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Synthesis of Nanoparticles Based on pH-sensitive Alginate-g-polyacrylonitrile Copolymer and Its Application in Drug Loading

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DIFFERENT samples of sodium alginate grafted by polyacrylonitrile copolymer were synthesized via the grafting process through a free radical polymerization mechanism. Graft structures were characterized and confirmed using Fourier Transform Infrared (FT-IR) spectroscopy and X-Ray diffraction (XRD). Thermogravimetric analysis (TGA) showed that the graft copolymers acquired higher thermal stability compared to native alginate. Moreover, its solubility in several solvents was examined as compared to that of native alginate. The main outcome of this paper was that a grafted copolymer with hydrophobic enrichment (Wt% = 150 %) of polyacrylonitrile as a core was sufficient to form stabilize colloidal system within nanoparticles have Z-average diameter equal 55 nm and sodium alginate as a shell. The SA-g-PAN graft copolymer showed a higher degree of swellability in the basic medium than in acidic medium. The consequence of that was the SA-g-PAN graft copolymer exhibited pH-responsive properties. Moreover, the formed nanoparticles were loaded by a hydrophobic model and proofed by a transmission electron microscope (TEM).

Keywords: Sodium alginate, Polyacrylonitrile, Graft, Nanoprecipitation, pH-sensitive, Encapsulation.

Introduction

Natural polysaccharides and their derivatives constitute a group of polymers broadly used in biomedical and pharmaceutical fields for the controlled delivery of drugs. Conventional drug delivery systems targeting specific sites are restricted by the non-targeting properties of drug carriers, breakdown of active drugs during circulation, solubility ,and stability of drugsand the nature of drug carriers[1-3]. The superiority of controlled drug delivery systems is due to their enhancement todrug activity as they protect them against the environment and minimize the drug side effects [4,5]. Natural polysaccharides havemany advantages as they are available, less expensive,nontoxic and biodegradable [4,6,7].Sodium alginate (SA) is one of the most efficient biopolymers used in pharmaceutical and medical industries due to its biocompatibility and biodegradability[8,9]. Sodium alginate (SA) is mainly extracted from the cell walls of brown algae.It is a linear copolymer with homo-polymeric blocks of (1-4)-linked-D-mannuronate and -L-guluronate, covalently bonded together[10].Nanoparticles formation fromSAcould offer a synergistic therapeutic effect [11-13].Graft copolymerization with vinyl monomers using radical initiators is the most suitable method for adding new properties to SA for broadening its medical use.Acrylonitrile (AN) isone of the most frequentlyused vinyl monomersdue toitshigh grafting efficiency[14,15]. Recently, poly(acrylonitrile) (PAN) hasalso been considered as a good drug carrier [16].

Several techniqueswere used to encapsulate drugs within SA-g-PAN such asethanol injection,emulsion solvent evaporation, emulsion solvent diffusion and ionic gelation. But nanoprecipitation-solvent displacement or interfacial deposition of a polymer following the

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displacement of a semi-polar solvent miscible with water from a lipophilic solution [17-19] seems to be the simplest technique and the most reproducible in nanoparticles preparation.In this study, SA-g-PAN copolymers have been prepared and characterized using FTIR, XRD and TGA. Also, SA-g-PAN nanoparticles were prepared using nanoprecipitation technique, and then they were characterized by TEM and applied in drug loading using *p*-phenylenediamine, as a model drug.

Experimental

Materials:

Sodium alginate (SA) was supplied from Nice Chemicals Pvt. Ltd., Kerala, India.Acrylonitrile (AN) was purchased from Merck (Schuchardt OHG, Hohenbrunn, Germany); it was purified by simple distillation before use. Potassium persulfate (KPS) was supplied from Hopkin & Walliams, Ltd., London. *p*-Phenylenediamine was purchased from Sigma-Aldrich. Solvents were of analytical grades and used without further purification.

Synthesis of grafted copolymer (SA-g-PAN)

The grafting process was performed as follow; 0.5 g of SA with predetermined amount of KPSwas dissolved in 25 ml distilled water under N_2 gas flowfor 15 min in definite temperature. Then, definite amount of AN was added dropwisely and the grafting process were continued for the required time and temperature. PAN (homopolymer) was removed by soxhlet extraction using dimethylformamide (DMF) till constant weight of dried samples.

The grafting parameters were calculated according to the following equations[20,21];

$$\text{Graft yield (\%G)} = ((W_1-W_0) / W_0) \text{ X100} \quad (1)$$

$$\text{Homopolymer (\%H)} = ((W_2-W_1) / W_3) \text{ X100} \quad (2)$$

$$\text{Grafting efficiency (\%GE)} = ((W_1-W_0) / (W_2-W_0)) \text{ X 100} \quad (3)$$

Where;

W_0, W_1 = the weights of the initial alginate and grafted copolymer, respectively.

W_2 = Total weight of grafted copolymer and that of the homopolymer before soxhlet extraction.

W_3 = weight of acrylonitrile.

Nano-precipitation technique for nanoparticles formation

50 mg of the prepared grafted copolymer was dissolved in a solvent mixture of THF:H_2O (95:5) v/v. Then, using a micropipette, 10 ml of distilled water was added with a rate of 0.1 ml.min^{-1}. After complete addition, certain amount of distilled water was added one timeto freeze the nanoparticles dispersion. Finally, the solution is centrifuged at 10,000 rpm at 20°C for 30 min to remove THF[22].

