Research Article EMUJPharmSci ISSN 2651-3587 https://dergipark.org.tr/emujpharmsci

EMU Journal of Pharmaceutical Sciences

EMUJPharmSci

Adsorption of iron, lead, paracetamol, imipramine on natural polymers

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Abstract

Poisoning results from many reasons such as misuse or overdose of drugs. Suicidal and murder purposes are mostly severe, serious and life-threatening cases which require immediate intervention and treatment. Among lifesaving methods external and/or internal decontamination is the most important. Internal decontamination (gastrointestinal) is an effective process for intoxication control that can be done by adsorptive materials. Activated charcoal is used as unique local antidote for adsorption of causative agent. Considering their significance and effectiveness, adsorptive materials are necessary to be developed. In the present study, starch and naturally extracted pectin from citrus, in the presence of trace amount of potassium per sulphate as initiator, were thermally grafted to chitosan to form natural, inert, and highly adsorptive polymeric surfaces. This polymer is convenient for biomedical purposes. Upon drying at 37°C for 48 hours, thermally cross-linked products were obtained. FTIR, UV-Visible spectrophotometer and SEM analyses were applied in order to characterize the products. To evaluate the adsorption potency of new adsorptive material, lead and iron which cause common poisoning were applied on the polymers. The results showed that adsorption degree of lead and iron were maximum 50% and 30% respectively. Desorption amounts can be a sign of adsorption potency. In this study, paracetamol and imipramine, which are commonly used drugs that can and caused intoxication in case they are misused or use for suicidal purpose were applied onto two polymers which contain pectin desorption amount for two drugs were determined. SEM pictures taken before and after blood/polymer contact didn't reveal any significant blood component attachment on the chitosan-*graft*- (starch; pectin) film surface. Indicating no hemocompatibility.

Keywords

Chitosan, decontamination, hemocompatibility, imipramine, iron, lead, paracetamol, pectin, starch.

Article History

Submitted: 24 June 2019 Accepted: 30 July 2019 Published Online: 11 September 2019

Article Info

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Research Article:
Volume: 2 Issue: 1 September 2019 Pages: 33-54

INTRODUCTION

Intentional and unintentional exposure to various types of drug, chemicals, residuals, wasting materials, herbal products, food contaminants and environmental pollutants at high doses via many ways are common reasons for health problems especially in human (Crowl and Louvar 2001). As a result, many different type poisonings can be seen. Intoxication approaches that consist of airway, breathing, circulation and decontamination (ABCD) are lifesaving and important.

Decontamination has both external and internal types. Internal decontamination of gastrointestinal system is very important in poisoning. For this purpose, some processes such as stomach washing and emesis are applied. Furthermore, adsorption of causative substance would be useful and effective.

Many drugs, chemicals and causative agents are easily adsorbed to local antidote at considerable amount. On the other hand, some others don't show affinity to local antidote. One of the best-known adsorptive materials is activated charcoal that has a wide range of adsorptive potency to different materials and drugs. Development of such adsorptive material with higher affinity will be very useful.

For this reason, in the present study some polymers were prepared as new adsorptive materials. Heavy metals like lead (Pb), essential metal iron (Fe), paracetamol as analgesics and a tricyclic antidepressant, imipramine, were analyzed to evaluate their adsorptive degree to these new polymers.

Although some metals are essential for the body heavy metals which cause toxic effects in human can be very harmful (Geiger and Cooper 2010). Lead exposure happens through air and food in almost the same amounts. More than 50% of lead productions are produced from petrol. Industrial lead exposure happens in mines and smelters, together with lead painted metal repairing, and in battery plants. Glass industries are responsible for low or moderate exposure. High levels of air discharges may lead to pollution in areas near lead mines and smelters. Soil and water can be contaminated by airborne lead deposition which may lead to human exposure via food chain.

Lungs absorb up to 50% of inhaled inorganic lead. Adults absorb 10–15% of the lead inside food, while children's gastrointestinal tract may absorb up to 50%. Lead is bound to erythrocytes in blood, and has a slow elimination rate via urine. Lead accumulates in the skeletal system and has a slow releasing rate from different tissues and structures. The half-life of lead is about 20–30 years and 1 month in skeleton and blood, respectively. Organic lead compounds can enter the body and cell membranes (Järup 2003). Tetramethyl and tetraethyl lead have

good skin penetration. These compounds also have the ability to cross the blood-brain-barrier in adults. That's why organic lead compounds may cause acute poisoning and encephalopathy in adults in consequence. Blood-brain-barrier permits the entrance of organic lead in adults. In babies the crossing ratio to brain is higher than adults. The high gastrointestinal uptake and the penetrable blood-brain-barrier make children good candidates for brain damage related with lead exposure. Headache, irritability, abdominal pain, proximal renal tubular damage and other different nervous system related symptoms are the symptoms of acute lead poisoning. Sleeplessness and restlessness are the most important symptoms of lead encephalopathy. Behavioral disturbances and learning and concentration difficulties are the results of lead poisoning in children (Järup 2003). Patients with lead encephalopathy may experience acute psychosis, confusion and reduction in consciousness. People who have been under lead exposure for a long time may undergo memory deterioration, prolonged reaction time and reduction in understanding ability. Individuals whose blood lead levels are under 3 μmol/l may express peripheral nervous symptoms with decreased nerve transference velocity and dermal responsiveness. If severe neuropathy occurs, the lesion may stay for life long. In less severe circumstances, the most noticeable sign of lead poisoning is hemoglobin synthesis disturbance, and long-term lead exposure may lead to anemia and kidney damage (Järup 2003). Inorganic lead shows toxicity in nephrons because of its high affinity to accumulate in proximal tubule. Kidney damage can occur as result of long-term lead exposure. According to a recent study including Egyptian policemen, NAG excretion was directly shown to be related with the duration of lead exposure (Gang *et al*. 1988).

Iron in trace amounts is essential element for body. Iron overdose may cause serious poisoning in which symptoms usually appear within 6 hours after poisoning. Iron poisoning occur at 5 stages which may result in life threating circumstances such as destructive damages to gastrointestinal (GI) mucosa, hemorrhagic gastritis, considerable fluid loss, bleeding and shock (Baranwal and Singhi 2003).

Moreover, drugs which are used at normal therapeutic doses for diagnosis, therapy and poisoning treatment, can also lead to poisoning (Prescon 1983).

Normally paracetamol (acetaminophen) is known as a safe drug but since it's an OTC drug which is consumed in large amount by adults and children, its toxicity which may cause acute centrilobular hepatic necrosis is common. Paracetamol poisoning has no specific or early signs and symptoms and doesn't lead to impaired consciousness.

Acute renal failure which is an uncommon complication may also occur (Prescon 1983; Haddah *et al.* 1983).

