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Original Article

Obtaining Hydrogel on the Basis of Rice Starch and Carboxymethylcellulose and its Role in Agricultural Plants

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Abstract *- In the article, the technologies of obtaining polysaccharides and biopolymers based on them are studied using the literature. Synthesis of rice starch, cellulose and carboxymethylcellulose is briefly reported, and a hydrogel based on starch and carboxymethylcellulose is obtained. Experiments were conducted with the obtained hydrogel in dry lands of many districts of the Surkhandarya region. The amounts of starch and KMS in the process of hydrogel synthesis were studied as percentages. Then, hydrogel swelling was tabulated in mg and water absorption in ml. The IR spectrum of the hydrogel was obtained and analyzed. The obtained hydrogel saves water up to 3-35%, mineral fertilizers up to 2.5 times, and increases the share of oil up to 47%. Finally, the importance of hydrogel in agricultural plants is summarized.*

Keywords *- Starch, KMS, Acrylamide, Acrylic acid, Montmorillonite, Superabsorbent hydrogel, Initiator, Polysaccharides.*

1. Introduction

In the period of water scarcity in recent years, we should value every drop of water and use it efficiently. Until now, Uzbek and foreign scientists (S.Rijkov, S. Ahmedov, A. Jalilov, Sh. Shirinov, B. Khannazarov and others) have created a number of scientific developments of world importance in terms of water-saving and resource-saving technologies and are in practice. is being used. In the following decades, the processes related to the emergence of new types of scientific and technical technologies, the reconstruction of existing technologies and their technical re-equipment, and the radical change of the processes of synthesizing a number of monomers and polymers are also being implemented [1].

From $C_6H_{12}O_6$ or disaccharides, we can take sucrose - $C_{12}H_{22}O_{11}$ as an example. It is 80% of the solid matter of plants. Carbohydrates are divided into two major groups: monosaccharides and polysaccharides. Polysaccharides are linearly branched high-molecular compounds; their molecules consist of monosaccharides connected by glycosidic bonds and store starch in reserve. Carbohydrates are important raw materials for the industry and national economy, pharmaceutical, medicine, and food industries. Polysaccharides have been found to contain more than 20 murine monosaccharides. Of the polysaccharides, cellulose and starch are used a lot [2,3].

Starch and cellulose can be obtained from the stalks of various annual plants such as rice, corn, wheat, cotton, jute, straw, reed, katop, their seed pods, and fruit and vegetable residues. The chemical industry is rapidly developing in our country, just as there is development in the chemical industry throughout the world. This is due to their unique properties and their diversity, which make it possible to widely use chemical polymers in industry, in various sectors of the economy, in everyday life, in medicine, and in the rapidly developing new areas of modern technology [4; pp. 284-312].

White, red, and black rice grains contain 76.1% starch, 17-24% amylase, 2.6% protein, 3.9% sugar, 1.8% dextrin, and 1-1.5% fat. , there are 1.4% ash and 0.2% klichatka, vitamins V, V2, RR. Wood can be mixed with rice straw to make cellulose, paper, cardboard, and rope.

Table 1. Chemical composition of cleaned rice.

№	Composition of rice	Fully dried starch				
		1	2	3	4	5
1	**Starch**	82,30	82,54	83,96	88,2	91,1
2	**Protein**	7,69	7,92	8.22	7,90	7,54
3	**Fat**	1,84	1,52	1,05	0,88	0,68
4	**Cellulose**	0,81	0,56	1,3	0,84	0,78
5	**Bran**	9,9	9,4	9,0	7,8	7,5

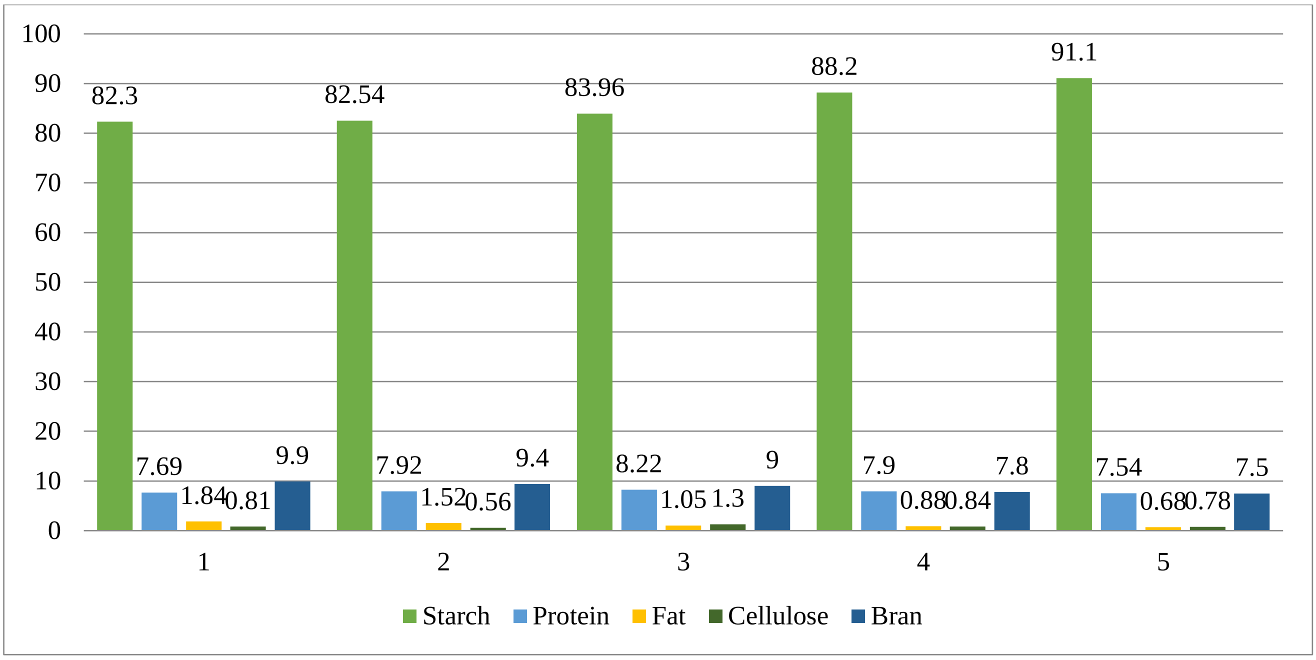

Fig. 1 Chemical composition of cleaned rice

Table 2. Chemical composition of rice bran.