Encapsulation of p-phenylenediamine:

Encapsulation of *p*-phenylenediamine took place during the formation of nanoparticles. *p*-phenylenediamine was chosen because it is colored so efficiency of loading onto nanoparticles can be easily measured the (In section 2.4.1. Loading efficiency onto nanoparticles). Firstly, 1 mg of *p*-phenylenediamine was dissolved in 1 ml of THF. Then, 0.1 ml of this solution was added before the nanoprecipitation step. The successful encapsulation was verified by TEM.

Loading efficiency onto nanoparticles

Firstly, colorimetric absorbance of 1 mg ml $^{-1}$ solution of PPD in THF was measured and found to be equal to 0.218.

Second, this amount was added to the solution of copolymer in THF and nanoparticles were collected by centrifugation and the residual was obtained by evaporation of water and the solid was dissolved in THF. The absorbance of PPD in THF was equal to 0.01

From the two absorbance values, the loading efficiency was calculated to be equal to 92 %.

Instruments used in the study:

FT-IR spectra were recorded on Testcan Shimadzu Infra-Red-Spectrophotometer (model 8000), the range of wave number from 400-4000 cm^{-1} at 25°C. The thermal behavior of the grafts was analyzed using Thermogravimetric analysis, TGA-50H Shimadzu analyzer. The temperature range was 0-700°C with heating rate 10°C.min^{-1} under N_2atmosphere.XRD patterns were recorded using equipment model (X'Pert PRO PANalytical, Netherland), which operated at 45 kV and 30 mA using filtered Cu Kα radiation (λ = 1.5406 Å) in

the 2θ range from 10° to 50° and high score plus software. TEM images were taken by transmission electron microscope (JEOL, TEM 1400, Japan) at acceleration voltage of 80-100 kV.

Results and Discussion

Effect of various reaction parameters onto grafting process

In this section, various copolymerization parameters affecting the grafting process have been studied as follows;

Effect of KPS concentration

The effect of KPS concentration onto the grafting of AN onto SA was studied keeping the other reaction conditions constant (Fig.1). The KPS concentration was changed from 0.02 to 0.10 mol.L^{-1} while all the other parameters were kept constant being AN concentration 4 mol.L^{-1}, reaction temperature 60^{o} C and the copolymerization reaction was conducted for 2 h.Theobtained data revealed thatboth graft yield (G%) and graft efficiency (GE%) increased with increasing the initiator concentration reaching their maximum values (224% and 92%, respectively) at 0.08 mol.L^{-1} of KPS. At this concentration of KPS, the homopolymerpercent (H%) acquired the lowest value (12%). A further increase in KPS concentration led to a decrease in both G% and GE%. This may be due to the competition between initiation and termination reactions through chain transfer to initiator.

Effect of AN concentration

The effect of monomer concentration onto the grafting process was studied keeping other reaction conditions constant (Fig.2). The AN concentration was changed from 1 to5mol L^{-1} while the KPS concentration was kept constant at 0.08 mol.L^{-1}, the temperature at 60^{o}C and the reaction time for 2 h. The results indicated that both graft yield (G%) and graft efficiency (GE%) increased with increasing the AN concentration reaching their maximum values (224% and 95%, respectively) at 4mol.L^{-1} of AN. At this concentration of AN, the homopolymer percent (H%) acquired the lowest value (12%).

A further increase in AN concentration led to a decrease in both G% and GE%. This is because of the degradative chain-transfer which form unreactive species with low ability for propagation[21].

Effect of reaction temperature

The effect of reaction temperature onto the grafting process was studied keeping other reaction conditions constant (Fig.3). The temperature of the polymerization process was changed from 55 to 70^{o}C, while the KPS concentration was kept constant at 0.08 mol. L^{-1}, the AN concentration at 4 mol.L^{-1} and the reaction time for2h. It was found that the optimum temperature at which maximumG% and GE%(224% and 97%, respectively) and lowest H% (12%) wereobtained is 60^{o}C.Further increase in the reaction temperature led to a decrease in G% and GE%which was probably due to possible chain-transfer reactions which came on the expense of the grafting process.

Effect of reaction time

The effect of reaction time onto the graft copolymerization process was studied keeping the other reaction conditions constant (Fig.4). The reaction time range was changed from 1 to 4 h, while the KPS concentration was kept constant at 0.08 mol.L^{-1}, the monomer concentration at 4 mol.L^{-1} and the reaction temperature at 60 ^{o}C. It was found that the maximumG% and GE% (224% and 87%, respectively), with the lowest H% (12%), were obtained at a reaction time of 2h and then their values decreased. The decrease in graft yield % at higher reaction time (after 2h) was probably due to the consumption of the majority of the monomer and the partial depolymerization of the growing chains due to the difficulty of termination by recombination as a result of increase in the viscosity of the medium with the time of copolymerization.

Characterization of sodium alginate-g-polyacrylonitrile

Fourier-transform infrared spectroscopy (FTIR)

FTIR spectra of SA and SA-g-PAN are shown in Fig.5. FTIR of SA (Fig. 5a) confirmed the presence of four strong absorption bands at 1155, 1073, 1030 and 895 cm^{-1} which are characterizing the polysaccharide structure. The strong broad absorption band at 3400 cm^{-1} is attributed to –OH stretching vibration of sodium alginate with –OH bending at 1030 cm^{-1}.

