Manufacturing or Formation of Polyacrylamide Hydrogel

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Abstract

Experimental analysis shows the effect of pH and ionic strength shows that hydrogels respond to change in environment during swelling. The swelling ratio increases with increase in pH and with increase in ionic strength and the swelling decreases as electrostatic attraction increases between the chains. Hydrogels prepared according to various proportions of the monomers, acrylamide and acrylic acid have different swelling properties. The swelling ratios of various batches largely depends on the ratio of monomers taken in the reaction mixture. As per observations it's clear that as the AAm/AAc ratio increase the swelling ratio also increase up to 70/30 beyond that swelling reduce. The swelling ratio again increase at 50/50 then decrease. The optimum value for AAm/AAc will be 70/30 have maximum swelling ratio. Swelling measurements of the powdered hydrogel indicated the absorption of considerably high amount of water. A highly viscous gel was formed upon the addition of initiator, potassium persulfate in the reaction mixture. Cross-linking is carried out between two monomers AAm and AAc. For preparing 70/30 monomer ratio, amount of MBA was increased to 0.06, 0.07 and 0.08 g and the swelling ratios. The swelling ratio of hydrogel at various time of hrs. in which the hydrogel put in water from time 2-20 hrs. From the table it's clear that the swelling ratio increase with increase the time. The optimum time for maximum swelling ratio is between 18-22 hrs. The copolymer with monomer ratio 70/30 of acrylamide and acrylic acid was synthesized by maintaining reaction temperatures of 50 °C, 60 °C and 70 °C. 0.5 gm of each sample were put in 500 mL distilled water for a period of 24 hours. Optimum value of temperature is 60 °C.

Keywords – Electrosensitive Hydrogel Synthesis, Acrylamide and Acrylic acid, Swelling ratio, AAm/AAc Monomer Ratio.

1. INTRODUCTION

Hydrogel products constitute a group of polymeric materials hydrophilic structure of which renders them capable of holding large amounts of water in three-dimensional networks. These products have number of industrial and environmental areas of application considered to be of prime importance. Natural hydrogels gradually replaced by synthetic types due to their higher water absorption capacity, long service life and wide varieties of raw chemical resources. Hydrogels to absorb water arises from hydrophilic functional groups attached to polymeric backbone and their resistance to dissolution arises from cross-links between network chains. Hydrogels have defined as two- or multicomponent systems consisting of a three-dimensional network of polymer chains and water that fills the space between macromolecules.Natural Hydrogels were gradually replaced by synthetic hydrogels which has long service life, high capacity of water absorption and high gel strength.Hydrogel-forming natural polymers include proteins such as collagen and polysaccharides such as starch, alginate. Hydrogels traditionally prepared by chemical polymerization methods. Hydrogels three-dimensional, hydrophilic, polymeric networks capable of absorbing large amounts of water or biological fluids.

Literature Reviews

Acrylic acid (AA) and sodium or potassium salts and acrylamide (AM) frequently use in hydrogel industrial production. Two pathways to prepare acrylic hydrogel polymerization and cross-linking by polyvinyl cross-linker and crosslinking of water-soluble prepolymer by polyfunctional cross-linker. Polymerization of acrylic acid (AA) and its salts with cross-linker used for hydrogel preparation. Carboxylic acid groups of product neutralized before or after polymerization. Initiation is most often carried out chemically with free-radical azo or peroxide thermal dissociative species or by reaction of a reducing agent with an oxidizing agent. [1].

Experimental analysis polymer with monomer ratio of acrylamide to acrylic acid 70:30 taken and immersed in 500 mL solutions of pH ranging from 3.75 to 9.6. At lower pH, carboxylic acid in copolymer structure turns into protonated form of carboxylic acid. Hydrogel in acidic environment gets less water to absorb and hence swelling ratio decreases at lower pH. At higher pH carboxylic acid group gets transformed into its basic salt form.[4].

