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# Research into the Process of Manufacturing Alginate-Chitosan Fibres

## Abstract

*The process of obtaining alginate-chitosan fibres intended for medical applications was the subject of our investigations. Two methods of forming two-component alginate-chitosan fibres of the core-skin type (calcium alginate and chitosan respectively) were developed. The first method of forming fibres (A), which consists in fibre spinning by feeding chitosan into a coagulation bath, allowed us to obtain alginate-chitosan fibres with a maximum chitosan content of about 3.1%. The second method (B) turned out to be more efficient. It consists in using chitosan in the finishing process, and enabled us to obtain alginate-chitosan fibres with a chitosan content of up to 9.2% wt. In order to further increase the chitosan content in the alginate-chitosan fibres manufactured by method B, polyvinylpyrrolidone (PVP), in amounts from 4% to 20% in relation to calcium alginate was introduced into the spinning solution. The two-component fibres manufactured with the use of PVP, and which included 11.6% wt of chitosan, were characterised by a tenacity of 22.2 cN/tex and an elongation at break of 19%. Additionally, the alginate-chitosan fibres of this type were characterised by very high water retention values (WRV) of up to 1300%, which makes these fibres suitable for use in sanitary and medical products.*

**Key words:** alginate-chitosan fibres, chitosan, core-skin type fibres, wet spinning, finishing, water retention value.

removing the dressing. Gel formation also prevents the wound surface from drying, and is very advantageous considering that a damp surrounding favours wound healing, and also causes a better cosmetic effect [2]. Gel dressings of this type are characterised by good permeability of gases and water content, which is similar to that of natural skin, resulting in the wound remaining damp during the whole time of contact [3]. It has also been stated that dressings from alginates have haemostatic properties and can accelerate wound healing [4].

Another polymer which finds wide application in the manufacture of new-generation dressings is chitosan [5]. The development of a new bio-active dressing material requires the selection of a polymer with a suitable molecular and supermolecular structure, as well as optimum properties for bio-stimulating the processes of epidermis and wound regeneration. Chitosan, which is a copolymer of  $\beta$ -(1 $\rightarrow$ 4)-2-amino-2-deoxy-D-glucopyranose and  $\beta$ -(1 $\rightarrow$ 4)-2-acetamido-2-deoxy-D-glucopyranose, together with its derivatives, are characterised by excellent bio-stimulating properties, which facilitate the reconstruction and vascularity of the damaged tissue, and compensate by the presence of cell components facilitating the creation of smaller scars [6, 7]. The biological activity of chitosan has its basis in its ability of enzymatic degradation in the presence of lysozyme, the enzyme included in body fluids, thanks to which the bio-active oligomers of N-acetylo-D-glucosamine and D-glucosamine are created. It was

stated that hexamines, to which group N-acetylo-D-glucosamine also belongs, facilitate the wound's granulation, and at the same time accelerate the process of wound healing [8 – 10].

So far it has been impossible to obtain composite alginate-chitosan fibres, resulting from the differences in the solubility of both polymers, as chitosan is soluble in aqueous solutions of organic and inorganic acids, whereas sodium alginate is soluble in water and aqueous alkali solutions. The properties mentioned above prevented the obtainment of alginate-chitosan solutions and fibre formation by the wet method, and at the same time the production of fibres which combined the required properties, especially the biological properties of both polymers.

The problems of directly manufacturing alginate-chitosan fibres were solved in different ways; for example, the alginate and chitosan staple fibres were manufactured separately, and then mixed in order to obtain a nonwoven [11, 12]. Another method consisted in introducing a chitosan solution into a coagulation bath containing an aqueous solution of calcium chloride while spinning alginate fibres, and using the strong effect of the mutual influence of cationic chitosan and anionic alginate [13]. However, as a result of the high viscosity of the solutions, the chitosan concentration should be relatively low; this in turn limits the amount of chitosan which could be introduced into the fibres (below 0.2% wt). Alginate-chitosan fibres have also been

## ■ Introduction

Cotton and cellulose fibres are used worldwide in dressing materials thanks to features such as a large specific area, softness, absorptive power, and the ease of processing them into different dressing materials. At present, dressing materials which use alginates are very popular among textile products, as they have various advantages in comparison with traditional dressings manufactured from cotton and viscose gauze [1]. They are biocompatible, and also form gels which absorb the fluids secreted by wounds. This eliminates the effect of enclosing dressing fibres within the wound, which is the main cause of discomfort while

obtained by a two-stage method. Alginate fibres were formed during the first stage, followed by washing, and in the second stage they were immersed into an acid bath including partially-hydrolysed chitosan with an average molecular weight of  $M_W \leq 30$  kD [14]. After the fibres were removed from the chitosan bath, they were squeezed, and the deposited chitosan layer was fixed using acetone solutions to dewater it, followed by drying the fibres. This process enabled us to obtain fibres with a chitosan content in the composite of up to 25%.