Two bands were observed around1620 and 1420 cm^{-1}due to stretching vibrations of carboxylate group –COO^{-} (asymmetric and

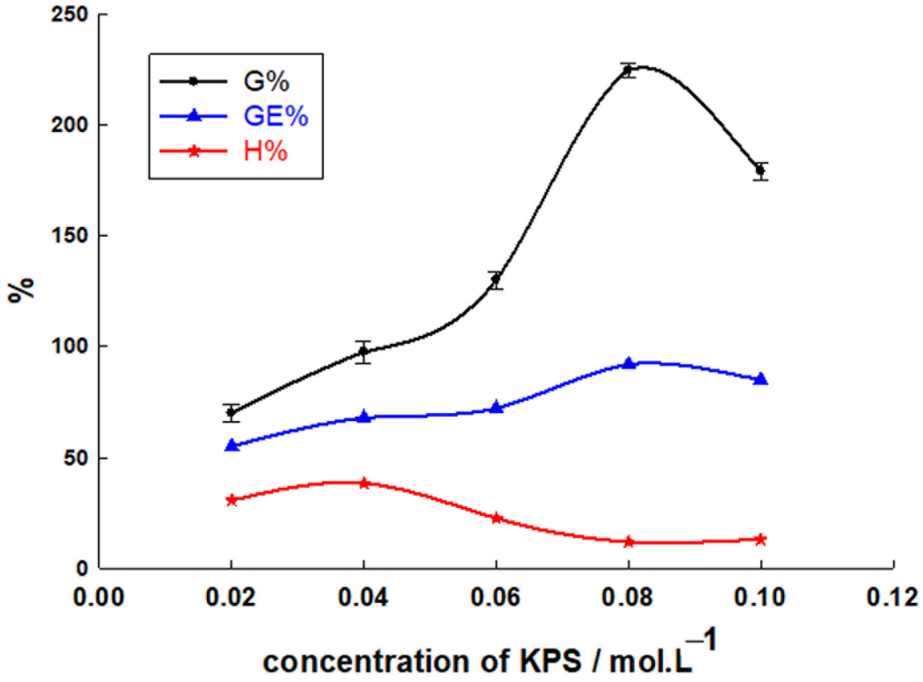

Figure 1. Effect of KPS concentration on graft yield (G%), graft efficiency (GE%) and homopolymer percent (H%).([AN]= 4 mol.L^{-1}, reaction time = 2 h and reaction temperature = 60 °C)

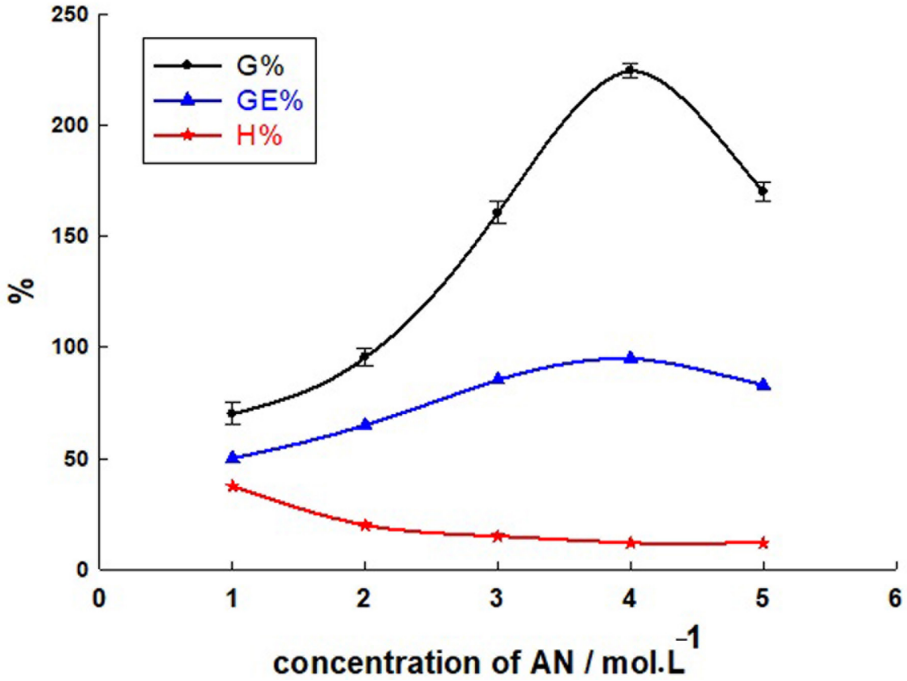

Figure 2. Effect of AN concentration on graft yield (G%), graft efficiency (GE%) and homopolymer percent (H%) ([KPS]= 0.08 mol L^{-1}, reaction time = 2 h and reaction temperature = 60 °C)