Raw material	**Composition and quantity**									
	Al_2O_3	Fe_2O_3	SiO_2	CaO	P_2O_5	K_2O	Na_2O	MgO	SO_2	substance
Husk	0,21	0,10	14,59	0,58	0,8	0,24	0,44	0,41	0,16	85
Bran	1,31	0,58	84,30	3,33	0,46	1,53	2,4	1,88	1,52	1,88

When studying the chemical composition of cleaned rice, the amount of starch, protein, fat, cellulose, and bran improves as it dries. Rice requires nitrogen, phosphorus and potassium elements from mineral nutrients. In the conditions of Uzbekistan, 2.3 kg of nitrogen, 0.8 kg of phosphorus and 3 kg of potassium are used to grow 1 s of grain and 1 s of straw. Starch is the main carbohydrate reserve of plants. It reaches 75% in wheat, 72% in corn, 80% in rice, and 12-24% in potatoes. Food, confectionery, ethyl alcohol, butyl alcohol, acetone, and glues are produced from starch. It is widely used in the fields of antibiotics, vitamins, powders and paper industry.

Starch can be easily obtained from various natural sources, such as rice husks, potatoes, corn, and wheat. There are two types of waste from rice milling, husk and bran. Husk makes up 22% of rice, and bran makes up 8-9%. The obtained pulp can be used as a fertilizer. The chemical composition of the pulp obtained from rice.

It is known that for thousands of years, our ancestors regarded water as sacred, revered it, used it wisely, and freely used the water in the stream as drinking water. Later, due to the development of industry and agriculture, clean drinking water became unfit due to the use of various chemicals. As a result, state control of water and water use has become not only necessary but also necessary. This means that it is necessary to pay special attention to the identification of sources of drinking water pollution and the development of effective methods of their neutralization, and it is one of the urgent problems of today.

2. Experimental Part

2.1. Material and Methods

Starch can be easily extracted from rice, potatoes and corn. Rice is ground into flour and mixed with 100g of rice and 1l of water in a bowl. The mixture first turns white and then begins to settle. Water is renewed 4-5 times to get clean starch. To obtain potato starch, 100 g of potatoes are grated and mixed with 1 liter of water; as a result, the starch rises to the water and settles; the water is renewed 4-5 times to obtain pure starch.

There are more than 155.5 million hectares of rice cultivated in the world, and it is planted in more than 115 countries; the yield is about 38.4 tons/ha, and the total yield is 594.6 million tons. (2000). [5]. Bleached cellulose is macerated with 15-18% isopropyl alcohol solution for 45-60 minutes. It is then etherified with the sodium salt of monoacetic acid and treated with dimethylsulfoxide for several hours before mercerization. As a result, carboxymethylcellulose with high molecular weight and relative viscosity is obtained.

2.2. Hydrogels Derived from Polysaccharides

The sodium salt of sulfuric acid esters of cellulose (Na-CET) has the greatest importance; it is white or yellowish (powdery or fibrous) like sulfuric acid esters of cellulose, and it has a powder weight of 48-720 kg/m3, odorless fashion. The density of Na-CETsis, 1452 kg/m3, turns yellow when heated to 180-190^{0}C and turns into coal at 205-210^{0}C. Sulfuric acid esters of cellulose and their salts are not the same according to the degree of polymerization and substitution. Sulfuric acid esters of cellulose and its salts are insoluble in low molecular weight alcohols and ketones. Na -CET, K -CET, and NH4 -CET dissolve when frozen in a 6% solution of NaOH or NH_4OH when their degree of substitution is up to 10 [5].

In order to obtain a hydrogel from starch, it is necessary to modify it. There are many types of chemical modification, the most optimal method of which is the polymerization of vinyl monomers and starch, in which we can use acrylic and acrylamide. The hydrogel obtained based on these is characterized by good water absorption and low cost. Hydrogels derived from natural polymers, especially polysaccharides, are very interesting materials because they are used in many fields (agriculture, textile engineering, pharmaceuticals, biosensors, etc.) with the advantage of being made from environmentally friendly, renewable and cheap raw materials [6].

Among the polysaccharides, cellulose is the most abundant worldwide, and it combines hydrophilicity with good mechanical properties. These two competing properties are associated with many hydroxyl groups that interact with hydrogen bonds preferentially with water (amorphous domains) or with hydroxyl groups of adjacent polymer chains (crystalline domains). A complex system of hydrogen bonds between hydroxyl groups (supramolecular structure) contributes to the mechanical strength of cellulose and its insolubility in the majority of water and solvents [7].

Table 3. Effects of sodium hydroxide concentration and alkylating reagent $CLCH_2COONa$ mole ratio on the properties of KMS.