Imipramine is an antidepressant medication that is a cheap and accessible. Therefore, its accidental consumption or use for suicidal purposes is common. The toxicity signs include, slow breath, low blood pressure, rapid heartbeats and disturbance of electrocardiograph (Brush and Aaron 2007). An adsorptive blood compatible polymer must be inert, non-reactive, form's strong bonds and possess high affinity to agents. The polymer-agent complex should be easily excreted by feces (Bahramzadeh *et al.* 2019).

MATERIALS AND METHODS

Following materials, instruments and methods were used to prepare and characterize the polymers: Chitosan medium molecular weight (450 kDa) with degree of deacetylation of 85% (Sigma-Aldrich), corn starch, lemon extracted from citrus fruit potassium per sulfate (KPS) (EDH Chemicals LTD), (Titrachem), acetic acid (Sigma-Aldrich), acetone (Tekkim Kimya San), ethanol (Selim ve Oglu Ltd), hydrochloric acid (Merck) without any purification, lead two oxide (Sigma-Aldrich), iron three chloride (Sigma-Aldrich), dithizone (Sigma-Aldrich), salicylic acid (Sigma-Aldrich), paracetamol tablet (Minoset), imipramine tablet (Novartis 25 mg) and methanol (Sigma-Aldrich). The products were characterized by FTIR (Perkin Elmer, Spectrum Two Spectrometer), UV-visible spectrophotometer (Perkin Elmer) and scanning electron microscope (SEM) (LEO 1450 VP Scanning Electron Microscope). SEM analysis was carried out in Ferdowsi University, Mashhad, Iran.

Preparation of new adsorptive material

Pectin extraction

25 g of lemon was weighted and transferred in a 250 ml beaker. 100 ml of water and 1.5 ml of 3 N sulphuric acid (H_2SO_4) solution were added. The mixture was heated by magnetic stirrer. Temperature of the mixture was controlled by a thermometer and heated at 85-90 °C for 30 minutes. Following heating, the aqueous part was filtered through a cotton swab of cotton wool. Cotton was squeezed with the help of baguette. The remaining crusts were further extracted for 15 minutes under the same conditions. The filtrates were combined. The filtrate was transferred to a 500 ml sieve and 96° ethanol was added until the alcohol grade became 55°. The precipitated pectin was filtered under Buchner funnel under a slight vacuum. The precipitate was completely transferred to a funnel and washed firstly with 25 mL of 96° alcohol and then continued washing, for two times with 15 mL of acetone.

Preparation of films

Specific amount of starch and pectin were dissolved in 15 mL of chitosan solution (1% w/v solution in 1% v/v acetic acid solution) at room temperature, as shown in Table 1. The mixture was transferred to a petri dish, and a film layer was formed due to thermal crosslinking, following the evaporation of solvent at 37°C for 48 hours. Dried samples were taken and impurities were cleaned off the films by immersing in water. Grafted products were named as chitosan-*graft*-(starch; pectin).

Under similar experimental conditions, in the absence of pectin, a mixture of chitosan/starch solution was also prepared in a form of film.

Table 1: Synthesis of chitosan-graft-starch and chitosan-graft-(starch; pectin) films*.

Film	Pectin (ml)	Starch (g)
F1	0	0.2
F2	2	0.2
F3	5	0.2

*15 mL of 1% v/v acetic solution, 0.15 g chitosan, 0.075 g KPS, 37°C, 48 hours.

Swelling kinetics

From each of dry thermally cross-linked sample film samples, 0.01 g was taken, soaked in water. The weight was recorded in every 30 minutes (leaking was avoided). Swelling percentage was calculated with respect to the following equation (Bahramzadeh *et al.* 2019):

$$\text{Swelling \%} = \frac{Ws-Wd}{Wd} \times 100 \text{ ; eq. (1)}$$

where Ws (g) and Wd (g) stands for the weights of swelled and dry hydrogels, respectively.

In-vitro platelet adhesion analyses

Films were covered by human fresh blood obtained from healthy donors, washed by ultra-pure water and dried to examine contact properties by SEM (Caner *et al.* 1998).

Lead adsorption by chitosan-*graft*-(starch; pectin) films

Films (0.05 g) were covered by 10 ml Pb^{2+} solution at 125, 250 and 500 ppm concentrations at 1, 2, 3 and 24 hour time intervals. 2 ml Pb^{2+} solution from each test tube was taken and mixed with 1 ml alcohol dithizone solution. Resultant absorbance values was recorded, at room temperature at 472 nm wavelength. Triplicated measurement was applied for each sample and the average value was recorded. Percent removal of Pb^{2+} was calculated according to following equation:

$$\frac{(Ai-Af)}{Ai} \times 100 \text{ ; eq. (2)}$$

where Ai is initial absorbance and Af shows final absorbance.

Fe^{3+} adsorption by chitosan-*graft*- (starch; pectin) films

0.01 g of the film was added to 4 different test tubes and covered by 4 ml Fe^{3+} solution at the concentrations of 125, 250, 500, 900 ppm and incubated for 1, 2, 3, 4 hours. From each of the test tubes, 0.5 ml Fe^{3+} solution was drown and mixed with 0.5 ml of 5-sulfosalicylic acid dehydrate, (10% w/v), and the volume was completed upto 4 ml using pH = 1 buffer solution. Absorbance was recorded by visible spectrophotometry at 505 nm. Finally, percent removal of Fe^{3+} was calculated according to equation 2.

Paracetamol loading into chitosan-*graft*-(starch; pectin) films

0.01 g of the film was added to 4 different test tubes and covered by 4 ml paracetamol solution at the concentrations of 3.75, 7.5 and 15 ppm and remained for 48 hours. After 48 hours, the films were taken from solution and dried. Afterwards, they were placed in a test tube and 4 ml distilled water was added to release the adsorbed paracetamol. Desorption results were monitored by UV-Visible spectrometer at 242 nm in 5 hours with 1 hour intervals.

Imipramine loading into chitosan-*graft*-(starch; pectin) films

0.01g of the film was added to 4 different test tubes and covered by 4 ml imipramine dissolved in methanol at the concentrations of 0.077, 0.155, 0.31 ppm. After 48 hours, the films were taken and placed in a test tube covered with 4 ml methanol and the desorption results were taken by visible spectrometer at 251 nm.

RESULTS

Figure 1 shows photograph of Chitosan-*graft*- (starch; Pectin) films.

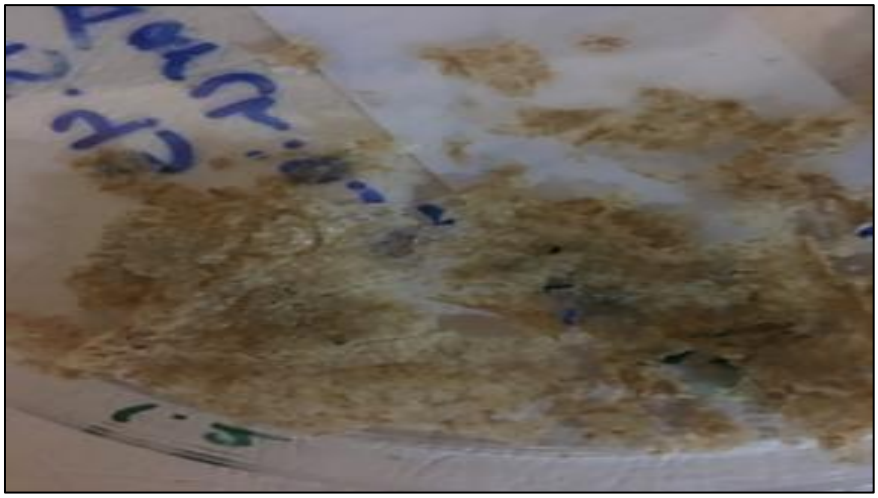

Figure 1: *Chitosan-graft- (starch; Pectin) films.*

Table 2 shows at (37℃) the percent of grafting increases while the amount of pectin increased.