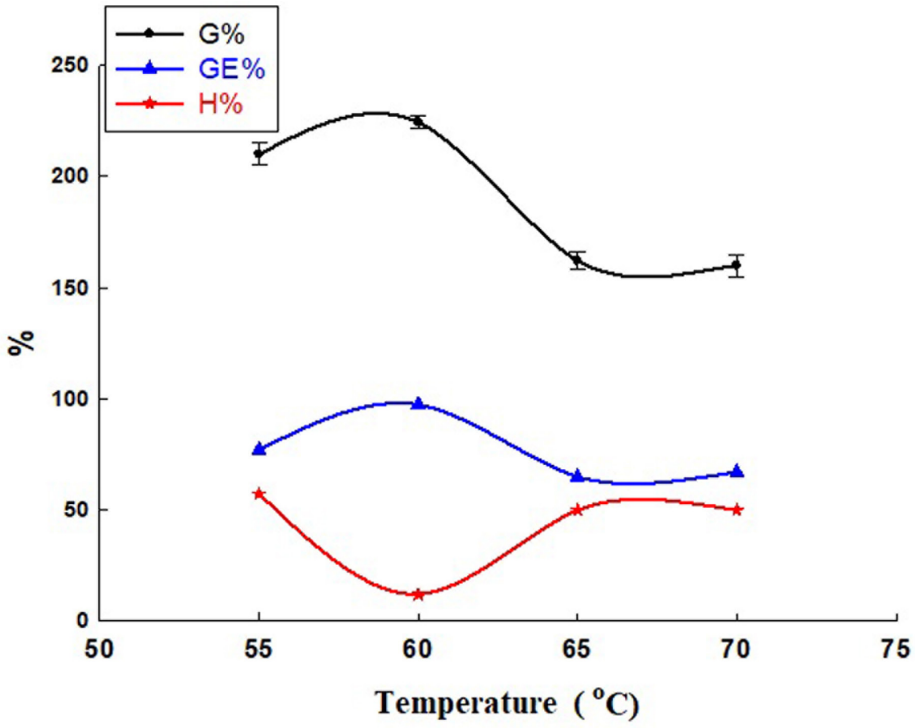

Figure 3. Effect of reaction temperature on graft yield (G%), graft efficiency (GE%) and homopolymer percent (H%) ([KPS]=0.08 mol.L^{-1}, [AN] = 4 mol.L^{-1} and reaction time =2h)

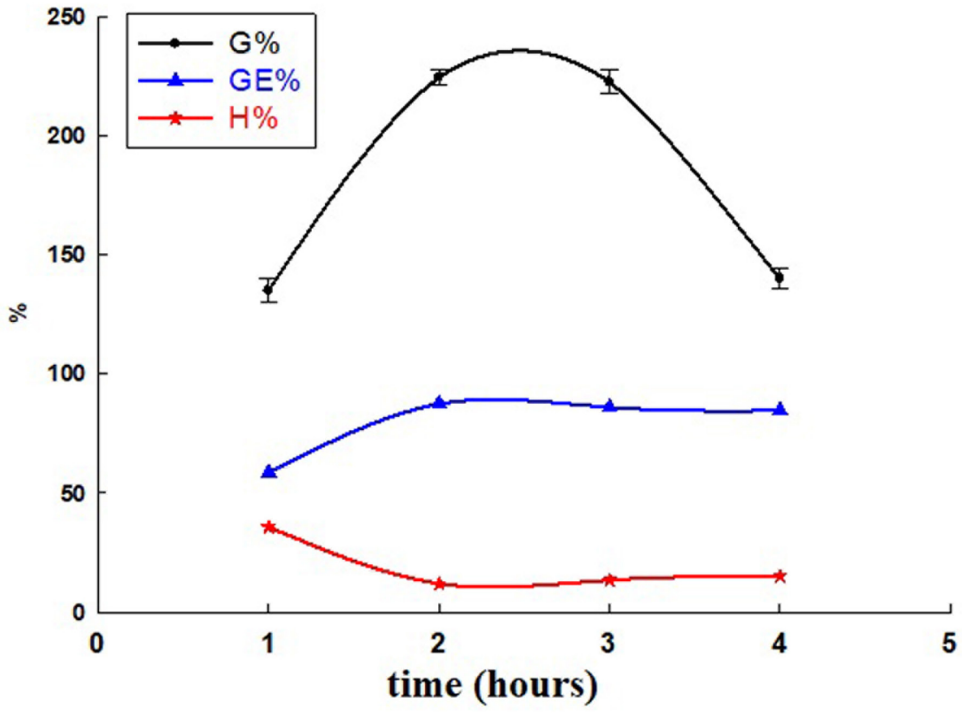

Figure 4. Effect of reaction time on graft yield (G%), graft efficiency (GE%)and homopolymer percent (H%) ([KPS]=0.08 mol.L^{-1}, [AN] = 4 mol.L^{-1} and the reaction temperature = 60 °C)

symmetric), respectively.These observations are in a good agreement with those reported in several literature[23-25]. Upon grafting SA with PAN (SA-g-PAN, Fig. 5b), additional new absorption bands appeared at 2244 and 2934 cm^{-1} specific for –CN and-CH_2-, respectively of PAN backbone which confirm the grafting of PAN onto SA[26] .

Thermal Analysis:

TGA of sodium alginate and its grafted copolymer (SA-*g*-PAN) are shown in Fig.6.TGA of SA(Fig. 6a) showed two degradation steps. The first stepoccurred over temperature range 225-275°C which was due to the decarboxylation and liberation of CO_2gas. The second degradation step, which occurred over temperature range 625-700°C, was due to the degradation of SA to carbonaceous residue and Na_2CO_3. 10% and 20% weight losses of SA were observed at 240, 253, and 300°C, respectively. This is a quit well matching with other previous data in literature [23-25].However, in case of SA-*g*-PAN (Fig. 6b), the initial decomposition temperature was observed at300°C.Weight losses 8 %, 9 % and 13% of the copolymer were observed at 240, 253, and 300°C, respectively. In other words, thetemperature at which the graft loses 20% of its weight (344°C) proved that PAN has improved the thermal stability compared to SA alone (253°C). Table 1 summarizes some readings obtained from Fig. 6.

