

# Development of Bio-based Superabsorbent from Jellyfish (*Aurelia aurita*) in the Sea of Marmara, Türkiye

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## Abstract

Superabsorbent polymers were synthesized from cross-linked acrylic acid using collagen and chitosan via the surface polymerization method, with N, N-methylene bis(acrylamide) as the cross-linker and ammonium persulfate as the initiator. Collagen obtained from jellyfish collected from the Sea of Marmara and marine-derived chitosan were chosen as monomers. Superabsorbent polymers were characterized using FT-IR, SEM, and DSC. The swelling capacities of superabsorbent polymers were measured and compared. The maximum water absorption capacities in saline solution were 79 and 136 g/g for chitosan-polyacrylic acid and collagen-polyacrylic acid superabsorbent polymers, respectively. The highest water retention capacities of chitosan-polyacrylic acid and collagen-polyacrylic acid superabsorbent polymers were calculated as approximately 70 times and 120 times their weight, respectively. Fickian diffusion and pseudo-second-order kinetics were applied to determine the swelling kinetics, revealing a perfect relationship. Consequently, the superabsorbent polymer synthesized with collagen obtained from jellyfish had a higher water absorption capacity. To our knowledge, no prior research has documented the production of a biobased superabsorbent derived from jellyfish (*Aurelia aurita*) in the Sea of Marmara. Hence, this study represents a novel and valuable contribution to the literature. Moreover, the increased use of biodegradable biobased superabsorbent polymers can help reduce the carbon footprint and mitigate environmental pollution.

## Introduction

The simplicity and ease of use of disposable products have brought convenience in many areas. However, waste generated due to rapid usage cycles has become an increasingly significant problem for the environment. Hygienic products, including baby diapers, feminine hygiene items, and adult incontinence supplies, are known for being non-degradable, primarily due to the use of superabsorbent polymers (SAPs) (Kim et al., 2017). SAPs, also known as hydrogels, are three-dimensional, cross-linked polymers that might swell vast amounts of water, physiological fluids, or saline solutions up to 1000 times their initial dry weight (Choi et al., 2022; Mignon et al., 2019; Pattanayak et al., 2023). Hydrophilic carboxyl, hydroxyl, sulfonic, amino,

et al., 2022; Mignon et al., 2019; Pattanayak et al., 2023). Hydrophilic carboxyl, hydroxyl, sulfonic, amino, and amide groups along the hydrogel chain contribute to high swelling (Qureshi et al., 2020). SAPs are utilized in various fields, including purification technologies, oil well operations, pharmaceuticals, personal care products, agriculture, and construction (Ganji et al., 2010). The most commonly used SAP is sodium polyacrylate, which is formed by combining multiple parts of petroleum-derived sodium acrylate (Qureshi et al., 2020; Zohourian & Kabiri, 2008). However, synthetic SAPs may cause environmental problems due to their poor degradability in the environment for a long time and embryotoxicity (Choi et al., 2022; Kim et al., 2017; Qureshi et al., 2020). Therefore, bio-based SAPs have

SAPs developed from biobased polymers are good alternatives due to biodegradability, low production costs, and environmental friendliness (Pascual et al., 2022; Tanan et al., 2018). SAPs are attained from biopolymers of various sources such as animal (fish, jellyfish) proteins (gelatin, collagen), plant proteins (soy, cotton), and polysaccharides (alginate, chitosan, starch, cellulose, carrageenan) (Bagheri Marandi et al., 2011; Feng et al., 2010; Hosseinzadeh et al., 2014; Hosseinzadeh et al., 2005; Maltais et al., 2009; Peng et al., 2016; Pourjavadi et al., 2004; Pourjavadi et al., 2006; Rathna & Damodaran, 2001; Soto et al., 2016; Tanan et al., 2018; Zhang et al., 2012; Zhang et al., 2011). Collagen has recently begun to be used frequently in industrial areas involving cosmetics, biomedical, and food (Nagai et al., 2000). While collagen attained from marine sources is known more for its use in cosmetics, that obtained from bovine and porcine sources is known for its use in industrial areas. Since jellyfish collagen has not caused any fatal disease reported so far, and there is no restriction on its use in terms of religion, Jellyfish have recently gained growing attention as a valuable source of collagen (Khong et al, 2018). To prevent the bloom of jellyfish around the world from causing environmental problems, utilizing this resource as a raw material in other areas may be a good solution. Jellyfish consist of nearly 95% water by weight, approximately 2-3% salt, and around 1-2% protein, depending on the species (Yusoff et al., 2013). The majority of this protein consists of collagen.

The major goal of the Paris Climate Agreement is to lower carbon emissions. In accordance with the aims of the Paris Agreement and Blue Growth, our research focuses on producing biobased materials as long-term alternatives to synthetic water-absorbent polymers frequently used by industry. The goals of this research are (I) to produce entirely or partially biobased superabsorbent polymers from jellyfish (*Aurelia aurita*) in the Sea of Marmara, collagen, chitosan, and synthetic acrylic acid, and (II) to measure the water absorption capacities of the produced superabsorbent polymers.

## Material and Methods

### Materials

N, N'-Methylenebis (acrylamide) (MBA, Merck, Germany), NaOH (Merck, Germany), glacial hydrochloric acid (88%, Merck, Germany), acetic acid (88%, Merck, Germany), disodium phosphate ( $\text{Na}_2\text{HPO}_4$ , Merck, Germany), ammonium persulfate (Sigma-Aldrich, USA), and acrylic acid (Merck, Germany) were of analytically pure grade. Chitosan obtained from marine sources (crab shells) was supplied by Mitosan Cor. The experiments were carried out utilizing a magnetic stirrer (MS3020D, Mtops, Korea), a freeze dryer (Alpha 1-4 LD, Christ, Germany), and an ultrasonic processor (UP-400S, Lawson Laboratory Ltd, China). Ultra-distilled water was

utilized for jellyfish desalination and to measure swelling.