Copolymer with monomer ratio 70/30 of acrylamide and acrylic acid synthesized by maintaining reaction temperatures of 50 ^{o}C, 60 ^{o}C and 70 ^{o}C.Preparing 70/30 monomer ratio, amount of MBA increased to 0.06, 0.07 and 0.08 gm and swelling ratios 300, 200 and 100.A 70/30 polymer put in different concentrations of salt solution from 0.1 to 0.9 gm of NaCl salts strength of solution initially decrease and finally increase.[4]

Hydrogels were prepared by Pourjavdi et al. using direct grafting of acrylamide (AAm) monomer onto chitosan using ammonium persulfate (APS) as an initiator and methylene bis acrylamide (MBA)as a crosslinking agent under an inert atmosphere. The effect of AAm and MBA concentrations on swelling capacity of hydrogel. Polymer structures characterized by FTIR spectroscopy. Water absorbencies of hydrogels compared before and after alkaline hydrolysis treatment. [5].

Saponification of acrylamide (PAAm) with hot sodium hydroxide solution rise to high water absorbency. Swelling of hydrogel samples in saline solutions. Swelling capacity of chitosan-g PAAm hydrogels in $CaCl_2$ and $AlCl_3$ solutions higher than hydrolyzed chitosan-PAAm hydrogels. Chitosan-g-PAAm and H-chitosan-g-PAAm hydrogels different swelling capacities in various pH. [5].

Polyacrylic acid (PAA) homopolymeric hydrogel and Its commercial version contains 2.5 % of PAA and 97.5 % of water. It is stable and optimal elasticity property. When used as an endoprosthesis it designed to be non-toxic, non-inflammatory and to imitate surrounding soft tissue. Polyethylene glycol diacrylate (PEGDA) hydrogels modified with β-chitosan, which has improved biocompatibility. The hydrogel is formulated by adding 10 % aqueous solution of PEGDA into 2% solution of chitosan in acetic acid. The mixture is cross-linked by UV radiation to form the hydrogel. This hydrogel displays IPN structure and contains 77-83 % of water. [7]

Applications of Hydrogel Products

1. Hydrogel applied to Hygienic Products.
2. Agriculture Industries.
3. Drug delivery systems.
4. Sealing.
5. Coal Dewatering.
6. Artificial Snow
7. Food Additives
8. Pharmaceuticals.
9. Biomedical applications.
10. Tissue Engineering.
11. Diagnostics.
12. Wound dressing.
13. Separation of Biomolecules or Cells.
14. Barrier Materials Regulate Adhesions.
15. Biosensor.
16. Regenerative Medicines.
17. Diaper Industries.
18. Good oxygen Permeability.
19. Soft Contact Lenses.
20. Aqueous Surface Environment to Protect Cells.
21. Industrial Applicability.
22. Rectal Delivery.
23. Perfume Delivery.

Technical Features of Hydrogel

1. The highest absorption capacity in saline.
2. Desired rate of absorption.
3. The highest absorbency under load (AUL).
4. Lowest soluble content and residual monomer.
5. The lowest price.
6. The highest durability and stability in the swelling environment and during the storage.
7. The highest biodegradability without formation of toxic species
8. pH-neutrality after swelling in water.
9. Colorlessness, odor lessness and non-toxic.
10. Photo stability.
11. Re-wetting capability
12. Show lowest soluble content and monomer.

Advantages of Hydrogels

1. Due to their significant water content they possess a degree of flexibility.
2. Release of medicines or nutrients timely.
3. Biocompatible, biodegradable and injected.
4. Hydrogels have ability to sense changes of pH, temp. and concentration of metabolite
5. Hydrogels also possess good transport properties and easy to modification.
6. Hydrogels Improved drug utilization.
7. Decreased side-effects.
8. Flexibility similar to natural tissues.
9. Improved patient compliance.
10. Sustained and prolonged action.

Disadvantages of Hydrogels

1. High cost.
2. Can be hard to handle.

3. Low mechanical strength.

4. Non-adherent and secured by secondary dressing.

5. Difficult to load with drugs/nutrients

Advantages of Hydrogel Polymer in Agriculture

1. Improve growth and crop productivity of Navel orange sandy soil conditions.

2. Increasing seedling survive ratio, enhancing root growth under stress conditions.

3. Increase water-use efficiency and provide a regular supply of water and nutrients.

4. Increase the soil's ability to reserve irrigation water for as long as possible.

5. Reduce soil erosion and reduces desertification of agricultural lands.

6. Improve nutrients efficiency and provide water.

7. Improve the nutritional status of the plant.

7. Reduce the fertilizers loss by leaching.

8. Protect environmental by reducing soil and water pollution.

Chemicals and Raw Materials

1. Acrylamide (AAm)

2. Tetramethylene Ethylene Diamine (TEMED)

3. Potassium Peroxodisulfate (KPS)/Ammonium Persulphate (APS)

4. Methylene Bis Acrylamide (MBA)

5. Methanol

6. Acrylic acid (AAc)

7. Distilled Water.

8. 0.1N HCL and 0.1 N NaOH for maintain pH.