Component consumption			**Indicators of KMT**		
NaOH concentration	**1 mole of cellulose $CLCH_2COONa$**	**Amount of substance %**	**Degree of substitution by carboxymethyl groups**	**Average polymer performance**	**Water solubility %**
200	1,2	40,6	62	943	0
	1,4	42,0	64	866	0
	1,6	43,8	72	820	0
	1,8	44,6	77	790	0
240	1,2	45,6	75	860	0
	1,4	47,4	77	780	0
	1,6	49,0	82	720	0
	1,8	50,2	84	700	0

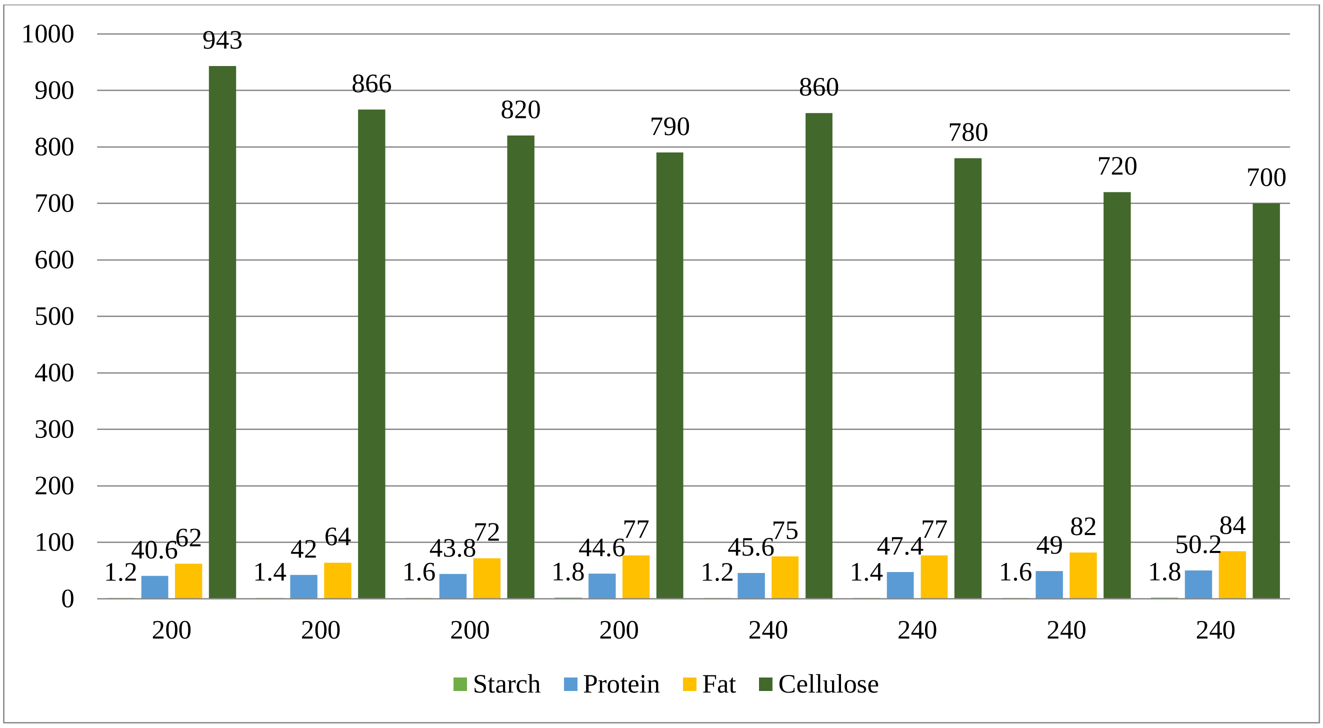

Fig. 2. Effect of sodium hydroxide concentration and alkylating reagent $CLCH_2COONa$ mole ratio on KMS properties

In order to obtain a hydrogel from starch, it is necessary to modify it. There are many types of chemical modification, the most optimal method of which is the polymerization of vinyl monomers and starch, in which we can use acrylic and acrylamide. Based on these, the hydrogel is characterized by good water absorption and low cost [8]. Hydrogels derived from natural polymers, especially polysaccharides, are very interesting materials because they are used in many fields (agriculture, textile engineering, pharmaceuticals, biosensors, etc.) [9] with the advantage of being prepared from environmentally friendly, renewable and cheap raw materials.

Among the polysaccharides, cellulose is the most abundant worldwide, and it combines hydrophilicity with good mechanical properties. These two competing properties are associated with many hydroxyl groups that interact with hydrogen bonds preferentially with water (amorphous domains) or with hydroxyl groups of adjacent polymer chains (crystalline domains). A complex system of hydrogen bonds between hydroxyl groups (supramolecular structure) contributes to the mechanical strength of cellulose and its insolubility in the majority of water and solvents [10]. In recent years, hydrogels have been widely used as water-absorbing and water-retaining polymeric materials all over the world.

2.3. High Absorption Properties of Hydrogels

Hydrogels are widely used in various fields of human activity, such as medicine, ecology, pharmacology, agriculture, etc., due to their high absorption properties, that is, their ability to absorb and retain large volumes of liquids. [11-12] is widely used to increase water efficiency; in arid and semi-arid regions with limited water supply, hydrogels provide the ability to conserve water and plant nutrients and deliver them to plants through the efficient use of hydrogels. [13-14].

On a global scale, positive, promising works and scientific research are being carried out on a very large scale to obtain new types of polymer hydrogels based on starch copolymers. For this, it is required to develop a technology for the production of high-quality, effective hydrogels by copolymerizing polysaccharides and acrylic monomers, saving water resources when used in various fields of agriculture and having certain high physical and chemical parameters [15]. At present, several works are being carried out in our Republic regarding the development of the Chemical industry and the replacement of existing technologies in its sectors with new ones and the management of production based on them based on new technologies, in particular, high-level flexible polymer hydrogels that serve to increase the efficiency of plant growth to a certain extent when used in agriculture based on local raw materials great attention is paid to production [16]—an overview of polymer hydrogels and their applications and details.