### Preparation of Jellyfish

Collagen was isolated from jellyfish (*Aurelia aurita*) collected from the Sea of Marmara. Samples were immediately brought to the laboratory on ice. The salted jellyfish was washed three times using ultra-distilled water to eliminate the salt.

### Extraction of Collagen

A new physically supported acid-assisted collagen extraction method was applied, which improved the solubility and homogeneity of jellyfish tissues (Yusoff et al., 2013). Jellyfish were washed 1-2 times with ultra-distilled water and cut into pieces measuring 1-1.5 cm. The samples were then extracted three times using a 0.1 N sodium hydroxide solution at a 1:1 (w/v) ratio. The insoluble tissue was mixed with 0.5 M Acetic acid (1:1, w/v) in a mechanical mixer for 1 hour. The suspension was sonicated for 15 minutes. The dissolved fractions were dialyzed in 0.02 M  $\text{Na}_2\text{HPO}_4$  (phosphate buffer), pH 7.2, at 4°C to maintain stable pH conditions. If precipitation occurred, it was redissolved in 0.5 M acetic acid containing 0.9 M sodium chloride. After that, it was further purified with dialysis using 0.1 and 0.025 M acetic acid. Subsequently, it was lyophilized to obtain pure collagen.

### Synthesis of Superabsorbent Polymers

Three types of monomers were used to synthesize superabsorbent polymers: collagen obtained from jellyfish, chitosan obtained from marine sources, and acrylic acid. Briefly, collagen (0.5 g) was dissolved in 0.01 M acetic acid (30 mL) and mixed under nitrogen gas for 30 min. Afterward, ammonium persulfate (APS, 0.1 g) was added, followed by acrylic acid (3.6 g), N,N'-methylene bisacrylamide (MBA, 0.1 g), and distilled water (10 mL). It was stirred at 80°C for 3 hours. Then, 2 M NaOH was added to neutralize the pH to 7. Finally, it was dried at 70°C. After milling, the superabsorbent polymer was stored away from heat, moisture, and light (Bagheri Marandi et al., 2011). All of these processes were also carried out for other monomers.

### Characterization of the Superabsorbent Polymers

#### FT-IR Spectroscopy

The chemical structures were determined using Fourier transform infrared spectroscopy (FT-IR) with a PerkinElmer Spectrum Two FT-IR Spectrometer (L1600401 Spectrum Two DTGS, Llantrisant, UK). The spectra were measured in the 4000 to 650  $\text{cm}^{-1}$  (4  $\text{cm}^{-1}$  resolution).

### Differential Scanning Calorimetry (DSC) Analyses

A TA Instrument DSC250 analyzer was utilized to conduct differential scanning calorimetry (DSC) of superabsorbent polymers under a nitrogen atmosphere. The heating rate and temperature range were 10°C/min and 30°C to 300°C, respectively.

### Scanning Electron Microscopy (SEM)

The morphologies of superabsorbent polymers coated with gold film were characterized by field-emission scanning electron microscopy (Philips/FEI Quanta 400F).

### Swelling Measurements

The swelling capacities of SAPs were quantified using the filtration method (Safari et al., 2021). A dried sample (1 g) was entered into a beaker and exposed to a 9% NaCl solution at room temperature for two hours. The filter paper, saturated with ultra-distilled water, was weighed and placed in the Büchner funnel. The excess liquid of the swollen sample was removed by filtration under a vacuum. Finally, the filter paper with SAP on it was weighed again. The swelling ratio (SR) was measured twice and computed using the following equation:

$$SR (g/g) = \frac{W_2 - W_1 - W_0}{W_0} \quad (1)$$

where  $W_0$ ,  $W_1$ , and  $W_2$  represent the weights of dry SAP, pre-wet filter paper using ultra-distilled water, and wet SAP, respectively.

### Results

The superabsorbent polymers were obtained by cross-linking acrylic acid monomer onto collagen and chitosan via surface polymerization. Ammonium persulfate, used as an initiator, removes hydrogen from the functional groups in the side chains (-OH, -SH, -NH<sub>2</sub>, and -COOH) in the structure of collagen and chitosan and forms sulfate radicals. These radicals initiate the polymerization process of acrylic acid onto the chitosan and collagen backbone. Following this, the addition of MBA (crosslinker) initiated a cross-linking reaction, resulting in the formation of a three-dimensional structure (Safari et al., 2021).

### FT-IR Analysis

The FT-IR spectrum of polyacrylic acid is presented in Figure 1. The peaks between 3000-3500 cm<sup>-1</sup> were due to alkenes, and those between 2800-2900 cm<sup>-1</sup> were due to alkyl structures. The peak of the -OH group attached to the carbonyl group appeared in the range of 2500-2700 cm<sup>-1</sup>. The strong peak at 1700 cm<sup>-1</sup> corresponded to the C=O bond; the peak around 1600 cm<sup>-1</sup> was associated with the C=C bond. The characteristic peak of carboxylic acid was in the range of 1200-1000 cm<sup>-1</sup>.