SA-g-PAN

X-Ray diffraction (XRD)

X-Ray diffraction pattern of SAshowed three peaks at 27.4º, 31.7º and 45.2º (Fig. 7a) indicating its crystalline nature[23]. At SA-*g*-PAN (Fig. 7b), a new diffraction peak appeared at 16.9º corresponding tothe presenceof PAN [27] indicating successful grafting of PAN ontoSA .

Solubility of SAand SA-g-PAN

The solubility of SAand SA-g-PAN wastested in different solvents. Table 2 summarizes these data. SAwas freely soluble in water and insoluble in organic solvents at room temperature. The grafted copolymer, SA-*g*-PAN, was insoluble in DMF and DMSO but it was solubleina mixture of THF:H_2O (95:5 v/v).

Swelling in different pH values

Swelling of SA-*g*-PAN was studied in different pH values (pH = 4 and 10). The grafted copolymer showed a higher degree of swellability in basic medium (DS% = 166) than in acidic medium (DS%= 114). That could be explained thatPAN has itshighest degree of water uptake in basic medium[22,28].

Transmission Electron Microscopy (TEM)

Transmission electron microscope (TEM) showed spherical nanoparticles of SA-*g*-PAN. As shown in Fig.8a, nanoparticles are clearly observed with average diameter about 55 nm, indicating the successful synthesis of nanoparticles using nanoprecipitation process. On the other hand, in diluted suspension of loaded nanoparticles with *p*-phenelyenediamine as a hydrophobic model drug(Fig. 8b), the diameter of encapsulated nanoparticles was increased to 156 nm.

Conclusions

Grafted copolymers based on SA-*g*-PAN were prepared and characterized by FTIR, TGA, and XRD. FTIR and XRD confirmed the synthesis of the grafted copolymer. TGA showed that PAN has improved SA thermal stability in SA-*g*-PAN compared to SA alone. Nanoparticles based on SA-*g*-PAN were fabricated by nanoprecipitation technique with an average diameter of about 55 nm. The diameter of these nanoparticles was increased to 156 nm after loading with *p*-phenylenediamine as a hydrophobic drug model indicating the successful encapsulation process. Based on these obtained results, the prepared nanoparticles could be used in drug loading therapeutic applications.

Declarations of interest

none

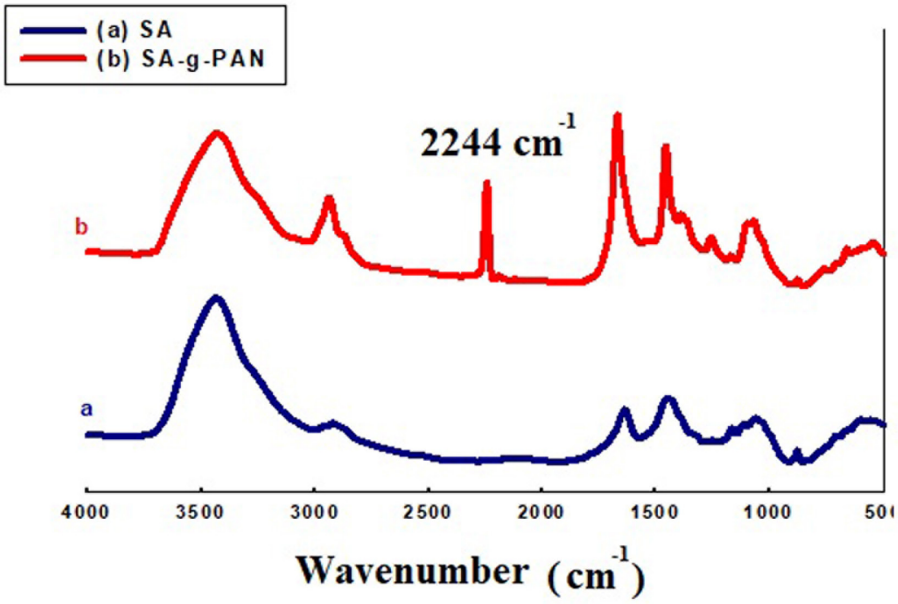

Figure 5.Infrared spectra of (a) sodium alginate SA and (b) grafted copolymer SA-g-PAN