Table 2: Synthesis of Chitosan-graft- (starch; pectin) Films.

Sample ID	Starch (g)	Pectin (g)	Grafting % 37℃
S1	0.2	0	0
S2	0.2	2	23
S3	0.2	5	43

Swelling behavior of chitosan-graft-polyHEAA and chitosan-graft-(polyHEAA;MBA) films

Figure 2A and 2B show the swelling behavior of chitosan-*graft*- (starch; pectin) films with different amount of pectin. They both showed maximum 70% swelling but at different time intervals. S3, standing for a compound with higher amount of pectin, marked maximum swelling after 30 minutes whereas S2, representing the same compound containing less amount of pectin showed maximum swelling after 90 minutes. They both increased the biodegradability time because samples lasted for a longer period. This promises the natural modification for drug loading and adsorbing toxins. On the other hand, S1 was degraded far faster and less controllable.

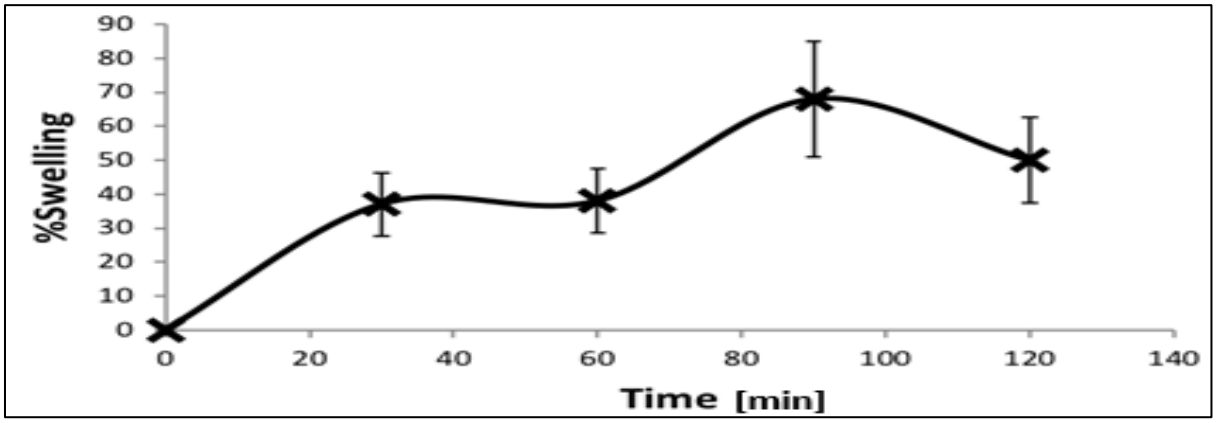

Figure 2A: Swelling behavior of S2 (Chitosan-graft-(starch; 2g Pectin) films at pH=7.4 in 2 hours within 30 min interval.

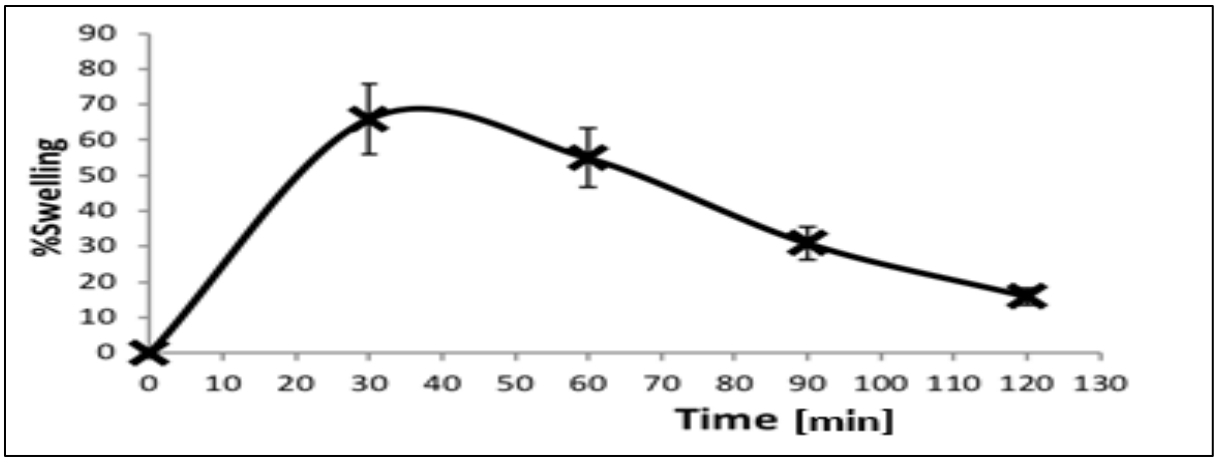

Figure 2B: Swelling behavior of S3 chitosan-graft-(starch; 5 g pectin) films at pH=7.4 in 2 hours within 30 min interval.

FT-IR Analysis

Films were characterized by FTIR spectrometer to assess modifications. Figure 3a shows major functional groups for chitosan where broad band after 3000 cm^{-1} represents H-bonding and 2 picks on 1551 and 1649 cm^{-1} stands for C-O and amide functional groups, respectively. Moreover, 2 picks at 2884 and 2974 cm^{-1} show C-H stretching. However, a pick at about 1370 cm^{-1} appeared when the polysaccharide chains were grafted onto the chitosan backbone which were concluded as C-H bond. In the FTIR spectrum of chitosan-starch shown in Figure 3b, amide band at 1649 cm^{-1}, C–H bending vibrations in the 1400–1500 cm^{-1} region, $–CH_3$ bending at 1380 cm^{-1}, C-H stretching at 2884 and 2974 cm^{-1} and O-H stretching at 3339 cm^{-1} were recorded.

When it comes to the pectin containing films, (Figure 3c and 3d), all the previous spectra were similar except between 1630 $cm^{-1}$and 1747cm^{-1}. Moreover, an additional signal appeared which became more intense once the pectin amount had been increasing (Figure 3d).