Figure 2 illustrates the FT-IR spectra of collagen and collagen-polyacrylic acid SAP. Upon examination of the IR spectrum of collagen (Figure 2a), amide structures were observed at wavelengths ranging from 3500 to 3250 cm<sup>-1</sup>. The carbonyl peak has appeared at a wavelength of 1700 cm<sup>-1</sup>. The peaks between 1500 cm<sup>-1</sup> and 1000 cm<sup>-1</sup> originated from amide I, II, and III structures resulting from the helical structure that

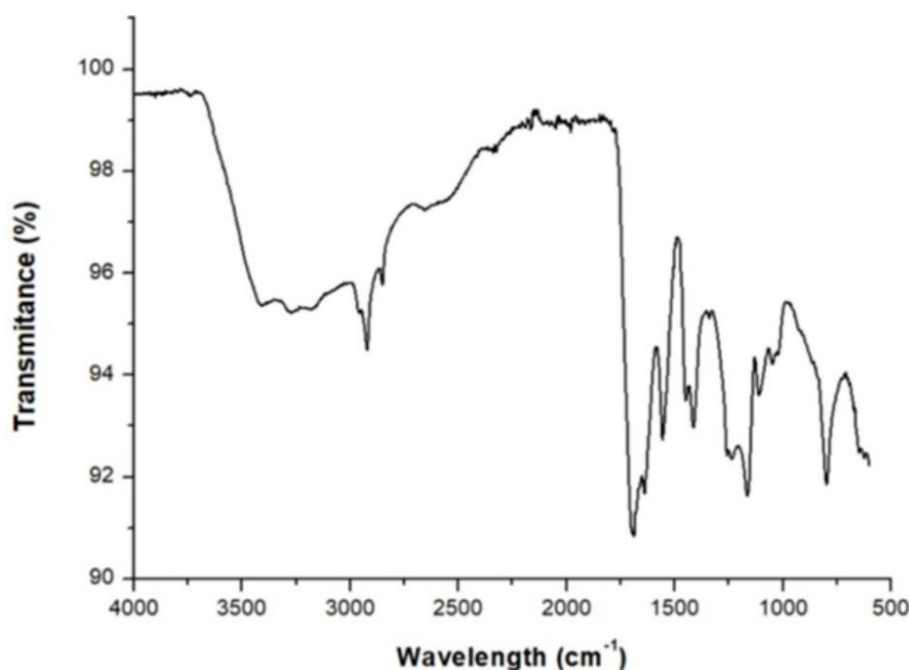


Figure 1. FT-IR spectra of the Polyacrylic acid.

provides flexibility. The amide I band is due to C=O stretching, the amide II band is due to N-H and C-N torsional vibrations, and the amide III band originates from C-N stretching vibrations (Figure 2a). When the collagen-polyacrylic acid SAP spectrum was examined (Figure 2b), it was observed that the amide peak at 3500-3250  $\text{cm}^{-1}$  decreased in intensity. The intensity of amide I, II, and III peaks between 1500  $\text{cm}^{-1}$  and 1000  $\text{cm}^{-1}$  decreased. In contrast, an increase in the carbonyl peak intensity was observed at 1700  $\text{cm}^{-1}$ , likely due to the presence of polyacrylic acid (Figure 2b).

FT-IR spectra of chitosan and chitosan-polyacrylic acid SAP are given in Figure 3. The broad double peak observed around 3300  $\text{cm}^{-1}$  is due to the -OH and -NH<sub>2</sub> structure. (Figure 3a). The peaks around 2800  $\text{cm}^{-1}$  are due to -CH<sub>2</sub>, which does not contain double bonds in the structure. The peaks at 1300  $\text{cm}^{-1}$  are attributed to the

C-N bond in amines, and the peaks at 1000  $\text{cm}^{-1}$  are due to the glycoside bond (Figure 3a). In Figure 3b, the two-peaked peak at 3200-3500  $\text{cm}^{-1}$  has disappeared, and a broad peak resulting from carboxylic -OH is observed. The amine peak at 1300  $\text{cm}^{-1}$  has disappeared. The carbonyl structure (C=O) originating from polyacrylic acid is observed at 1700  $\text{cm}^{-1}$ .

### Differential Scanning Calorimetry (DSC) Analyses

The DSC analysis reveals distinct thermal degradation behaviors for chitosan, collagen, and their polyacrylic acid (PAA) counterparts (Figure 4). The values for Degradation temperature and degradation enthalpy of chitosan, collagen, and polyacrylic acid composites are given in Table 1. Pure chitosan exhibits an exothermic peak at 202.6°C, attributed to the

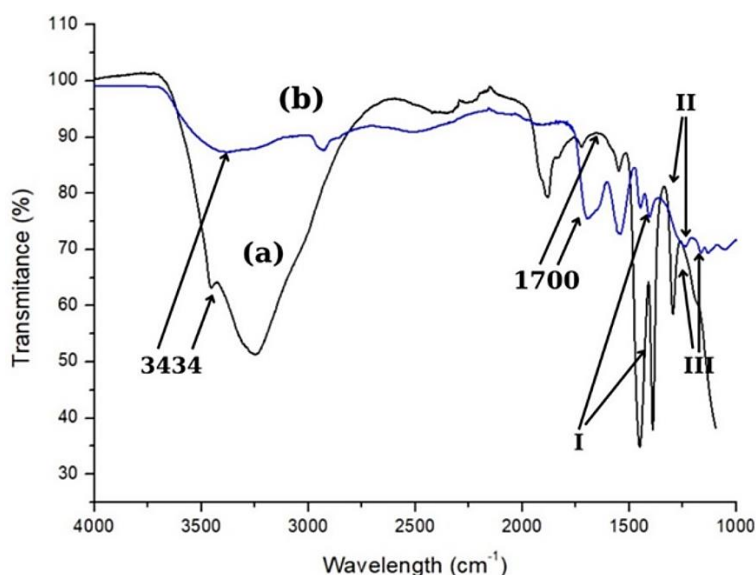


Figure 2. FT-IR spectra of the collagen (a), the collagen-polyacrylic acid SAP (b).