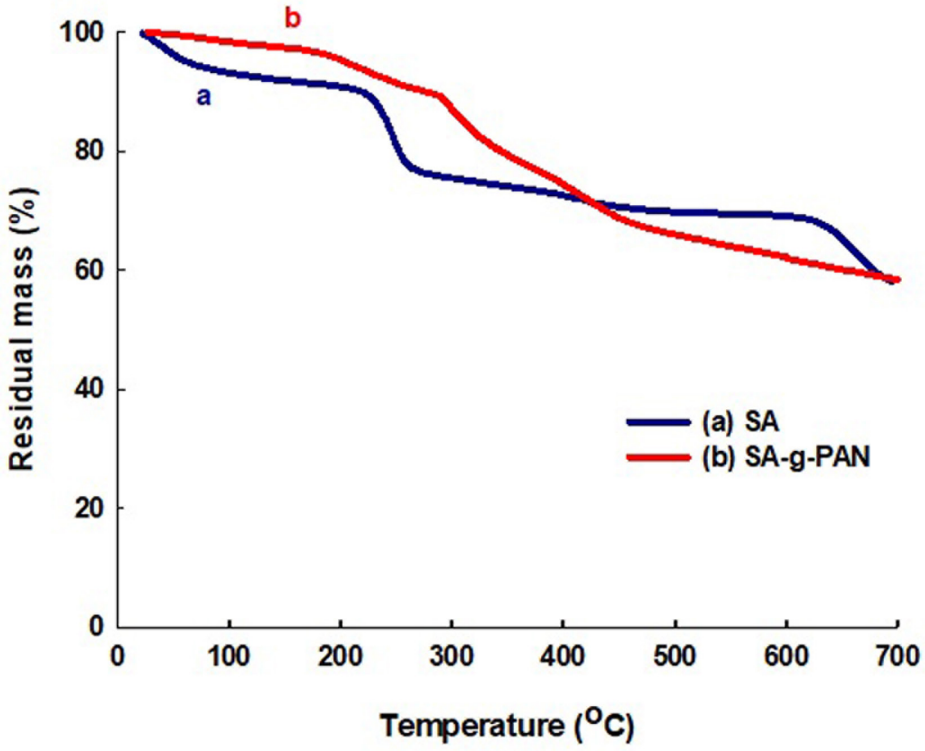

Figure 6.Thermal gravimetric analysis of (a) sodium alginate and (b) grafted copolymer

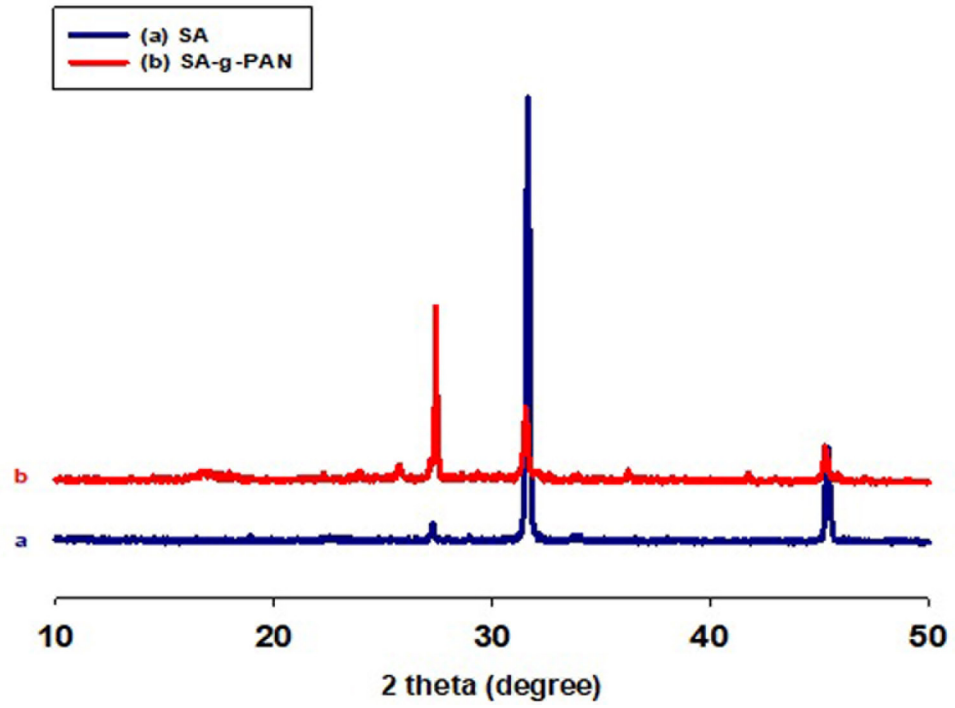

Figure 7: X-Ray diffraction of (a) sodium alginate (SA) and (b) grafted copolymer SA-g-PAN

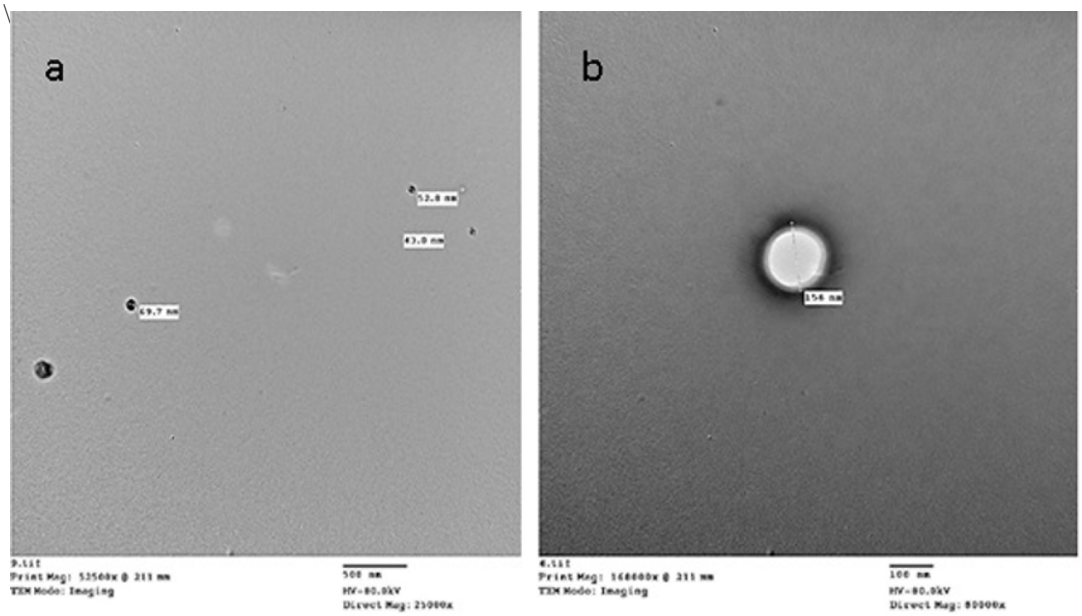

Figure 8. TEM images of prepared nanoparticles based on grafted copolymer SA-g-PAN a) unloaded and b) loaded with p-pheneylenediamine.