Hydrogels are composed of three-dimensional polymers, which have the ability to absorb large amounts of water but become insoluble due to chemical or physical cross-linking of the polymer chains between them [17; 27-46]. Hydrogel is determined by critical parameters for the degradation of polymers under the influence of different temperatures. If the temperature is higher than the melting point, the water-binding properties of such polymers are lost. Temperature-sensitive hydrogels are used in implants and other systems. [18; 27-46]. Whereas these synthetic polymers have structures that allow them to be modified to obtain appropriate degradation and biofunctionality that have not been well studied [19; 251–259]. These hydrogels are highly absorbent and can contain more than 90% water. Hydrogels also have a degree of flexibility very similar to natural tissue due to their significant water content. The main material is sodium carboxymethyl cellulose, which is a biomaterial for the preparation of an optimal cross-linked hydrogel [20]. Polysaccharides are one of the main sources of obtaining bio-based hydrogels. Many studies have used starch, carboxy methyl cellulose, alginate, and chitosan [21; 612-616]. Hydrogels based on cellulose and starches have many favorable properties such as hydrophilicity, biodegradability, biocompatibility, transparency, low cost and non-toxicity. Thus, hydrogels based on cellulose and starch are widely used in tissue engineering [22; 1259-1267], controlled delivery system [19; 92-100], through blood purification [24; 4143-4152], sensor [21; 3040-3050], in agricultural plants [24; 3440-3444], as well as in water treatment projects [25; 3755-3762] and chromatographic supports various application prospects of cellulose- and starch-based hydrogels are shown. It was found that hydrogel production contains several chemicals such as starch, polyacryl, dichlorohydrin, hippan, acrylinite, urea, and acrylic acid available in our country.

3. Results and Discussion

3.1. Hydrogel Synthesis based on Starch, Polyacryl, Acrylamide, Potassium Persulfate and Bentanite

12 g of polyacrylic is dissolved in 100 ml of water. Then methylenebisacrylamide, acrylamide, potassium persulfate and bentanite are mixed in turn, and the temperature is gradually increased to 60^0C. The reaction is continued slowly for two and a half hours. After the end of this process, the etchant is hydrolyzed in a 1M solution of sodium at a temperature of 90^0C for 150 minutes. At the end of the experiment, it is treated by washing in water and dried in a drying oven. Any iodine is placed in special plastic bags to protect it from objects or moisture [26].

The resulting hydrogel is naturally non-toxic and has no adverse effects on living organisms. It absorbs atmospheric water, including rain and snow. Hydrogel has the ability to absorb and retain water several tens of times more than its weight. In our country, under the soil and climate conditions, rice can be planted as a repeated crop after two seasons of autumn grain. If hydrogels obtained from rice are used, they are abundant and high allow the growth of high-quality crops. Hydrogels are superabsorbent, turning into water-insoluble gels; they can absorb several times more water than themselves. After the soil dries, water is provided by hydrogels. This process can last up to 4-5 years [27].

Table 4. Water absorption properties of the new hydrogel.

№	Amount of hydrogel (g)	H_2O amount (ml)	The general rate of hydrogel sorption in water sources		
			Distilled water pH 7	Rainwater pH 7	The of stream water is pH 8.5
1	0,5	50	70%	60%	30%
2	1	50	100%	80%	40%
3	1,5	50	120%	100%	70%
4	2	50	130%	120%	90%
5	2,5	50	150%	140%	100%