Quantities of Material for Synthesis of Hydrogel

Sample No.	Acrylamide AAm (gm)	Acrylic Acid AAc(mL)	KPS (gm)	MBA (gm)
01	5	0.5	0.1	0.05
02	4.5	1	0.1	0.05
03	4	1.5	0.1	0.05

TableQuantities of Material for Synthesis of Hydrogel

Above table shows the various quantity of material for synthesis of hydrogel for different quantities of material for calculating the swelling ratio.

Experimental Procedure

1. 5 gms Acrylamide is added to 100 mL distilled water to form a solution.

2. 1 ml of activator Tetramethylene Ethylene Diamine (TEMED) is added.

3. Then solution is allowed to stirring for 20 minutes.

3. Maintain a temperature of 60 ^{O}C throughout the reaction.

4. After that 0.5 gm of acrylic acid and 0.05 gm Methylene bis (MBA) which is the cross-linker are added while the contents of the beaker are constantly being stirred.

5. The initiator 0.1 gm Potassium Peroxodisulfate (KPS) is added after 30 minutes.

6. The addition of the initiator result in formation of highly viscous translucent gel.

7. The prepared hydrogel is cut into pieces and immersed in methanol for dehydration.

8. Finally hydrogel dried under the sun to obtain the dried hydrogel.

9. Then measure swelling characteristics of dried hydrogel.

10. Repeat above process for different quantities of Acrylamide (AAm) and Acrylic Acid AAc for making hydrogel.

Swelling Measurement

To know the water absorption capacity of the hydrogel a sample of the prepared hydrogel (1 gm) was put in 100 mL distilled water for 16-18 hours and the initial weight of the hydrogel is compared with the final weight. The degree of swelling is found by the swelling ratio.

Swelling Ratio = [Ws – Wd] /Wd

Where,

Ws is the weight of hydrogel in swollen state

Wd is the weight of hydrogel in dry state.

Results And Discussion

Observations

Swelling Measurement

Swelling Ratio = [Ws – Wd] /Wd

Where,

Ws is the weight of hydrogel in swollen state

Wd is the weight of hydrogel in dry state.

1. For Sample No. 1

We take 5 gm of Acrylamide (gm) and 0.5 ml of Acrylic acid and synthesis of Hydrogel carried out in lab. After synthesis drying of hydrogel carried out in sunlight. After drying 1 gm of gel put in the water for 18 hrs. to analyses the swelling ration. By experimental analysis final weight of sample have 93 gm.

Swelling Ratio = [93 – 1] /1 = 92

For Sample No. 2

We take 4.5 gm of Acrylamide (gm) and 1 ml of Acrylic acid and synthesis of Hydrogel carried out in lab. After synthesis drying of hydrogel carried out in sunlight. After drying 1 gm of gel put in the water for 18 hrs. to analyses the swelling ration. By experimental analysis final weight of sample have 109 gm.

Swelling Ratio = [109 – 1] /1 = 108

For Sample No. 3

We take 4 gm of Acrylamide (gm) and 1.5 ml of Acrylic acid and synthesis of Hydrogel carried out in lab. After synthesis drying of hydrogel carried out in sunlight. After drying 0.5 gm of gel put in the water for 18 hrs. to analyses the swelling ration. By experimental analysis final weight of sample have 129 gm.

Swelling Ratio = [129 – 1] /1 = 128

Swelling Ratio at Various Ratio of (AAm/AAc.)

Weight of Acrylic acid (AAc) in gms	Weight of Acrylamide (AAm) in gms	Weight Ratio of AAm/AAc	Swelling Ratio
0.5	5	90/10	92
1	4.5	80/20	108
1.5	4	70/30	128

TableMeasurement of Swelling Ratio at Various Ratio of AAm/AAc.