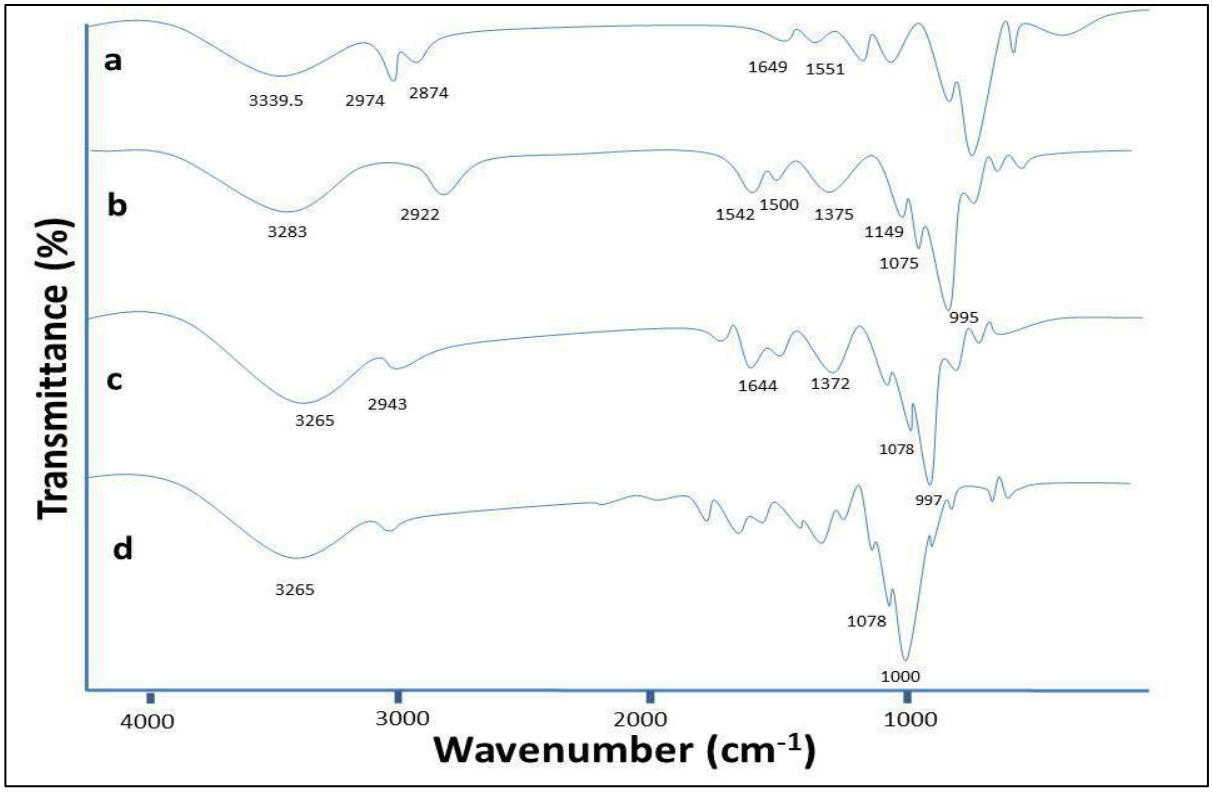

Figure 3: The FTIR spectrum of a. chitosan b. S1 (chitosan grafted starch) c. S2 (chitosan-graft-(starch; 2 g Pectin) films d. S3 (chitosan-graft-(starch; 5 g pectin) films.

SEM analysis for chitosan-graft-(starch; pectin)

The surface morphologies of grafted products were examined using SEM pictures as shown in Figure 4A, 4B and 4C. SEM images of samples exhibit more spherical structures on the surface and therefore wider surface area and more adsorption potency due to excessive exposed active sites, in the presence of pectin in samples S2 and S3. On the other hand, less fine spherical structures were detected in S1 where starch was grafted on to chitosan. In brief, addition of pectin showed a positive modification role when its entire surface area was taken into account.

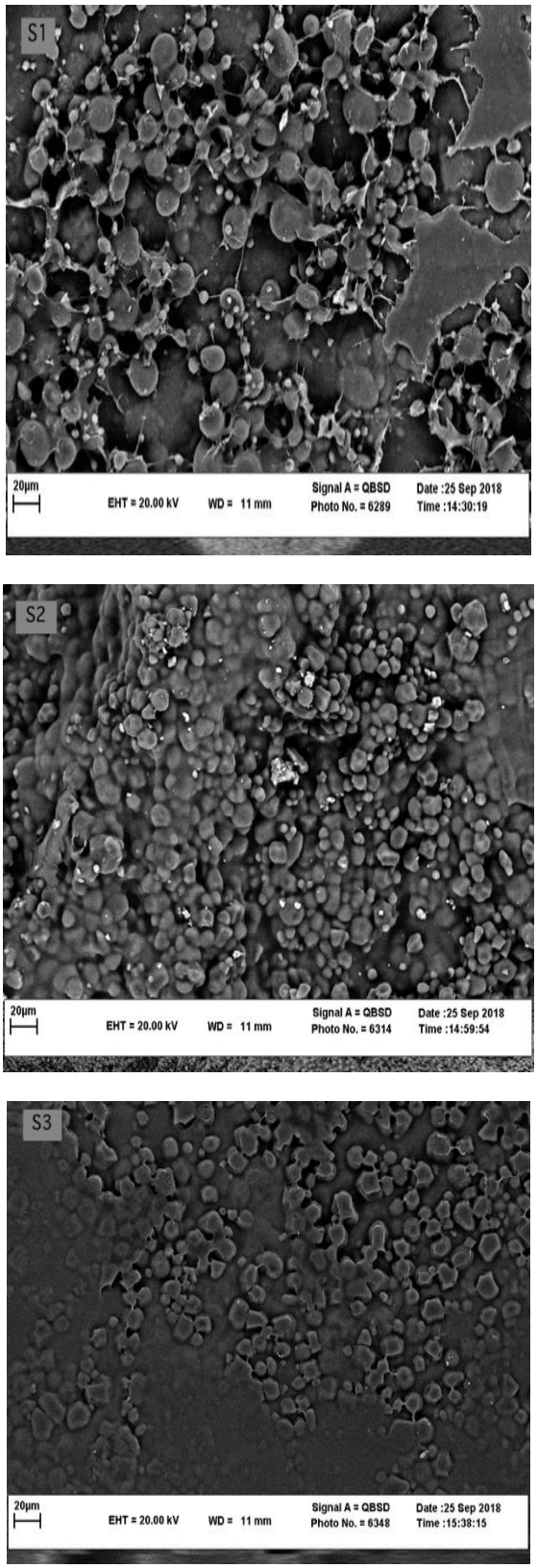

Figure 4A: SEM pictures (200 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (2 g) (S2), and starch (0.2 g) chitosan-graft-pectin (5 g) (S3),