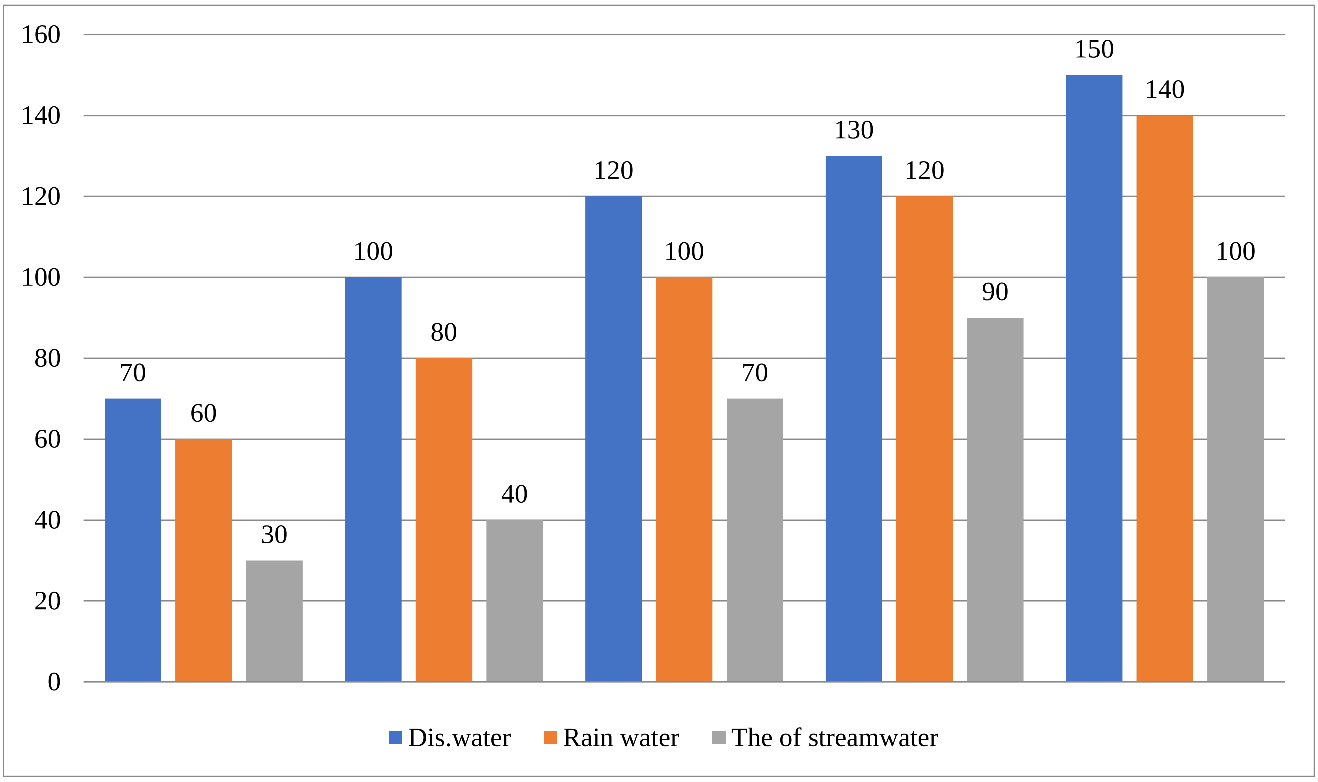

Fig. 3 Water absorption properties of the new hydrogel

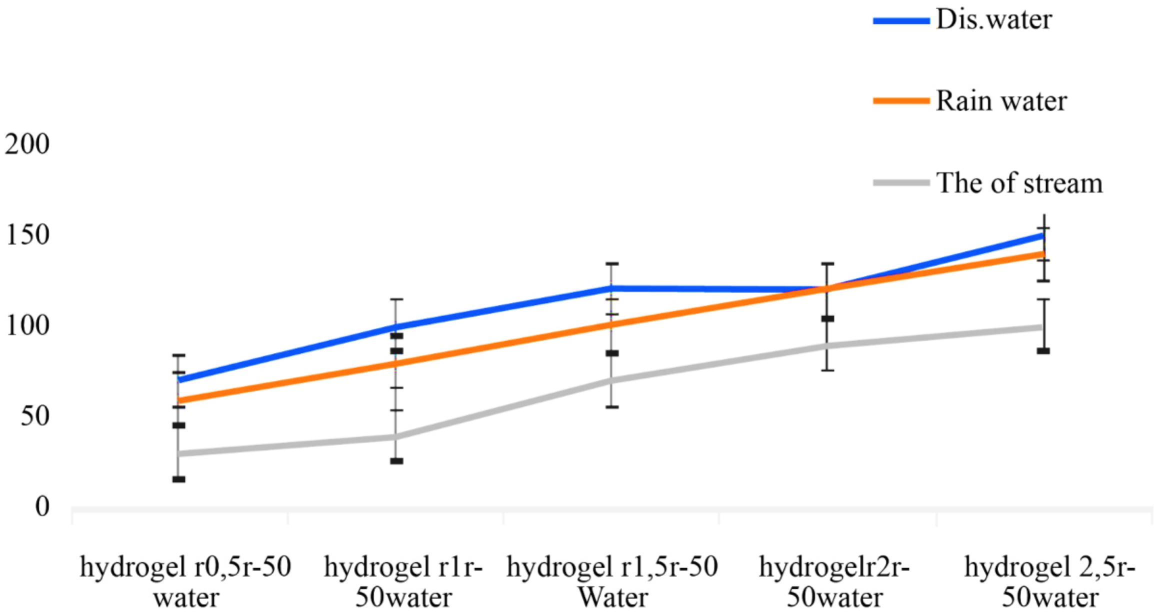

Fig. 4 Water absorption properties of the new hydrogel.

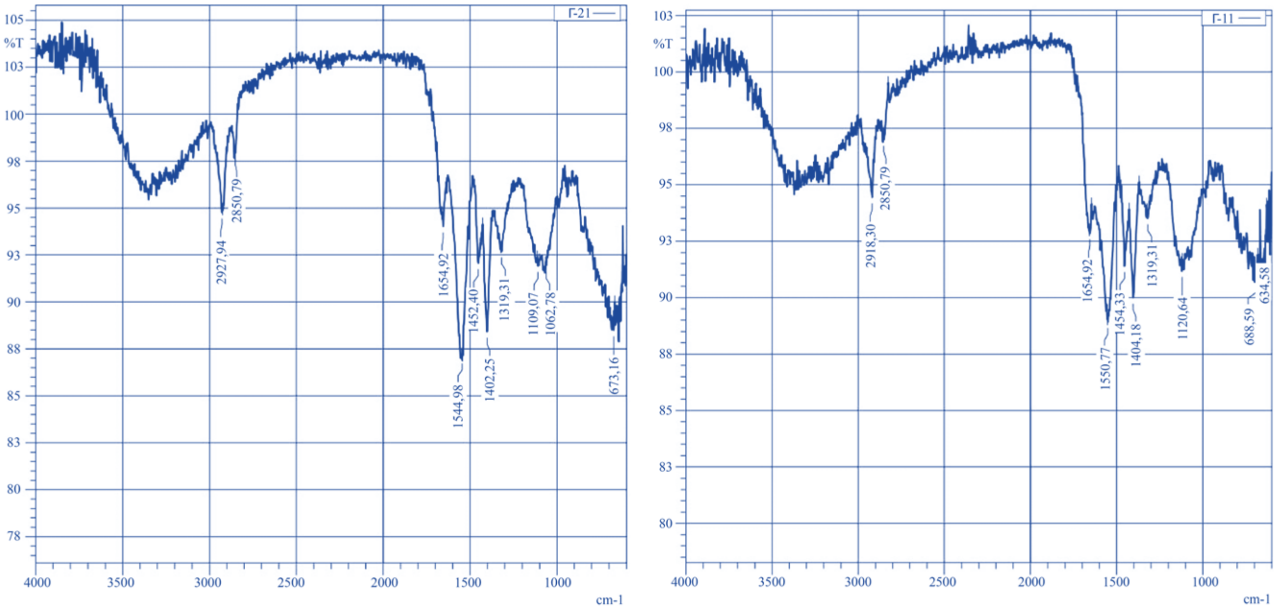

Fig. 5 The IR spectrum of the hydrogel and new type of hydrogel 'Gidorgel'