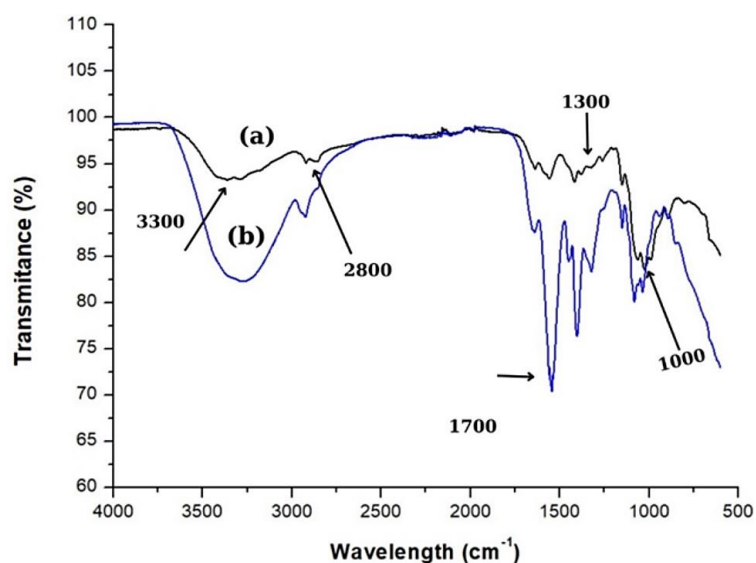


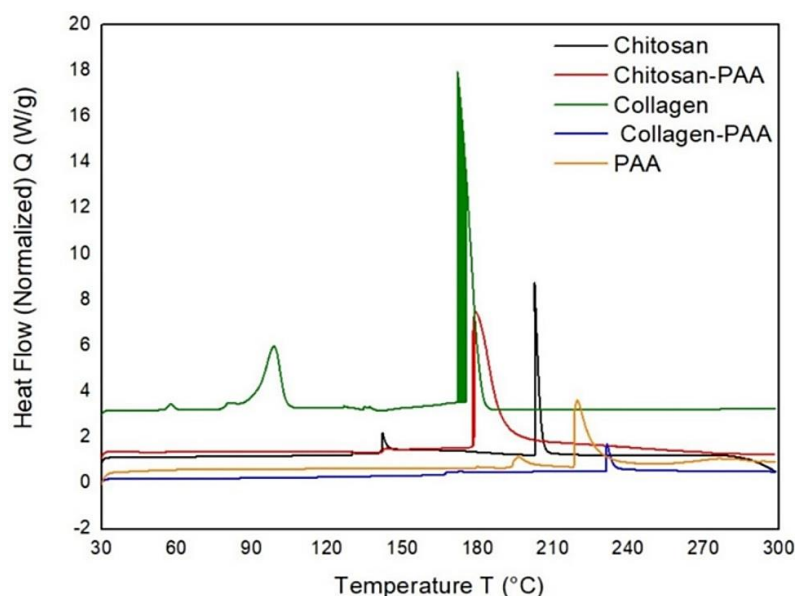
Figure 3. FT-IR spectra of the chitosan (a), the chitosan-Polyacrylic acid SAP (b).

decomposition of its glycosidic bonds and the release of ammonia. In contrast, collagen degrades at 171.8°C due to the denaturation of its helical structure. PAA onto chitosan lowers its degradation temperature to 179.1°C, indicating destabilization of the polymer backbone, whereas collagen-PAA shows enhanced thermal stability (231.5°C), reflecting a robust cross-linked network (Figure 4, Table 1). This aligns with FT-IR data, which show reduced amide peaks and the presence of new carboxylate groups, confirming successful polymerization.

### Scanning Electron Microscopy

The microstructure morphologies of hydrogels are one of the critical features that determine their performance and usage areas. The microstructure morphologies of the synthesized superabsorbents were determined using SEM. The SEM displays are illustrated in Figure 5. The provided SEM images reveal distinct morphological differences between the pure biopolymers (chitosan, collagen) and their polyacrylic acid (PAA) counterparts, which correlate directly with their swelling performance and structural integrity. Chitosan (exhibits a relatively smooth, dense surface with minor irregularities, typical of its linear polysaccharide structure. In contrast, collagen displays a fibrillar, networked morphology characteristic of its

triple-helical protein arrangement. These structural differences align with FT-IR data, where collagen's amide groups ( $3500\text{--}3250\text{ cm}^{-1}$ ) and chitosan's glycosidic bonds ( $1000\text{ cm}^{-1}$ ) were identified. Adding PAA significantly alters the morphology. Chitosan-PAA shows a heterogeneous surface with moderate porosity, likely due to the introduction of carboxyl groups from PAA disrupting chitosan's hydrogen-bonded matrix. However, collagen-PAA demonstrates a highly porous, interconnected 3D network, with pore sizes visibly larger than those in chitosan-PAA. This porous architecture is critical for its superior water absorption capacity (136 g/g vs. chitosan-PAA's 79 g/g), as it provides a larger surface area and capillary channels for fluid retention. The manuscript attributes this to collagen's higher density of  $\text{--NH}$  and  $\text{--OH}$  groups, which facilitate more extensive cross-linking with PAA, as confirmed by FT-IR (reduced amide peaks, increased carbonyl intensity at  $1700\text{ cm}^{-1}$ ). The SEM findings support the DSC results, where collagen-PAA's enhanced thermal stability ( $231.5^\circ\text{C}$ ) was linked to its cross-linked network. The porous structure also explains its higher swelling kinetics, absorbing 100× its weight within 5 minutes. In summary, the SEM data validate that collagen-PAA's unique microstructure underpins its exceptional performance as a bio-based superabsorbent, making it a promising alternative to synthetic hydrogels.