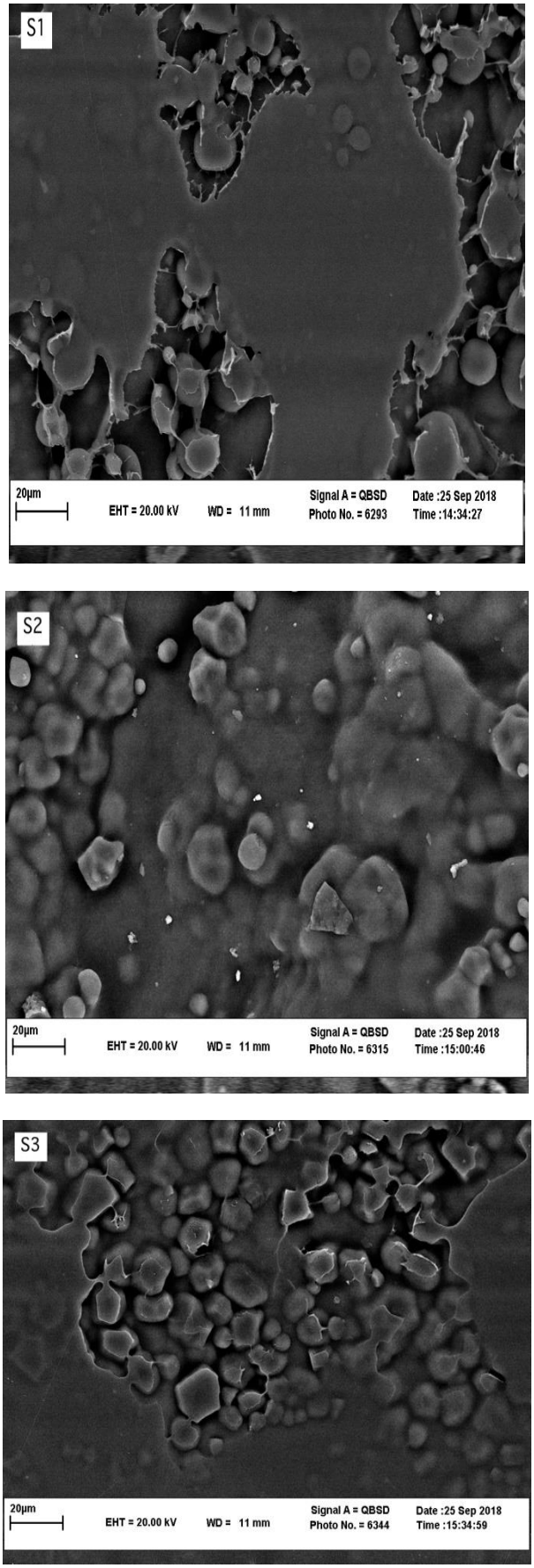

Figure 4B: SEM pictures (2000 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (2 g) (S2), starch (0.2 g) chitosan-graft-pectin (5 g) (S3).

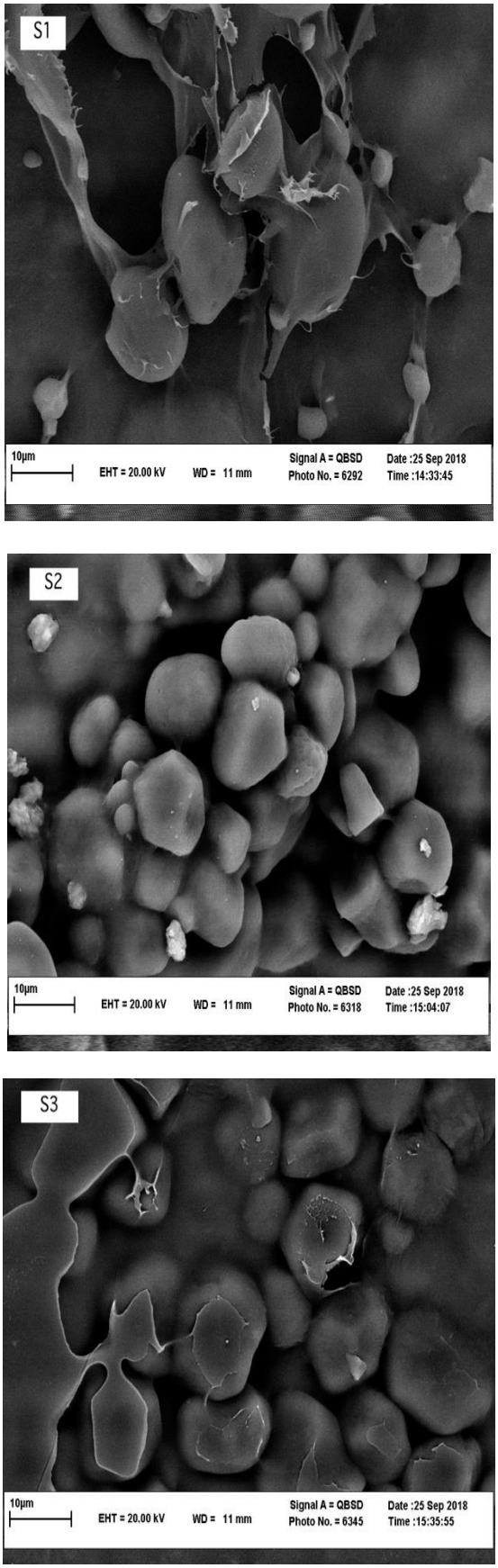

Figure 4C: SEM pictures (5000 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (2 g) (S2), starch (0.2 g) chitosan-graft-pectin (5 g) (S3).

In vitro platelet adhesion

Figure 5 shows the SEM images for films when they come in contact with blood in vitro conditions. The surface of polymers does not exhibit any notable different texture. Any sign of blood coagulation is not detectable before and after blood contact. However; denser matrix, as a result of physical blood stream, seems to be loaded in pores of films.