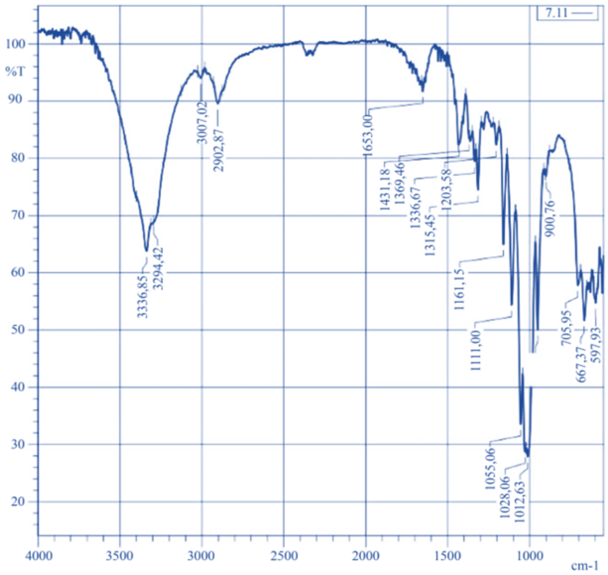

Fig. 6 (a) Dry hydrogel

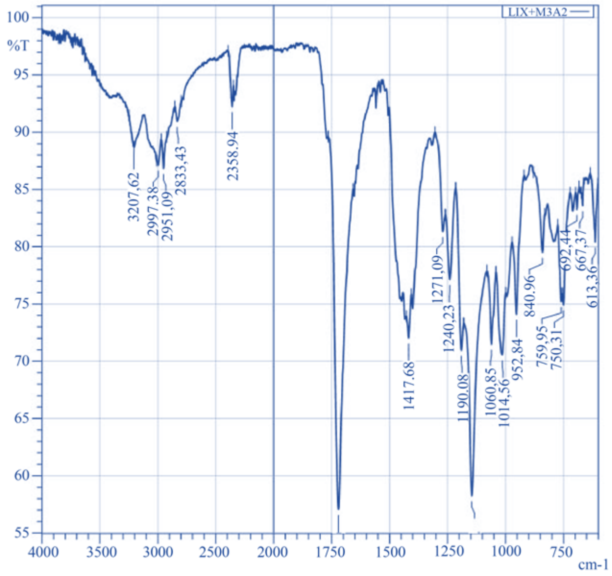

Fig. 6 (b) Hydrogel soaked in water

According to the IR spectra of the dry and water-soluble hydrogel, the obtained product corresponds to the observed peak at 3336 cm^{-1}. SO-N is the potassium salt of polyphosphoric acid and the =O extension of polyvinyl acetate, 2902 cm $^{-1}$ and polyvinyl acetate in superabsorbent. After the reaction, the absorption peak associated with the OH- bentonite group changed from 3600 to 3400-3200 cm-1.

The absorption peak at 1190 cm^{-1} associated with starch was shifted, indicating the change of the OH group in starch during the reaction. The absorption peaks at 3207, 2348 and 1026 cm^{-1} of hydrogels wetted with water $-CONH_2$ and $-SO_2$ also change during the reaction. A new peak appears at 1403 cm^{-1} belonging to the group. The above results showed that the characteristic absorption peak of OH and $-CONH_2$ groups in starch changed after the copolymerization reaction.

3.2. Differential Scanning Calorimetric

The absence of drastic weight loss of the starch-based hydrogel was proven by differential scanning calorimetric analysis. Weight loss above 700 C begins in three stages.

The first stage occurs at a temperature of 700 C -1980 C at a rate of 11.07%/min, the second stage at a rate of 1980 C -3780 C at a rate of 8.28%/min and the third at a rate of -3200 C -3780 C at a rate of 3.71%/min with decay.

Tests have shown that weight loss at temperatures above 70°C occurs due to the low moisture content of the hydrogel. And at temperatures above 3780 C - as a result of the decomposition of amino acids in the polymer.

It can be seen that there are two weight losses, the first of which takes place at a temperature of 70-198°C at a rate of 12.11% min and the second stage at a temperature of 378°C -500°C.

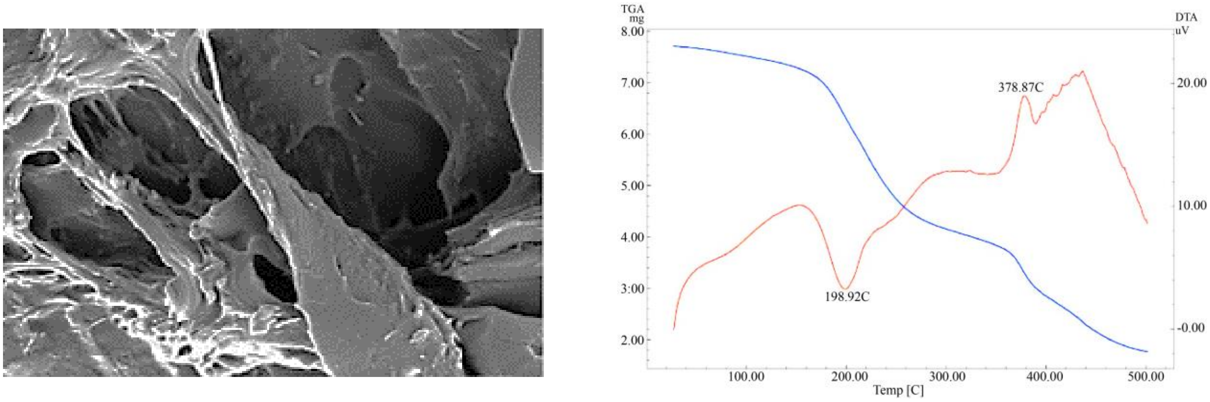

Fig. 7 Differential scanning calorimetric

Table 5. Physical properties of the hydrogel

Content	Swelling(mm)	Density
Composition of corn-based hydrogel		
Starch\KMS (50\50)	0,0460	0,012
Starch\KMS (25\75)	0,0425	0,016
Starch\KMS (75\25)	0,0315	0.033
The composition of hydrogel obtained on the basis of potatoes		
Starch\KMS (50\50)	0,0450	0.011
Starch\KMS (25\75)	0,0400	0,015
Starch\KMS (75\25)	0,0310	0,030
The composition of the hydrogel obtained on the basis of rice		
Starch\KMS (50\50)	0,0440	0,012
Starch\KMS (25\75)	0,0410	0,014
Starch\KMS (75\25)	0,0317	0,031

Table 6. The degree of swelling of hydrogels based on starch copolymers with different cross-linking agents.