**Figure 4.** DSC thermogram of the chitosan, chitosan-polyacrylic acid (chitosan-PAA), collagen, collagen-polyacrylic acid (collagen-PAA), and polyacrylic acid (PAA).

**Table 1.** Values for Degradation temperature and degradation enthalpy of chitosan, collagen, and polyacrylic acid composites.

Samples	Ttd (°C)	$\Delta\text{Htd}$ (J/g)
Chitosan	202.64	83.512
Chitosan- polyacrylic acid SAP	179.06	373.27
Collagen	171.84	371.34
Collagen- polyacrylic acid SAP	231.50	23.886
Polyacrylic acid	219.64	128.06

Ttd thermal degradation temperature,  $\Delta\text{Htd}$  thermal degradation enthalpy.



### Swelling Analysis

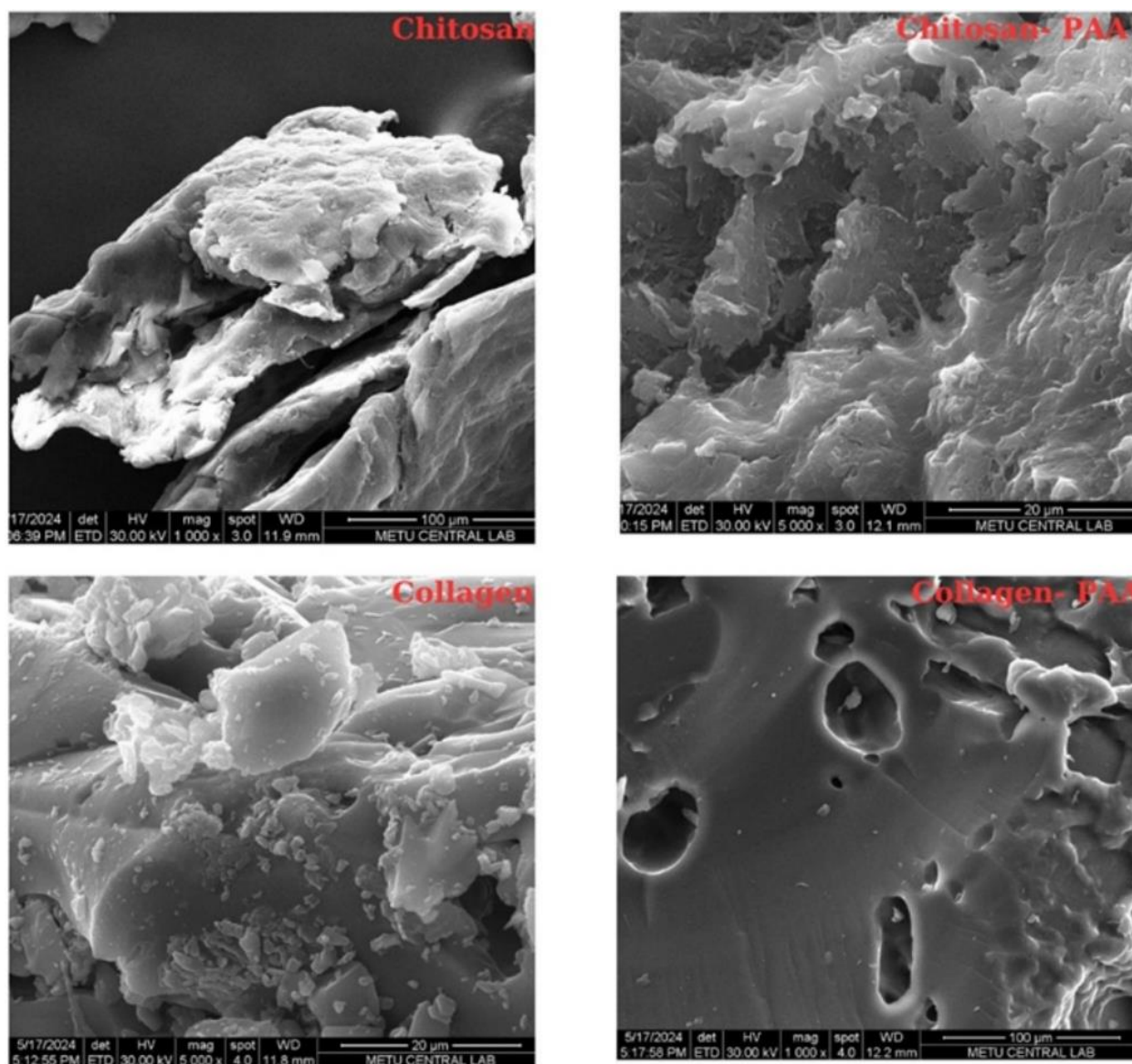
Swelling capacities were analyzed using saline solution (9‰ NaCl) as the swelling media. Figure 6 presents the time dependency of the water absorption capacity in the saline solution. SAPs' swelling capacities were measured in saline solution due to their use in products (incontinence products for adults, feminine hygiene products, and diapers) commonly used to absorb body fluids.