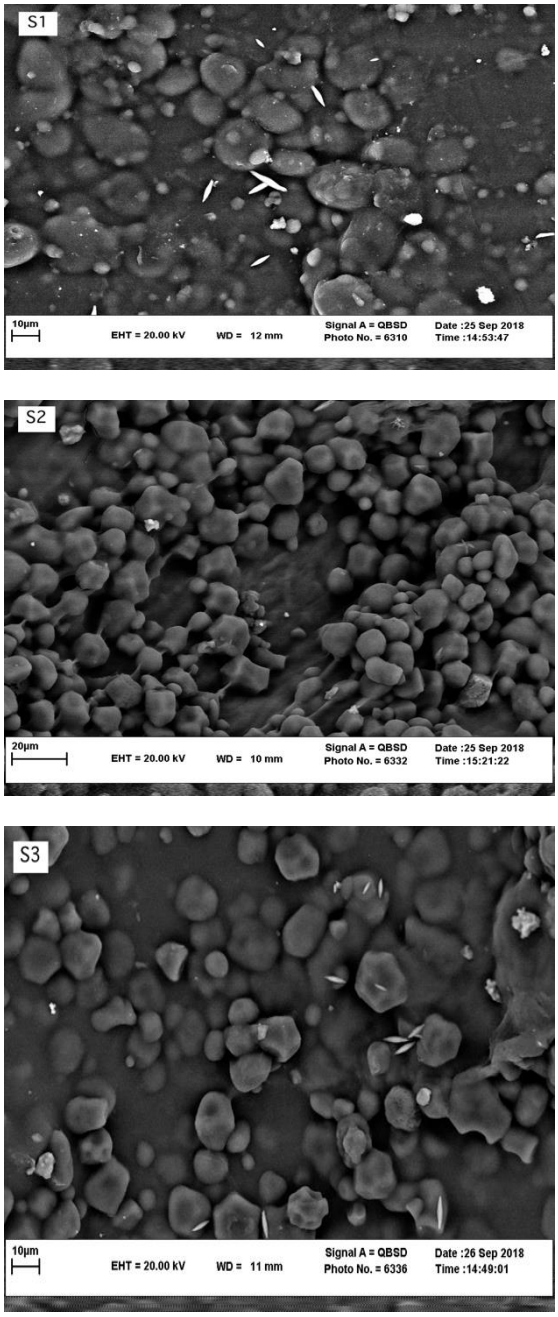

Figure 5: SEM picture after blood contact (2000 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (2 g) (S2), starch (0.2 g) chitosan-graft-pectin (5 g) (S3).

Lead adsorption on chitosan-*graft*- (starch; pectin) films spectrometric adsorption analysis of lead on chitosan-*graft*- (starch; pectin) films

Tables 3A, 3B and 3C show lead removal percentage from lead solutions at various concentrations.

The results show that as the amount of pectin increases, higher amounts of lead were adsorbed by the films. This evidence was generally and specifically confirmed by SEM. The SEM pictures are exhibited in Figure 4A, 4B and 4C. Despite some fluctuations at low concentration, S3 was adsorbed well whereas at high concentration S2 was dominating adsorbent. In order to monitor lead adsorbtion, SEM pictures were taken. As a result, lead was adsorbed more on the surface of chitosan-*graft*-starch films when compared to chitosan-*graft*-(starch; pectin) sample that showed intensive adsorption. This could be the result of higher lead adsorption potency of pectin containing films.

Table 3A: Pb^{2+} removal at 125 ppm solution.

Removal % (125 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	0	1,531729	1,531729
2	32,82276	43,32604	55,57987
3	21,00656	27,78993	41,57549
24	17,72429	23,63239	38,0744

Table 3B: Pb removal at 250 ppm solution.

Removal % (250 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	2,534113	0,584795	2,534113
2	23,97661	20,07797	22,02729
3	37,4269	27,87524	38,79142
24	-6,23782	26,90058	13,84016

Table 3C: Pb removal at 500 ppm solution.

Removal % (500 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	7,749077	9,409594	8,671587
2	9,225092	10,88561	8,671587
3	11,43911	12,36162	9,594096
24	28,78229	31,18081	27,12177

Results about lead adsorption on chitosan-*graft*- (starch; pectin) films

Figure 6A, 6B and 6C exhibit lead adsorption on low pectin and high pectin polymers in different magnifications.

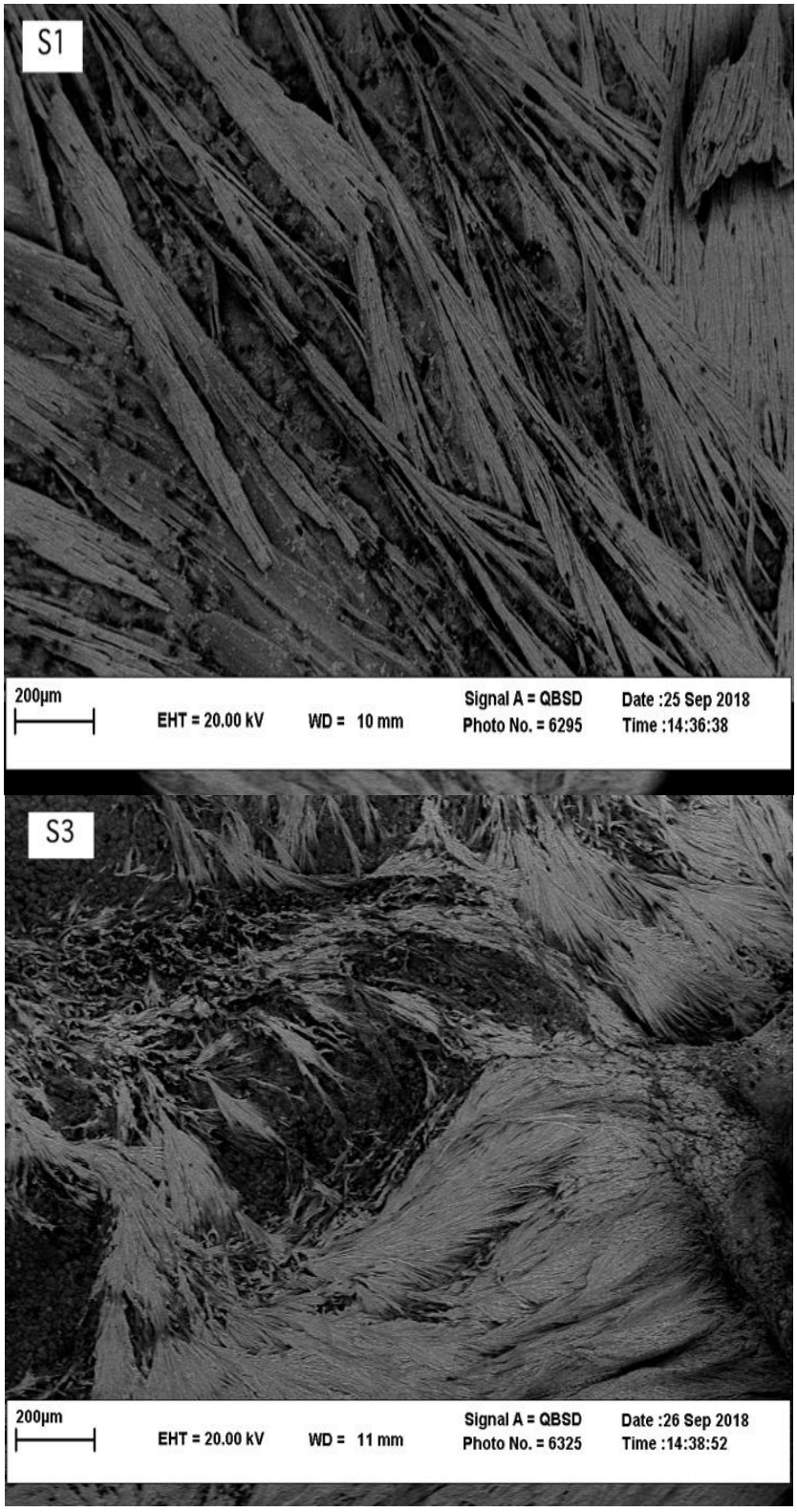

Figure 6A: SEM pictures of lead adsorption (200 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (5 g) (S3).