TABLE 1. TGA of Sodium alginate and Grafted copolymer SA-g-PAN

Polymers	Initial Decomposition Temp. (IDT) (°C)	Temperature (°C)		Weight loss (%) at 300 °C
		10 % wt. loss	20% wt. loss	
SA	225	240	253	25
SA-g-PAN	360	277	344	13

TABLE 2. Solubility behavior of Sodium alginate (SA) and Grafted copolymer SA-g-PAN in different solvents

Solvent	**SA**	**SA-g-PAN**
Water	Soluble	Insoluble
Methanol	Insoluble	Insoluble
Ethanol	Insoluble	Insoluble
Dimethylsulphoxide (DMSO)	Insoluble	Insoluble
N,N′- Dimethylformamide (DMF)	Insoluble	Insoluble
Tetrahydrofuran (THF)	Insoluble	Soluble in THF:H_2O 95:5 % (v/v)

References

1. Hare, J. I., Lammers, T., Ashford, M. B., Puri, S., Storm, G. and Barry, S. T., Challenges and strategies in anti-cancer nanomedicine development: An industry perspective. *Advanced Drug Delivery Reviews*108, 25-38 (2017).

2. Shi, J., Kantoff, P. W., Wooster, R. and Farokhzad, O. C., Cancer nanomedicine: progress, challenges and opportunities. *Nature Reviews Cancer*17, 20-37 (2016).

3. Singh, P., Ren, X., He, Y., Wu, L., Wang, C., Li, H., Singh, V. and Zhang, J., Fabrication of β-cyclodextrin and sialic acid copolymer by single pot reaction to site specific drug delivery. *Arabian Journal of Chemistry*In press, https://doi.org/10.1016/j.arabjc.2017.1011.1011 (2017).

4. Maiti, S., Ranjit, S. and Sa, B., Polysacchride-based graft copolymers in controlled drug delivery. *International Journal of pharmtech research*2, 1350-1358 (2010).

5. Parmar, N. S. and Shivprakash. in *Controlled and Novel Drug Delivery* (ed N.K. Jain) Ch. 1, 1-2 (CBS publishers and Distributors, 1997).

6. Bhardwaj, T. R., Kanwar, M., Lal, R. and Gupta, A., Natural gums and modified natural gums as sustained-release carriers. *Drug Development and Industrial Pharmacy*26, 1025-1038 (2000).

7. Youssef, A. M., Nasr, H. E., Ramadan, A. M. and Mohamed, W. S., MMT Modified with Cationic Carbohydrates as Deliver Carrier for Praziquentel Drug. *Egyptian Journal of Chemistry* 55, 143-159 (2012).

8. Ciocoiu, O., Staikos, G. and Vasile, C., Thermoresponsive behavior of sodium alginate grafted with poly(N-isopropylacrylamide) in aqueous media. *Carbohydrate Polymers*184, 118-126 (2018).

9. Taher, M. A., Omer, A. M., Hamed, A. M., Ali, A. M., Tamer, T. M. and Eldin, M. S. M., Development of Smart Alginate/chitosan Grafted Microcapsules for Colon Site-specific Drug Delivery. *Egyptian Journal of Chemistry* 62, 1037-1045 (2019).

10. Sand, A., Vyas, A. and Gupta, A. K., Graft copolymer based on (sodium alginate-g-acrylamide): Characterization and study of Water swelling capacity, metal ion sorption, flocculation and resistance to biodegradability. *International Journal of Biological Macromolecules*90, 37-43 (2016).

11. Bilal, M., Rasheed, T., Iqbal, H. M. N., Li, C., Hu, H. and Zhang, X., Development of silver nanoparticles loaded chitosan-alginate constructs with biomedical potentialities. *International Journal of Biological Macromolecules*105, 393-400 (2017).

12. Kumar, C. S. S. R. and Mohammad, F., Magnetic nanomaterials for hyperthermia-based therapy and controlled drug delivery. *Advanced Drug Delivery Reviews*63, 789-808 (2011).

13. Zamora-Mora, V., Fernández-Gutiérrez, M., González-Gómez, A., Sanz, B., Román, J. S., Goya, G. F., Hernández, R. and Mijangos, C., Chitosan nanoparticles for combined drug delivery and magnetic hyperthermia: From preparation to in vitro studies. *Carbohydrate Polymers*157, 361-370 (2017).

14. Zohuriaan-Mehr, M. J. and pourjavadi, A., New Polysacchride-g-polyacrylonitrile Copolymers: Synthesis and Thermal Characterization. *Polymers for Advanced Technologies*14, 508-516 (2003).