As indicated in Figure 6a-c, the maximum water absorption capacities in saline solution were 71, 79, and 136 g/g for polyacrylic acid (a), chitosan-polyacrylic acid SAP (b), and collagen-polyacrylic acid SAP (c), respectively. It has been determined that the water retention capacity of polyacrylic acid obtained with the polymerization process of acrylic acid retained approximately 50 times its weight within the first 5 minutes and approximately 70 times its weight within 70 minutes in salt water (Figure 6a). The water retention capacity of the SAP obtained through the polymerization

process of acrylic acid and chitosan was measured, and it was observed that the saline solution was retained approximately 60 times its weight within the first 5 minutes and 70 times its weight within 70 minutes (Figure 6b). The water retention capacity of collagen-polyacrylic acid SAP held approximately 100 times its weight in the first 5 minutes and 120 times its weight in 70 minutes in salt solution (Figure 6c).

### Swelling Kinetic Analysis

Swelling kinetics were employed to evaluate the absorption rate and swelling behavior of polyacrylic acid, chitosan-polyacrylic acid SAP, and collagen-polyacrylic acid SAP in a saline solution (9 ‰ NaCl). The sorption kinetics were analyzed using the Fickian diffusion and second-order kinetic models. Lagergren's pseudo-first-order kinetics has typically been used by plotting  $t$  against  $\ln(Q_e - Q_t)$ ; however, the value of  $\ln(Q_e - Q_t)$  becomes unclear as  $Q_t$  draws near  $Q_e$ . This fact decreases the accuracy when applying the pseudo-



**Figure 5.** SEM images of chitosan, chitosan-polyacrylic acid (chitosan-PAA), collagen, and collagen-polyacrylic acid (collagen-PAA).

first-order equation to SAPs (Choi et al., 2022; Rehman et al., 2019). The reaction equation of the pseudo-second-order is as follows:

$$\frac{t}{Q_t} = \frac{1}{k_2 Q_e^2} + \frac{1}{Q_e} t \quad (2)$$

where  $Q_t$ : absorption capacity at different times,  $Q_e$ : absorption capacity at equilibrium,  $k_2$ : pseudo-second-order rate constant.

The parameters of the absorption kinetic model were calculated and shown in Figure 7a and Table 2. The excellent linear correlation coefficient values ( $R^2 > 0.99$ ) for polyacrylic acid, chitosan-polyacrylic acid SAP, and collagen-polyacrylic acid SAP indicate that the second-order kinetic models accurately fit the swelling process of all three materials, as shown in Figure 7a. These results align with the findings of earlier studies (Choi et al., 2022; Dai et al., 2019; Ho & McKay, 1999; Rehman et al., 2019).

The mechanism by which the solvent penetrates during the initial swelling stage was explained using the Fickian diffusion model (Choi et al., 2022; Dai et al., 2019). The reaction equations are given below:

$$F = \frac{Q_t}{Q_e} = Kt^n \quad (3)$$

$$\ln F = n \ln t + \ln K \quad (4)$$

where  $Q_e$  and  $Q_t$  are the weights of solvent absorbency at equilibrium and time  $t$ , respectively;  $K$  represents a characteristic constant;  $F$  denotes the fractional uptake at time  $t$ ;  $n$  symbolizes the solvent's diffusional exponent.

In accordance with the classification of the diffusion model, water transport shows Fickian diffusion, which is controlled by a simple concentration gradient at  $n < 0.5$ . At  $0.5 < n < 1$ , water transport displays non-Fickian diffusion, where both water diffusion and relaxation of polymer chains are controlled together. At  $n > 1$ , water transport illustrates anomalous diffusion, which is controlled by the relaxation of polymer chains of the diffusion system (Choi et al., 2022; Dai et al., 2018; Dai et al., 2019). The graph plot of  $\ln(t)$  versus  $\ln(F)$  is shown in Figure 7b, and the model parameters ( $n$ ,  $K$ , and  $R^2$ ) are calculated and given in Table 2. As shown in Figure 7b, the data display flat lines with a very good linear correlation coefficient ( $R^2 > 0.99$ ), demonstrating the impact of the Fickian diffusion model. The  $n$  values for polyacrylic acid, chitosan-polyacrylic acid SAP, and collagen-polyacrylic acid SAP ranged from 0.5 to 1, indicating a predominance of non-Fickian diffusion during the initial swelling phase in a 9 % NaCl solution.

## Discussion

The formation of collagen-PAA and chitosan-PAA superabsorbents was achieved first by free radical polymerization, followed by cross-linking reactions. FT-IR, DSC, and SEM analyses were used to characterize these synthesized superabsorbents. Furthermore, the swelling capacities of these superabsorbents were determined, and their efficiencies were compared both with each other and with similar biopolymer-based SAP systems reported in the literature.