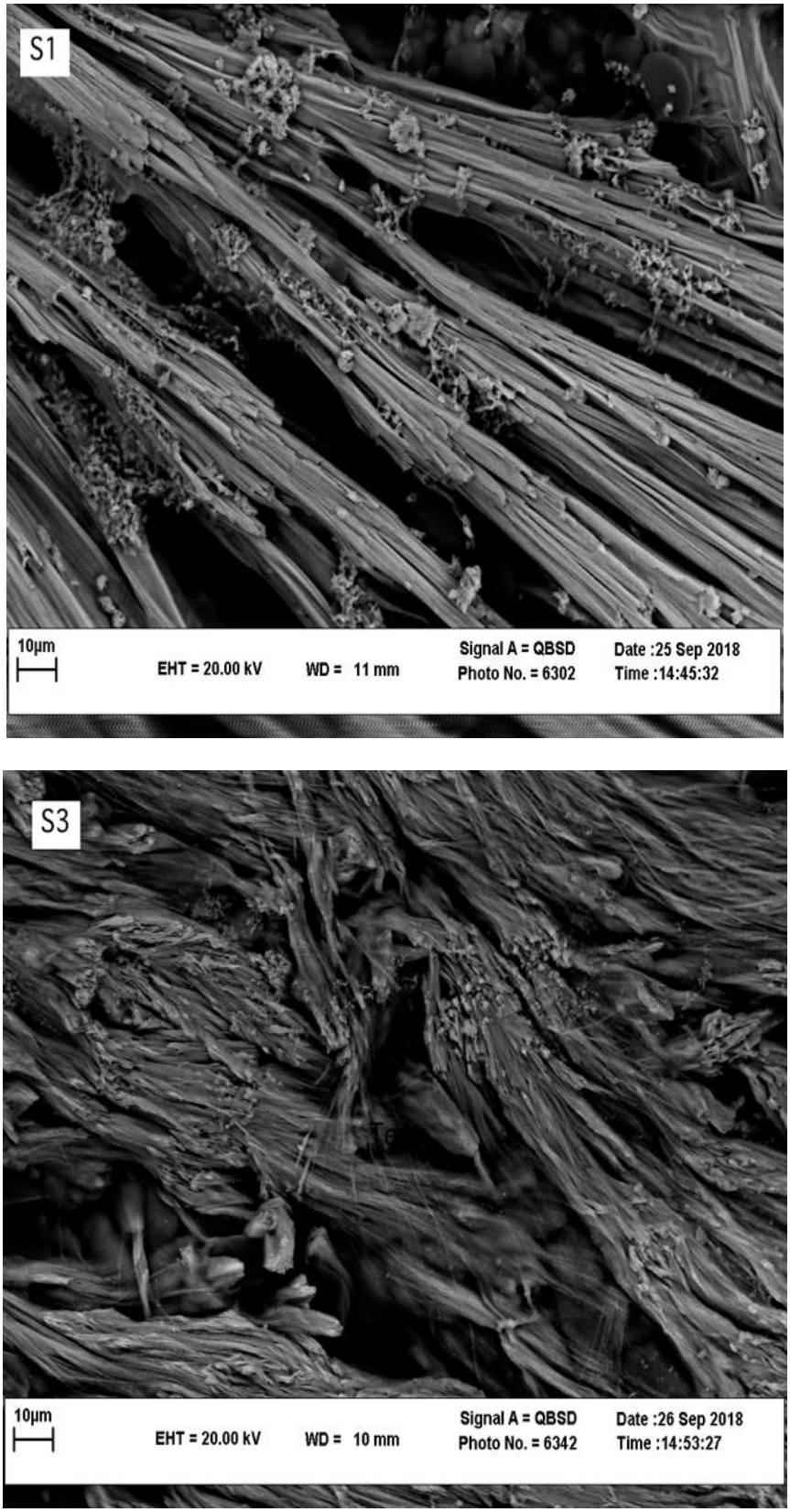

Figure 6B: SEM pictures of lead adsorption (2000 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (5 g) (S3).

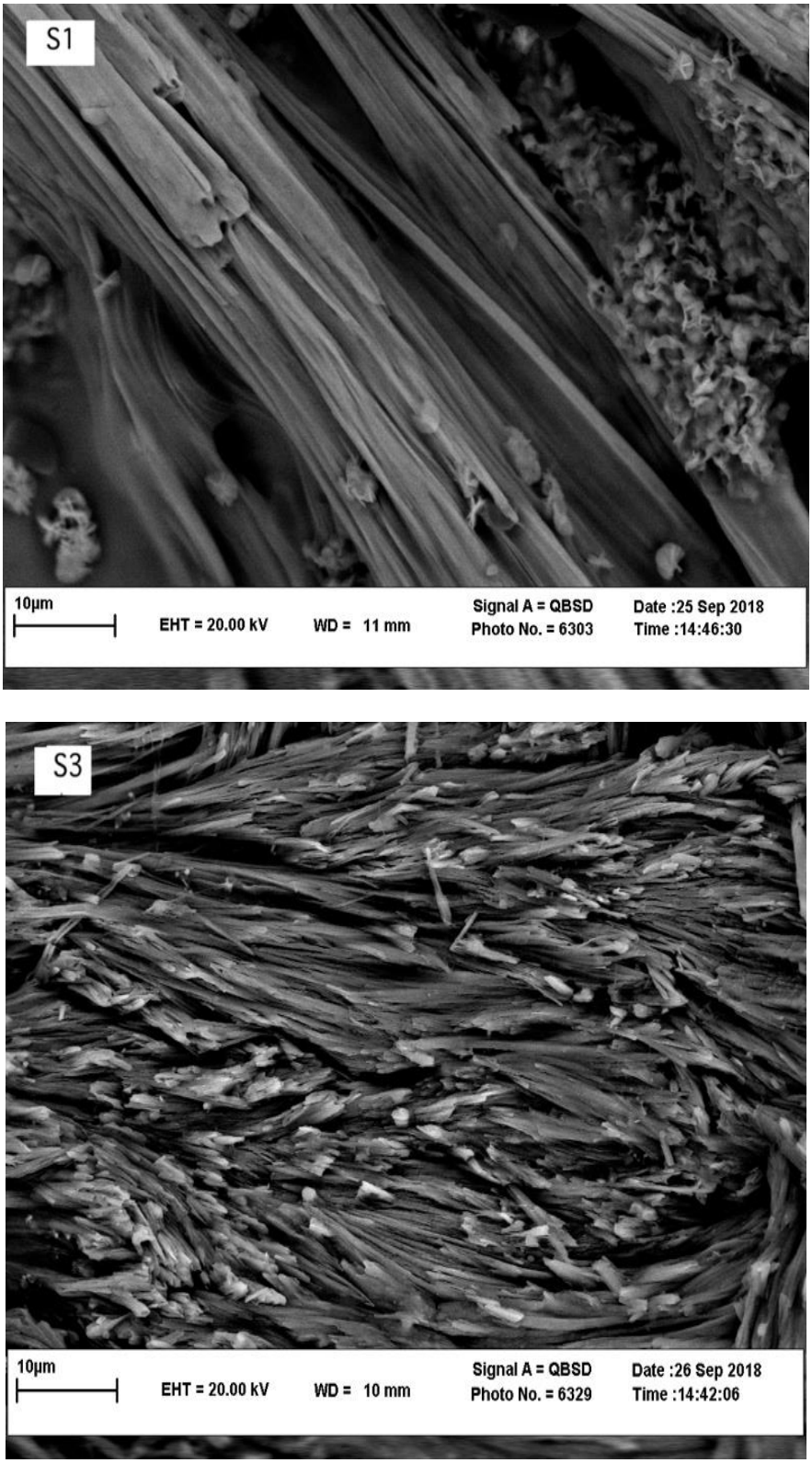

Figure 6C: SEM pictures of lead adsorption (5000 times magnified) of starch (0.2 g) chitosan (S1), starch (0.2 g) chitosan-graft-pectin (5 g) (S3).