15. VD, A. and SC, R., Graft polymerization: Starch as a model substrate. *Journal of Macromolecular Science - Reviews in Macromolecular Chemistry & Physics*39, 445-480 (1999).

16. Nie, H. L., Ma, Z., Fan, Z., Branford-White, C. J., Ning, X., Zhu, L. and Han, J., Polyacrylonitrile fibers efficiently loaded with tamoxifen citrate using wet-spinning from co-dissolving solution. *International Journal of Pharmaceutics*373, 4-9 (2009).

17. Martínez Rivas, C. J., Tarhini, M., Badri, W., Miladi, K., Greige-Gerges, H., Nazari, Q. A., Galindo Rodríguez, S. A., Román, R. Á., Fessi, H. and Elaissari, A., Nanoprecipitation process: From encapsulation to drug delivery. *International Journal of Pharmaceutics*532, 66-81 (2017).

18. Letchford, K. and Burt, H., A review of the formation and classification of amphiphilic block copolymer nanoparticulate structures: micelles, nanospheres, nanocapsules and polymersomes. *European Journal of Pharmaceutics and Biopharmaceutics*65, 259-269 (2007).

19. Mora-Huertas, C. E., Fessi, H. and Elaissari, A., Polymer-based nanocapsules for drug delivery. *International Journal of Pharmaceutics*385, 113-142 (2010).

20. Kim, J. Y., Ha, C. S. and Jo, N. J., Synthesis and Properties of biodegradable chitin-graft-poly(l-lactide) copolymers. *Polymer International*51, 1123-1128 (2002).

21. Sabaa, M. W., Mohamed, N. A., Mohamed, R. R., Khalil, N. M. and Soliman, S. M. A., Synthesis, characterization and antimicrobial activity of

poly (N-vinyl imidazole) grafted carboxymethyl chitosan. *Carbohydrate Polymers*79, 998-1005 (2010).

22. Soliman, S. M. A., Mohamed, M. E. and Sabaa, M. W., Synthesis, characterization and application of gelatin-g-polyacrylonitrile and its nanoparticles. *polymer Bulletin*75, 1403-1416 (2018).

23. Soliman, S. M. A., Ali, A. M. and Sabaa, M. W., Alginate-based hydrogel for water treatment *Desalination and Water Treatment*94, 129-136 (2017).

24. Sun, Y.-J., Zhao, X., Illeperuma, W. R. K., Chaudhuri, O., Oh, K. H., Moony, D. J., Vlassak, J. J. and Suo, Z., Highly stretchable and tough hydrogels. *Nature*489, 133-136 (2012).

25. Liang, C. X. and Hirabayashi, K., Improvements of the physical properties of fibroin membranes with sodium alginate. *Journal of Applied Polymer Science*45, 1937-1943 (1992).

26. Salisu, A., Sanagi, M. M., Naim, A. A., Karim, K. J. i. A., Ibrahim, W. A. W. and Abdulganiyu, U., Alginate graft polyacrylonitrile beads for the removal of lead from aqueous solutions. *polymer Bulletin*73, 519–537 (2015).

27. Yang, L., Guo, J., Wu, J., Yang, Y., Zhang, S., Song, J., An, Q. and Gong, Y., Preparation and properties of a thin membrane based on sodium alginate grafting acrylonitrile. *RCS Advances*7, 50626-50633 (2017).

28. Radhakrishnan, N., Lakshminarayana, Y., Devi, S. U. and Srinivasan, K. S. V., Studies on Graft Copolymarization of Acrylonitrile Onto Sodium Alginate *Journal of Macromolecular Science, Part A: Pure and Applied Chemistry*31, 581-591 (1994).

تحضير جسيمات نانونية مبنية علي بوليمر مشترك من الجينات والبولي اكليرونيتريل الحساسة لدرجة الحامضية وتطبيقه في تحميل الدواء

مجدي سبع وديد فرج، ريهام رشاد محمد علي، ياسمين عبد السلام السيد محمد، سليمان مهاود عبد اللطيف سليمان
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تم تحضير ثلاث مختلفة من صوديوم ألجينات المطعم بالبولي أكريلونيتريل عن طريق تقنية التطعيم خلال البلمرة بالالكترون الحر. تم تاكيد و توصيف ألجينات المطعم باستخدام التحليل الطيفي للأشعة تحت الحمراء و انحراف أشعة-اكس. التحليل الحراري أظهر انبوليمر المشترك اعلي ثبات حراري عن ألجينات الأصلي. بالعلاوة علي ذلك تم فحص قابليته علي الذوبانية في مذيبات مختلفة بالمقارنة مع ألجينات الاصلي. النتيجة الرئيسية من هذا البحث هي ان البوليمر المشترك غني بالبولي اكريلونيتريل الكاره للماء و هذا كان كافيا للمحافظة علي ثبات النظام المعلق مكون من جسيمات نانونية بقطر ٥٥ نانوميتر. أظهر البوليمر المطعم المشترك صوديوم ألجينات مطعم بالبولي اكريلونيتريل درجة انتفاش في الوسط القوي اكبر من الوسط الحمضي. نتيجة ذلك البوليمر صوديوم ألجينات مطعم بالبولي اكريلونيتريل اصبح له حساسية اتجاه درجة الحموضة الوسط. علاوة علي ذلك تم تكوين حسيمات النانونية محملة بنموذج كاره للماء وتم اثباته الميكروسكوب الالكتروني النافذ.