Analyzing the FT-IR spectra, our spectra show a large O-H stretching band ( $\sim 3300$ - $3400 \text{ cm}^{-1}$ ) caused by hydrogen bond interactions and hydroxyl vibrations, similar to a band ( $3369 \text{ cm}^{-1}$ ) seen in Xu et al.'s (2019)

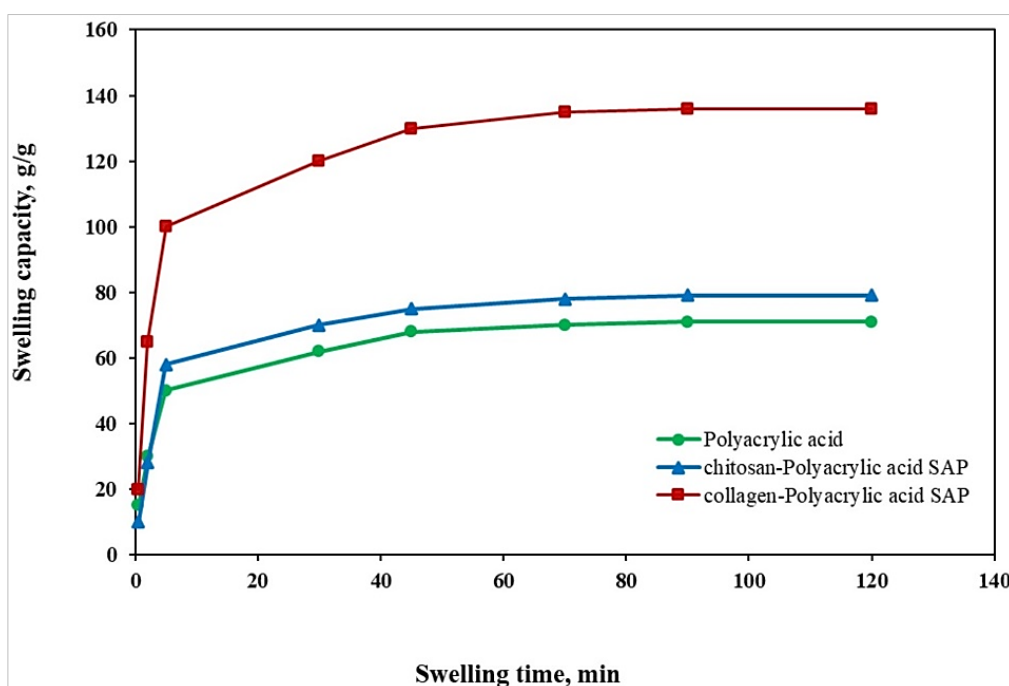


Figure 5. SEM images of chitosan, chitosan-polyacrylic acid (chitosan-PAA), collagen, and collagen-polyacrylic acid (collagen-PAA).

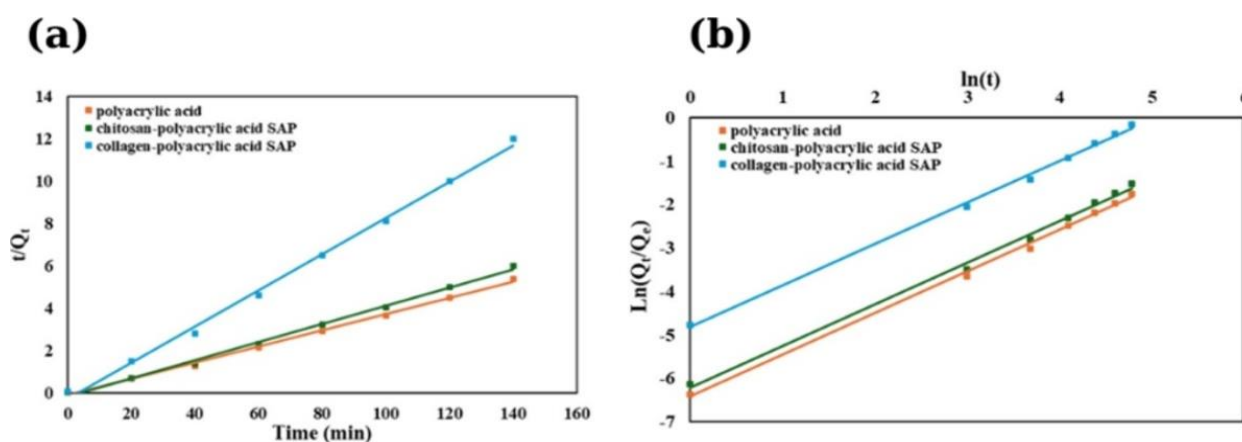
study on collagen-g-PAA superabsorbents Xu et al. (2019). Paneva et al. (2003) found a distinct C=O band in the 1700-1720  $\text{cm}^{-1}$  area, indicating carboxylic groups in poly(acrylic acid)-based compounds, which is consistent with our findings (Paneva et al., 2003). Our investigation found that the intensity of the amide I-III bands (1500-1000  $\text{cm}^{-1}$ ) decreased, similar to recent findings in chitosan-graft-Poly(acrylic acid) SAPs (Jayanudin et al., 2022).

Evaluation of the DSC data reveals the chitosan-PAA composite degradation temperature ( $\sim 179^\circ\text{C}$ ) is consistent with recent DSC/TGA assessments of modified chitosan systems (Ostrowska-Czubenko & Gierszewska-Drożdż, 2015; Bernal et al., 2023). The decrease in thermal stability following grafting with acrylic acid has been linked to the breaking of hydrogen bonds and the creation of a less ordered polymeric network. Yang et al. found that applying PAA to collagen raised denaturation temperature ( $T_d$ ) by 4.8-5.9  $^\circ\text{C}$  when compared to native collagen. This was also linked to the presence of strong crosslinks between collagen and PAA (Yang et al., 2020). As a result, the thermal profiles of both composites reflect published trends in which acrylic-based modification reduces chitosan stability while increasing collagen stability through network reinforcement. The superior thermal stability of collagen-PAA correlates with its higher swelling capacity (136 g/g) compared to chitosan-PAA (79 g/g), as the cross-linked 3D structure accommodates more water without structural breakdown. SEM images further support this, revealing a porous morphology in collagen-PAA that facilitates water retention. The DSC results underscore how polymerization tailors the thermal and functional properties of these biopolymers, with

collagen-PAA emerging as a promising biodegradable superabsorbent material. Future studies could explore humidity-dependent DSC profiles to assess the practical applicability of these materials in hygroscopic environments.