Table shows the effect of Weight ratio of AAm/AAc on the swelling ratio of hydrogel. As per observations it's clear that as the AAm/AAc ratio increase the swelling ratio also increase up to 70/30 beyond that swelling reduce. The swelling ratio again increase at 50/50 then decrease. The optimum value for AAm/AAc will be 70/30 have maximum swelling ratio. According to swelling ration and strength the 70/30 is the optimum ration for synthesis of hydrogel. By experimental analysis the swelling ration for 90/10, 80/20 and 70/30 are 92, 108 and 128.

Effect of Various Parameters

1. Effect of pH

The polymer with monomer ratio of acrylamide to acrylic acid 70:30 was taken and immersed in 500 mL solutions of pH ranging from 3 to 10. The pH of distilled water was modified either by adding HCl to decrease pH or NaOH to increase the pH. After 24 hours the final weight of the hydrogel was noted after draining the excess water. The swelling ratio is observed to increase with increasing pH of the solution.

2. Effect of Temperature

The copolymer with monomer ratio 70/30 of acrylamide and acrylic acid was synthesized by maintaining reaction temperatures of 50 °C, 60 °C and 70 °C. 0.5 gm of each sample were put in 500 mL distilled water for a period of 24 hours. Optimum value of temperature is 60 °C.

3. Effect of Cross-Linker Concentration

Cross-linking is carried out between two monomers AAm and AAc. For preparing 70/30 monomer ratio, amount of MBA was increased to 0.06, 0.07 and 0.08 g and the swelling ratios were noted.

4. Effect of Ionic Strength

A 70/30 sample of polymer was taken and put in different concentrations of salt solution and the corresponding swelling. At this weight ratio maximum swelling ratio hence, this is optimum value for AAm/AAc ratio for synthesis of hydrogel.

CONCLUSION

Experimental analysis shows the effect of pH and ionic strength shows that hydrogels respond to change in environment during swelling. The swelling ratio increases with increase in pH and with increase in ionic strength and the swelling decreases as electrostatic attraction increases between the chains. While preparation of polymer changing reaction, conditions leads to different swelling in samples. The pH of distilled water was modified either by adding HCl to decrease pH or NaOH to increase the pH.Decrease in concentration of cross linker leads to increased swelling in the polymer but its strength decreases.Hydrogels prepared according to various proportions of the monomers, acrylamide and acrylic acid have different swelling properties. The swelling ratios of various batches largely depends on the ratio of monomers taken in the reaction mixture. As the pH of the solution increases the amount of swelling increases. This is because the number of fixed charges on the gel increases as more carboxylic groups get converted to their basic salt form. This increases electrostatic repulsion between the polymer chains and allows more water to get absorbed. With increase in concentration of the crosslinker MBA the swelling decreases since the density of cross-linking increases and available spaces for water absorption become lesser. The ionic strength of the solution in which hydrogel is immersed also has an impact on absorption capacity. The electrostatic repulsion between crosslinked chains decreases with increasing NaCl concentration as it tends to partially neutralize the carboxylic acid attached to polymer chains. Lesser amount of water is absorbed at high strength. As per observations it's clear that as the AAm/AAc ratio increase the swelling ratio also increase up to 70/30 beyond that swelling reduce. The swelling ratio again increase at 50/50 then decrease. The optimum value for AAm/AAc will be 70/30 have maximum swelling ratio. Swelling measurements of the powdered hydrogel indicated the absorption of considerably high amount of water. A highly viscous gel was formed upon the addition of initiator, potassium persulfate in the reaction mixture. Cross-linking is carried out between two monomers AAm and AAc. For preparing 70/30 monomer ratio, amount of MBA increased to 0.06, 0.07 and 0.08 g and the swelling ratios decreases. The swelling ratio of hydrogel at various time of hrs. in which the hydrogel put in water from time 2-20 hrs. From the table it's clear that the swelling ratio increase with increase the time. The optimum time for maximum swelling ratio is between 18-22 hrs. The copolymer with monomer ratio 70/30 of acrylamide and acrylic acid was synthesized by maintaining reaction temperatures of 50 ^{O}C, 60 ^{O}C and 70 ^{O}C. 0.5 gm of each sample were put in 500 mL distilled water for a period of 24 hours. Optimum value of temperature is 60 ^{O}C.

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