The aim of the research work presented in this paper was to investigate how to establish the parameters of a manufacturing process for obtaining modern two-component alginate-chitosan fibres, in which sodium alginate would be the core, and chitosan the skin of the fibres. Selected properties of the two-component fibres were estimated, as were the molecular, supermolecular, and morphological structures, among others.

## Materials and agents

The following materials were used in our investigations:

- Two kinds of sodium alginate: a high-guluronic of the Protanal LF 10/60 type, and a high mannuronic of the Protanal LF 10/60 LS type, both from FMC Biopolymer, Norway.
- Chitosan (I) with a de-acetylating degree (SD) equal to 81.3%, and a viscometric average molecular weight of  $M_V = 285.1$  kD.
- Chitosan (II) with a de-acetylating degree (SD) equal to 78.9%, and a viscometric average molecular weight of  $M_V = 120.6$  kD.
- Chitosan (III) after hydrolysis of chitosan (I) with hydrogen peroxide and a viscometric average molecular weight of  $M_V < 30$  kD.
- Poly-N-vinylpyrrolidone K-30 from BASF.

## Research methods

### Preparing the sodium-alginate spinning solution

The sodium-alginate spinning solution was prepared in a mixer equipped with a high-speed stirrer. Sodium alginate, in the form of powder and glycerine in an amount of 0.1 g per 1g of alginate, was introduced into demineralised water being continually mixed. Additionally,

poly-N-vinylpyrrolidone in amounts from 0.04 to 0.2 g/g of sodium alginate was introduced into selected solutions. The concentration of sodium alginate in the spinning solutions was 6%. The dissolution process was carried out over 120 minutes, at temperatures of 20 °C at the start and 45 °C at the end of the process. The alginate solution was filtered with the use of a frame filtration press using filtration woven fabrics.

### Preparing the chitosan solution

Chitosan was introduced into water and next acetic acid was added during mixing, in order to obtain its concentration of 3%. The chitosan dissolution process was carried out at a temperature of 20 °C. The chitosan solutions prepared were used after suitable dilution in the process of forming the alginate-chitosan fibres.

### Formation of the alginate-chitosan fibres

The sodium-alginate spinning solution, after filtration and deaeration, was poured into a pressure vessel, and then determined amounts of the solution were fed by a gear pump through a disk filter to the spinning head of a laboratory spinning machine. A multi-orifice spinneret was used for spinning. In order to obtain alginate-chitosan fibres, the chitosan solution was introduced into the process at different stages of the fibre formation, namely during coagulation (method A), and during the finishing process (method B).

Aqueous solutions of the following compositions and weight ratios were used as the coagulation bath in method A:

- 2% of calcium chloride, 0.15%–0.6% of chitosan (I),
- 2% of calcium chloride, 0.3 of chitosan (II).

The temperature of the coagulation bath was about 20 °C, whereas the pH was maintained at the level of 4.1 to 4.3. The fibres were spun with a speed of 21.5 m/min in air, at a drawing ratio of  $R = 20\%$ . The fibres obtained were taken off in a wet state by a godet, and then treated with aqueous solutions of acetone with an increasing concentration from 50% to 100%. Next, the fibres were dried and conditioned at a temperature of 20 °C over 24 hours.

An aqueous solution of sodium chloride with a concentration of 25 g/dm<sup>3</sup> and a temperature of 40 °C was used as the

coagulation bath in method B. The fibres obtained in the coagulation bath, in order to wash-out its remainings were fed into two water baths of different temperatures. The fibres spun were drawn in water baths to a total drawing ratio of  $R = 45\%$ . The fibres were spun at a final speed of 26.7 m/min. The fibres obtained were taken off in a wet state by a godet placed in a rinsing tank, and next carried out in the form of a hank into a bath containing an aqueous chitosan solution with a concentration from 0.2% to 1.5%, a pH of 4.5 to 5.0 and at a temperature of 25 °C. In the subsequent stage, the fibres were finished in aqueous solutions of ethyl alcohol with a concentration of 70% and 95% v/v, in both solutions over about 10 minutes, following by drying at room temperature.

The alginate-chitosan fibres were also formed in the final form of multifilaments, under the same conditions as those used in method B. The tow of alginate fibres, after feeding it through the rinsing tank, was treated by a 1.5% chitosan (II) solution, at pH 4, and next dried on heated godets and taken up in the form of a multifilament (test symbol: A/Ch-6/P) with the use of a take-up machine from Sahn, Germany.

## Analytical methods

### Determining the average molecular weight of chitosan

The average molecular weight of chitosan  $M_V$  was determined by the viscometric method on the basis of intrinsic viscosity  $[\eta]$ . The following solvent composition was used: 15.01 g/l of 80% acetic acid, 240 g/l of urea, and 5.84 g/l of sodium chloride. The values of average molecular weight were calculated according to the Mark-Houwink equation [15]:

$$[\eta] = K M_V^a$$

where  $K$  and  $a$  are constants for measurements carried out at a temperature of 25 °C,  $K = 8.93 \times 10^{-4}$ ,  $a = 0.71$ .