Starch/AA/B	**1**	**2**	**3**	**4**	**5**
The name of the interconnector	Methylene bisacrylamide	EXG	Citric acid	Ethylene glycol	Glutaric aldehyde
Percentage of crosslinker	1	1	1	1	1
The degree of swelling	800	360	250	200	165

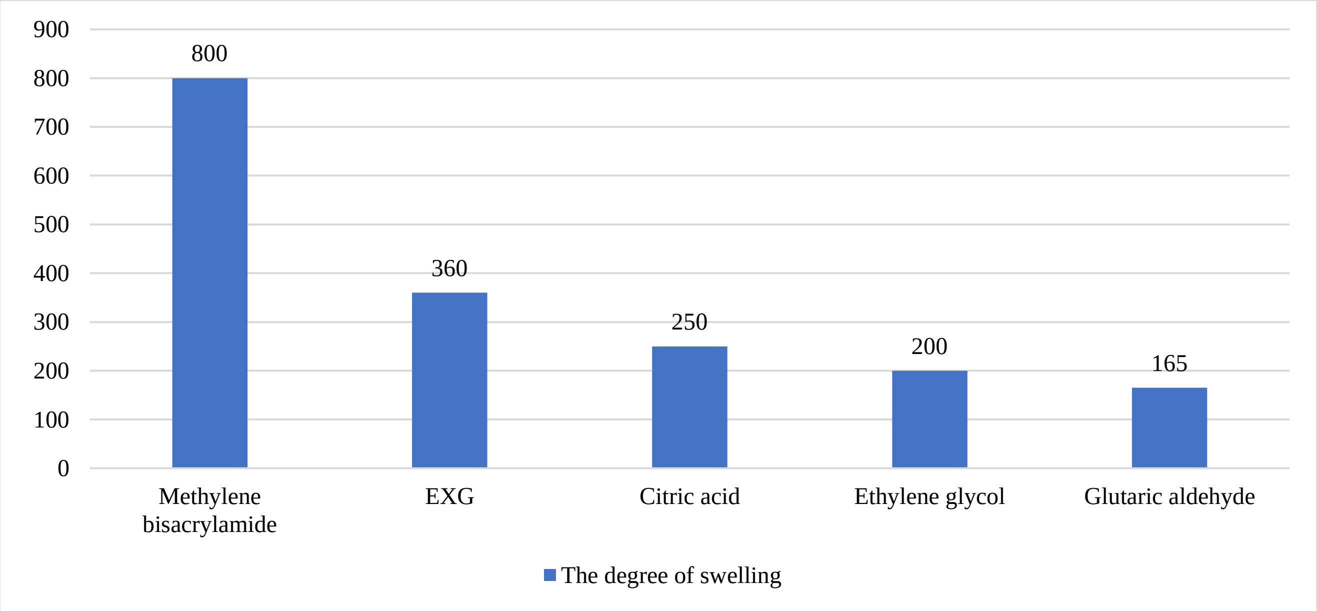

Fig. 8 The degree of swelling of hydrogels based on starch copolymers with different cross-linking agents

4. Results and Discussion

For example, 10g of polyacrylic has been found to retain up to 2.5-3.0 liters of water through experiments. One ton of it today is 50-60 thousand soms. Hydrogel does not lose its properties for up to five years; 40-50 kg of hydrogel was used on 1 hectare; as a result, the water deficit of plants was greatly reduced, and the yield and yield of plants were greatly improved, and the need for mineral fertilizers was greatly reduced [28].

So, when the hydrogel obtained on the basis of rice starch and KMS is 50/50, its swelling properties have been found to be much higher. Also, the hydrogel obtained based on potato and corn starch and KMS in a ratio of 50/50 has been found to have high swelling properties.

5. Conclusion

The obtained hydrogel was tested on agricultural plants in the foothills and desert conditions of the Surkhandarya region, as well as grain crops grown in dry conditions. Because arid lands are irrigated at the expense of atmospheric water in large quantities. In the desert and semi-desert areas, the need for water corresponds to the frequent presence of very hot, dry and hot winds in the summer season.

Experiments were conducted in dry lands of many districts of the Surkhandarya region. 70-75% of the vegetation in these districts is dry land. Therefore, it is appropriate to use hydrogel in these areas. “Hydrogels” synthesized by the scientists of our republic for the purpose of saving water are synthetic polymers that swell in water, swell due to the moisture content of the soil and have the property of storing water for a long time. When we conducted experiments in the regions mentioned above and when hydrogels were used, it was observed that the plants were much more productive. The incidence of diseases was much less. Due to this, the hydrogel has reduced the consumption of fertilizers by providing water absorption. The obtained hydrogel saves water up to 3-35%, mineral fertilizers up to 2.5 times, and increases the share of oil up to 47%.

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References

[1] Hikmat S. Nematov et al., “Development of Productive Cotton Cultivars with Increased fibre Quality for Bukhara Region of Uzbekistan,” *Asian and Australasian Journal of Plant Science and Biotechnology*, vol. 7, pp. 16-18, 2013. [Google Scholar] [Publisher Link]

[2] Suresh Vundavalli et al., “Biodegradable Super Absorbent Nano Polymer: Properties and its Applications,” *SSRG International Journal of Agriculture and Environmental Science*, vol. 7, no. 6, pp. 59-71, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[3] L.M. Khananashvili, and K.A. Andrianov, *Technologies of Organoelement Monomers and Polymers*, 2nd Ed., Moscow: Khimiya, 1973. [Google Scholar]

[4] A.I. Rodionov, V.N. Klushin, and V.G. Sister, *Technological Processes of Environmental Safety*, Kaluga: Izd-vo N. Bochkarevoy, 2000. [Google Scholar]

[5] Kh.S. Beknazarov, and A.T. Dzhalilov, “The Synthesis of Oligomeric Derivatives of Gossypol and the Study of their Antioxidative Properties,” *International Polymer Science and Technology*, vol. 42, no. 7, pp. 27-31, 2016. [Google Scholar] [Publisher Link]

