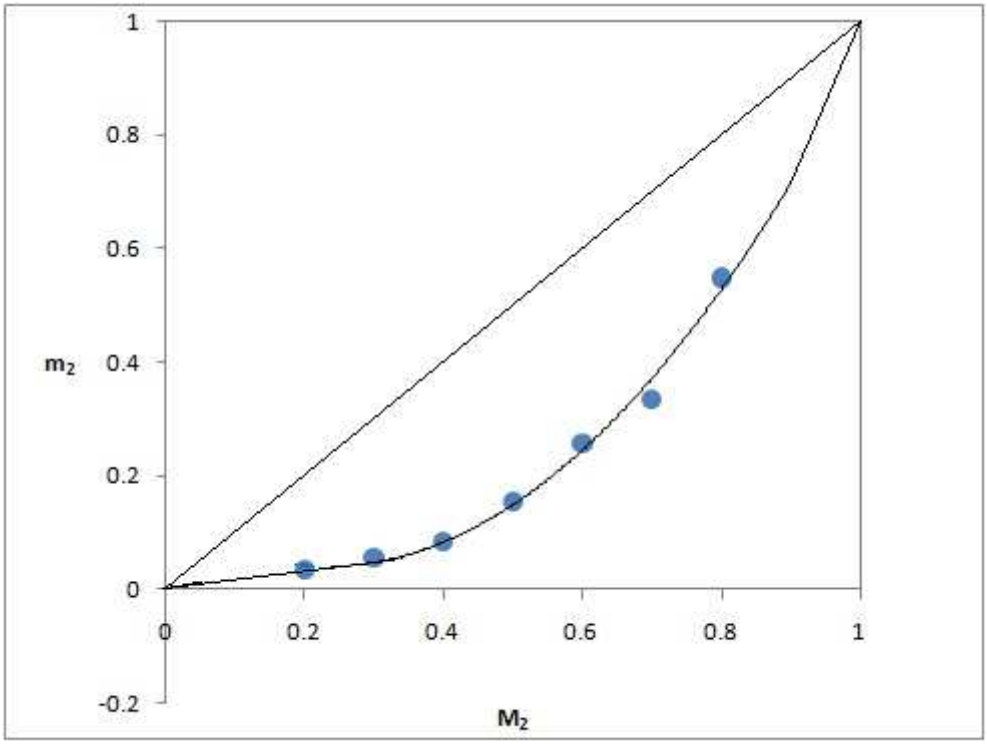


Figure - 2: Copolymer composition diagram of Poly (NTB-co-QA)

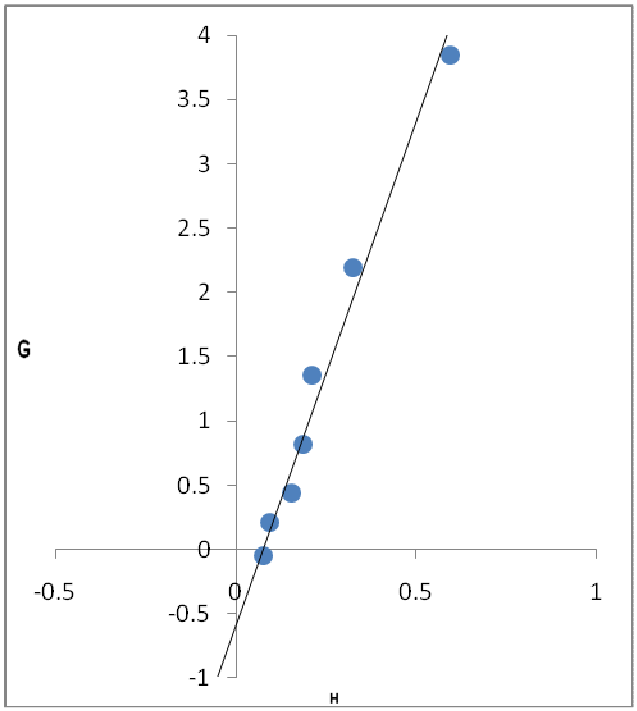


Figure - 3: Fineman -Ross plot of Poly(NTB-co-QA)

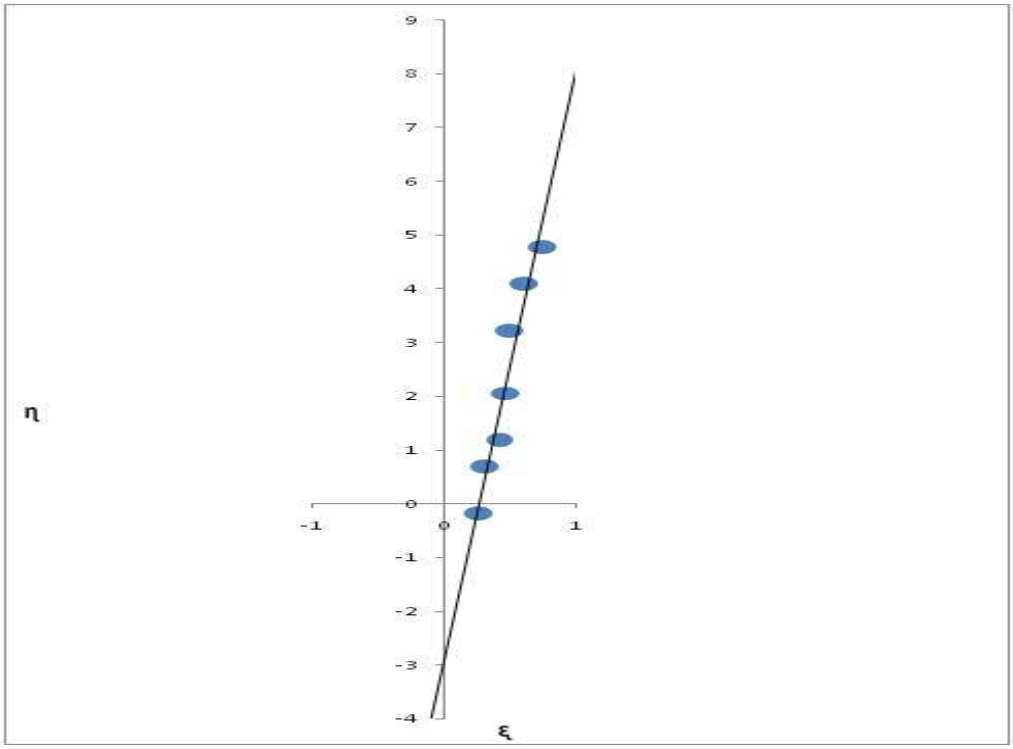


Figure - 4: Kelen –Tudos plot of Poly(NTB-co-QA)

CONCLUSION

A novel acrylate/acrylamide based copolymers were synthesized by free radical polymerization technique. The monomers and copolymers were characterized by spectroscopic methods. The reactivity ratio of NTB (r_1) is greater than QA (r_2) and the product of $r_1 . r_2 > 1$; this indicates that the copolymers are weakly order with predominantly a random distribution of monomeric unit in the polymer chain. The results of antimicrobial activity shows that the copolymers containing QA shows excellent growth inhibition against microorganisms and as QA content in the copolymers increases the growth inhibition of microorganisms also increases.

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