Assessment of the SEM results shows that this study's findings on the association between microstructure and performance are consistent with prior work on acrylic acid-modified biopolymer hydrogels. Jayanudin et al. (2022) employed SEM pictures to demonstrate the porous, void-like structure of chitosan-g-PAA hydrogels, which improves water diffusion and increases swelling (Jayanudin et al., 2022). Similarly, Pourjavadi et al. (2008) discovered that collagen-based hydrogels cross-linked with acrylic monomers produce extremely porous, interconnected 3D networks in SEM images, which are associated with better water uptake and resilience to ions and pH fluctuations (Pourjavadi et al., 2008). Another work discovered that P(AA-co-AMPS)-grafted chitosan hydrogels have different morphological-mechanical interactions, with pore size and wall thickness influencing water retention and structural strength, larger pores cause more swelling but less mechanical strength (Phonlakan et al., 2023). Our findings are supported by the literature: chitosan-PAA with moderate porosity displays modest swelling, whereas collagen-PAA with a more open, linked 3D structure exhibits increased water absorption and stability.

In terms of swelling behavior, in 2011, Liu et al. used chitosan (CTS), acrylic acid (AA), and poly(vinyl alcohol) (P-PVA) as raw materials to create the CTS-g-PAA/P-PVA superabsorbent hydrogel. They found that this hydrogel has a swelling capacity of 47 g/g in a 0.9



**Figure 7.** The pseudo-second-order equation (a) and the Fickian diffusion equation graphs of polyacrylic acid, chitosan-polyacrylic acid SAP, and collagen-polyacrylic acid SAP (b).

**Table 2.** Absorption Parameters of Fickian Diffusion Model and Pseudo-Second-Order Kinetics.

	Fickian Diffusion Model			Pseudo-Second-Order Kinetics		
	K	n	R <sup>2</sup>	k	Q <sub>e</sub>	R <sup>2</sup>
polyacrylic acid	0.0016	0.958	0.9975	0.0142	26.04	0.9971
chitosan-polyacrylic acid SAP	0.0020	0.958	0.996	0.0116	23.31	0.9964
collagen-polyacrylic acid SAP	0.0080	0.956	0.9971	0.0258	11.70	0.9963



weight percent NaCl solution. The chitosan-polyacrylic acid SAP value of 79 g/g found in this investigation is much higher than this value (Liu et al., 2011). Pourjavadi and Kurdtabar (2007) and Pourjavadi et al. (2008) synthesized superabsorbent polymer from synthetic collagen and measured their water absorption capacity in saline (NaCl solution) water (Pourjavadi et al., 2008; Pourjavadi & Kurdtabar, 2007). Pourjavadi et al. (2008) reported a water absorption capacity of 60 g/g for collagen-g-PAA hydrogel in NaCl salt solution, which is relatively low compared to the findings of this study. Similarly, the water absorption capacity of the collagen-g-(PAA-co-PHEA) hydrogel prepared by Sadeghi et al. in NaCl salt solution was also lower than ours (Sadeghi & Hosseinzadeh, 2013). Additionally, collagen-g-poly (Sodium Acrylate-co-Acrylamide)/sodium montmorillonite superabsorbent nanocomposites synthesized in another study also exhibited lower water absorption in NaCl salt solution compared to the current results (Bagheri Marandi et al., 2011). It was determined that collagen has a higher water retention capacity because it contains more -NH and -OH groups than chitosan. In addition, it is thought that collagen has higher voids in the three-dimensional structure due to its longer chain than chitosan, which is another factor that increases its water retention capacity.

## Conclusion

In this study, SAPs were fabricated by surface copolymerization using acrylic acid monomer on collagen and chitosan with MBA as the cross-linker, as verified by FT-IR spectroscopy. The swelling rates over time in a saline solution were measured to determine the water absorption capacity of the SAPs. The maximum water absorption capacities in saline solution (9‰ NaCl) were 71, 79, and 136 g/g for polyacrylic acid, chitosan-polyacrylic acid SAP, and collagen-polyacrylic acid SAP, respectively. The highest water retention capacities of chitosan-polyacrylic acid SAP and collagen-polyacrylic acid SAP were determined to be approximately 70 times and 120 times their weight, respectively. The swelling kinetics showed excellent linear correlation with Schott's pseudo-second-order kinetics and Fickian diffusion models. Jellyfish are a resource with no economic value and pose an environmental problem due to their high tolerance to pollution. This study aims to transform jellyfish into a high-value-added product, thereby positively reducing its carbon footprint. By reducing long-term ecological pollution, the synthesized materials' biodegradability promotes environmental sustainability. Future research will concentrate on creating superabsorbent polymers entirely made of biobased materials to improve their environmental friendliness further. Subsequent efforts should focus on scaling up the synthesis process for industrial applications, assessing raw material availability and economic viability, and carrying out thorough life-cycle evaluations to gauge environmental

implications. These developments will facilitate the incorporation of biobased superabsorbents into large-scale sectors such as wastewater treatment, biomedical materials, hygiene goods, and agriculture.

## Ethical Statement

Not applicable.

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## Author Contribution

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Nagihan Ersoy Korkmaz: Conceptualization, Methodology, Writing - Original draft, Writing - Reviewing and Editing, Visualization.

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## Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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