[6] Chunyu Chang, and Lina Zhang, “Cellulose-Based Hydrogels: Present Status and Application Prospects,” *Carbohydrate Polymers*, vol. 84, no. 1, pp. 40-53, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[7] Joydeep Dutta, “Synthesis and Characterization of γ-Irradiated PVA/PEG/CaCl2 Hydrogel for Wound Dressing,” *American Journal of Chemistry*, vol. 2, no. 2, pp. 6-11, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[8] P. Sunny Gils et al., “Designing of New Acrylic Macroporous Superabsorbent Polymer Hydrogel and its Suitability for Drug Delivery,” *International Journal of Pharmacy and Pharmaceutical Sciences*, vol. 1, no. 2. pp. 43-54, 2009. [Google Scholar] [Publisher Link]

[9] H.L. Abd Yel-Mohdy, “Radiation Synthesis of Nanosilver/Poly Vinyl Alcohol/Celluloseacetate/Gelatin Hydrogels for Wound Dressing,” *Journal of Polymer Research*, vol. 20, no. 177, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[10] N. A. Peppas et al., “Hydrogels in Biology and Medicine: From Molecular Principles to Bionanotechnology,” *Advanced Materials*, vol. 18, no. 11, pp. 1345–1360, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[11] T.V. Budtova, I.E. Suleimenov, and S.Ya. Frenkel, “Highly Swelling Polymer Hydrogels—Some Current Problems and Prospects (Review),” *Journal of Applied Chemistry*, vol. 70, no. 4, pp. 529-539, 1997. [Google Scholar]

[12] Kumaresh S. Soppirnath, and Tejraj M. Aminabhavi, “Water Transport and Drug Release Study from Cross-Linked Polyacrylamide Grafted Guar Gum Hydrogel Microspheres for Thcontrolled Release Application,” *European Journal of Pharmaceutics and Biopharmaceutics*, vol. 53, no. 1, pp. 87-98, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[13] N.A. Peppas et al., “Hydrogels in Pharmaceutical Formulations,” *European Journal of Pharmaceutics and Biopharmaceutics*, vol. 50, no. 1, pp. 27-46, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[14] Sharipov Muzafar Samandarovich, and Ganiyev Baxtiyor Shukurulloyevich, “Synthesis and Characterization of Poly(Styrene-co-Acrylamide) Polymers,” *Young Scholar Srepublican Sceintific - Practical Conference*, pp. 1-2, 2017. [Google Scholar] [Publisher Link]

[15] Yunfeng Lu et al., “Chemical Sensors Based on Hydrophobic Porous Sol-Gel Films and ATR-FTIR Spectroscopy,” *Sensors and Actuators B: Chemical*, vol. 36, pp. 517-521, 1996. [CrossRef] [Google Scholar] [Publisher Link]

[16] D.Y. Sasaki et al., “Molecular Receptors in Metal Oxide Sol-Gel Materials Prepared Via Molecular Imprinting,” *United States Patent*, pp. 1-11, 2000. [Google Scholar] [Publisher Link]

[17] Rumiko Fujioka, Yukari Tanaka, and Toshio Yoshimura, “Synthesis and Properties of Superabsorbent Hydrogels Based on Guar Gum and Succinic Anhydride,” *Journal of Applied Polymer Science*, vol. 114, pp. 612-616. 2009. [CrossRef] [Google Scholar] [Publisher Link]

[18] C. Vinatier et al., “An Injectable Celluloze-Based Hydrogel for the Transfer of Autologous Nasal Chondrocytes in Articular Cartilage Defects,” *Biotechnology and Bioengineering*, vol. 102, no. 4, pp. 1259-1267, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[19] Chunyu Chang et al., “Superabsorbent Hydrogels Based on Cellulose for Smart Swelling and Controllable Delivery,” *European Polymer Journal*, vol. 46, no. 1, pp. 92-100, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[20] Sang Ho Ye et al., “Antifouling Blood Purification Membrane Composed of Cellulose Acetate and Phospholipid Polymer,” *Biomaterials*, vol. 24, no. 23, pp. 4143-4152, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[21] A. Sannino et al., “Spin Coating Cellulose Derivatives on Quartz Crystal Microbalance Plates to Obtain Hydrogelbased Fast Sensors and Actuators,” *Journal of Applied Polymer Science*, vol. 106, no. 5, pp. 3040-3050, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[22] C. Ivanov et al., “Synthesis of Poly(Vinyl Alcohol)-Methyl Cellulose Hydrogel as Possible Scaffolds in Tissue Engineering,” *Journal of Optoelectronics and Advanced Materials*, vol. 9, pp. 3440-3444, 2007. [Google Scholar] [Publisher Link]

[23] Dao Zhou, Lina Zhang, and Shenglian Guo, “Mechanism of Lead Biosorption on Cellulose/Chitin Beads,” *Water Research*, vol. 39, no. 16, pp. 3755-3762, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[24] Xiaopeng Xiong, Lina Zhang, and Yifeng Wang, “Polymer Fractionation Using Chromatographic Column Packed with Novel Regenerated Cellulose Beads Modified with Silane,” *Journal of Chromatography A*, vol. 1063, no. 1-2, pp.71-77, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[25] A. Isogai, and R.H. Atalla “Dissolution of Cellulose in Aqueous Naoh Solutions,” *Cellulose*, vol. 5, pp. 309-319, 1998. [CrossRef] [Google Scholar] [Publisher Link]

[26] István Siró, and David Plackett, “Microfibrillated Cellulose and New Nanocomposite Materials: A Review,” *Cellulose*, vol. 17, no. 3. pp. 459-494, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[27] Abdul Saboor Dawlatzai, R. Jayanthi, and SaidajanAtiqAbdiani, “Efficacy of Graded Doses of Pusa Hydrogel on Growth and Quality of Coleus (Coleus Blumeil.) Under Polyhouse Condition,” *SSRG International Journal of Agriculture and Environmental Science*, vol. 4, no. 4, pp. 32-36, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[28] Umirova Gulnora Abdurakhmonovna et al., “Study of the Sorption of Metals by Covalently Immobilized Polyampholytes Based on Amino Acids,” *Journal of Chemistry and Chemical Technology*, vol. 66, no. 5, pp. 41-51, 2023. [Google Scholar] [Publisher Link]