Iron (Fe^{3+}) adsorption

Table 4A, 4B, 4C and 4D show iron adsorption at different concentrations. Except 125 ppm which low amounts of pectin showed higher adsorption potency in comparison with S1 (no pectin), at other concentrations all samples show some degree of adsorption but generally S1 was the best adsorbent.

Table 4A: Fe removal at 125 ppm solution.

Removal % (125 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	9,558824	25	15,44118
2	-1,47059	37,5	13,97059
3	8,088235	18,38235	15,44118
4	14,70588	25,73529	18,38235

Table 4B: Fe removal at 250 ppm solution.

Removal % (250 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	28,48665	32,64095	16,32047
2	29,67359	34,7181	28,18991
3	16,32047	13,05638	6,824926
4	33,53116	23,1454	16,91395

Table 4C: Fe removal at 500 ppm solution.

Removal % (500 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	4,761905	11,72161	10,80586
2	22,71062	14,46886	16,66667
3	12,08791	13,00366	10,25641
4	29,30403	31,68498	27,65568

Table 4D: Fe removal at 900 ppm solution.

Removal% (900 ppm)			
Time (h)	S1	S2	S3
0	0	0	0
1	4,761905	11,72161	10,80586
2	22,71062	14,46886	16,66667
3	12,08791	13,00366	10,25641
4	29,30403	31,68498	27,65568

Drug loading

Paracetamol

Table 5A, 5B and 5C show drug loading results after 2 hours of contact time. chitosan-graft- (pectin; starch) films released more paracetamol than chitosan-graft-starch films in certain time intervals which means pectin containing films have higher desorption potency and indirectly can be a sign of higher adsorption potency.

Table 5A: Desorption of sample placed at 3.75 ppm paracetamol solution.

Time (h)	S1	S2	S3
1	0.124	0.105	0.124
2	0.147	0.155	0.168
3	0.156	0.179	0.198
4	0.185	0.178	0.202
5	0.182	0.190	0.219

*Initial: 0.233

Table 5B: Desorption of sample placed at 7.5 ppm paracetamol solution.

Time (h)	S1	S2	S3
1	0.138	0.107	0.116
2	0.154	0.155	0.163
3	0.175	0.182	0.190
4	0.183	0.180	0.230
5	0.186	0.187	0.211

*Initial: 0.464

Table 5C: Desorption of sample placed at 15 ppm paracetamol solution.

Time (h)	S1	S2	S3
1	0.127	0.109	0.108
2	0.156	0.158	0.157
3	0.178	0.187	0.186
4	0.174	0.192	0.238
5	0.190	0.225	0.224

*Initial: 0.233

Imipramine

Table 6A, 6B and 6C shows drug loading results after 2 hours of contact time. Generally, imipramine loaded films follow the same patterns of paracetamol loaded films. This shows that pectin containing films have higher desorption potency for imipramine and indirectly can be a sign of higher adsorption potency.

Table 6A: Desorption of sample placed at 0.31 ppm imipramine solution.

Time (h)	S1	S2	S3
1	0.188	0.153	0.152
2	0.189	0.169	0.198
3	0.197	0.155	0.206
4	0.206	0.169	0.225
5	0.217	0.183	0.207

*Initial: 0.956

Table 6B: Desorption of sample placed at 0.155 ppm imipramine solution.

Time (h)	S1	S2	S3
1	0.164	0.162	0.166
2	0.157	0.193	0.156
3	0.155	0.181	0.186
4	0.176	0.184	0.197
5	0.190	0.212	0.203

*Initial: 0.538

Table 6C: Desorption of sample placed at 0.077 ppm imipramine solution.

Time (h)	S1	S2	S3
1	0.146	0.149	0.164
2	0.171	0.180	0.168
3	0.155	0.181	0.186
4	0.165	0.175	0.179
5	0.166	0.197	0.197

*Initial: 0.357

DISCUSSION

Poisoning cases are very common due to improper drug usage all around the world. These types of cases require immediate curative application and treatment. Among these, decontaminations is very important. For this purpose, adsorbant material like activated charcoal as a local antidote is used. In previous studies, the polymer without pectin was prepared (Hasipoglu *et al.* 2005; Caner *et al.* 2007; Yilmaz *et al*. 2007; Adali and Yilmaz 2009; Yilmaz *et al.* 2016). However, in the present study almost the same polymer with high and low amount of pectin were assayed. The present polymer (thermally grafted natural chitosan-(starch; pectin) showed promising adsorptive potency with respect to natural adsorbent advantages for Pb^{+2}, Fe^{3+} removal and also for paracetamol, imipramine drug loading properties. Pectin grafted polymeric film shows up to 50% Pb^{+2} and up to 34% Fe^{3+} adsorption potency. It also shows up to 46% and 36% better releasing property for paracetamol and imipramine, respectively, after 48 hours of drug loading which indirectly can be a sign of better absorbance capacity.

According to the results of present study, the grafted polymer may be a good candidate as a local antidote for internal decontamination in the treatment of drug and metal poisoning due to it's natural, blood compatible, cost-effective, high chelating and sustained released nature.

Internal decontamination is a very important and effective process for intoxication control that can be done by adsorptive materials.

It should be non-thrombogenic and non-hemolytic which can be found in pectin and starch. Since chitosan is known for its biocompatibility, pectin for its being adoptive, environmentally friendly and having controlled release and starch for its having hydrogen accepting and polymeric properties, the material has got the potential to improve the surface and bulk properties of chitosan as a biomaterial. As synthesis of chitosan-graft starch pectin copolymers have not been reported in the literature before, this study aimed to find out if natural thermal grafted polymers have the adsorptive and drug loading properties. If so, to identify the optimum process conditions, and to characterize the physicochemical characteristics of the products. Although the adsorbent properties of pectin had been studied before, it has not been investigated in terms of it hemocompatibility as an adsorptive matrix grafted to chitosan and starch. The polymer may be applicable for soil, water, air decontamination purposes and worths the further studies.

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