### Determining the chitosan deacetylation degree

The degree of de-acetylation (DD) of chitosan was determined by the method of the first derivative of the UV absorption spectrum [16], in accordance with a procedure developed at the Institute of Biopolymers and Chemical Fibres [17]. The absorption spectra were carried out

with the use of the UV-Vis spectrophotometer from Unicam.

### Determining the crystallinity degree of alginate-chitosan fibres

The wide-angle X-ray spectroscopy (WAXS) process was carried out with the use of a URD 63 diffractometer from Seifert (Germany) at the University of Bielsko-Biala, Poland. The analysis of diffractograms was carried out by the Hindeleh & Johnson method [18]. The whole procedure of evaluating the diffractograms was performed with use of the Optifit computer program [19].

### Analysis of alginate-chitosan fibre composition

The polymer composition of the alginate-chitosan fibres was determined on the basis of assessing the chitosan content by the ninhydrin method [20] according to a procedure developed in the Institute of Biopolymers and Chemical Fibres [21]. The method uses the phenomenon of the colour reaction of ninhydrin with amide groups of chitosan. The reaction of chitosan with ninhydrin is sensitive, rapid, and yields repeatable results.

### Determining the fibres' water retention value (WRV)

The fibres' water retention value (WRV) was determined according to the standard method [22].

### Fibre analysis by scanning electron microscopy (SEM)

Photos of the longitudinal views and cross-sections of the fibres were carried out with the use of a Quanta 200 scanning electron microscope from FEI (USA).

### Assessing the mechanical fibre properties

The mechanical properties of the fibres obtained were assessed in their conditioned state with the use of an Instron 55/44 type tensile-tester (USA) in accordance with standards [23, 24].

## Research results and discussion

### Investigation into the process of manufacturing alginate-chitosan fibres

Table 1 presents the influence of the type of alginate used in fibre formation, and the concentration of chitosan diluted in the coagulation bath on the polymer composition and the mechanical properties of alginate-chitosan fibres formed by

method A. The concentration of calcium chloride in the coagulation bath was 2% wt, whereas the pH value was maintained at the level between pH 4.1 and 4.3. Aqueous solutions of acetone were used as a fixing bath for the chitosan layer deposited.

On the basis of the results presented in Table 1, we may state that the kind of sodium alginate used has no essential influence on the mechanical properties or the polymer composition of the fibres. With the increase in the chitosan concentration in the coagulation bath, a distinct decrease in the fibre strength was noted, together with a decrease in the elongation at break. Considering the low chitosan content in the alginate fibres, we conclude that the worsening of the mechanical properties in relation to the control tests (A-1, A-2) was caused by the worsening of coagulation conditions in the presence of chitosan. The chitosan content in the fibres spun by this method was limited by the short time which the fibres spent in the coagulation bath. The maximum chitosan (I) content with an average molecular weight of 285 kD in the alginate-chitosan fibres was 2.5%, and at the same time the tenacity was 13.5 cN/tex. Using chitosan (II) with  $M_V = 121$  kD caused an increase in the chitosan content of up to 3.1%. On the other hand, the increase in the chitosan content in the bath of over 0.3% resulted in a distinct increase in the coagulation bath viscosity, limited the penetration of chitosan into the fibres, and caused the elementary fibres to become sticky.

The basic problem of forming alginate-chitosan fibres by method A, which consisted in introducing chitosan into the coagulation bath, was how to suitably select the fixing bath components to fix the chitosan

layer on the alginate fibres. The alkali bath used for spinning chitosan fibres could not be applied in this case, considering the insufficient resistance of alginate fibres on alkali. Therefore, aqueous solutions of acetone were used as the fixing bath. The need to extract the calcium chloride which originated from the coagulation bath from the fibres forced us to use relatively large amounts of acetone solution. A negative aspect of applying the one-stage formation of alginate-chitosan fibres was the large losses of unbounded chitosan which was carried from the coagulation bath onto the fibres' surface.

Considering the problems discussed above connected with the method of alginate-chitosan fibre formation, consisting in introducing chitosan into the coagulation bath, we deemed it appropriate to apply chitosan at a further stage of formation the fibres, i.e. during the finish processing (method B). Table 2 presents the influence of chitosan concentration in the deposition bath on selected properties of the alginate-chitosan fibres formed by method B.

The results presented in Table 2 indicate that method B enabled an increase greater by three times in the chitosan content in the fibres in relation to method A. We observed that the fibres obtained from high-guluron LF-10/60 alginate had a higher chitosan content than those manufactured from the high-mannuron LF-10/60 LS alginate. The maximum chitosan (I) content in the fibres was 7.3%, whereas in the case of applying chitosan (II) with a lower molecular weight, the content increased to 9.2%. In contrast to method A, with the increase in chitosan content in the fibres, the elongation at break increased at a relatively small decrease of tenacity. The alginate-

**Table 1.** Influence of the formation conditions of alginate-chitosan fibres by method A on their polymer composition and mechanical properties; n.d. - not determined.

Symbol of sample	Kind of sodium alginate	Chitosan concentration in coagulation bath, %	Polymer composition, %		Linear density, dtex	Tenacity, cN/tex	Elongation at break, %
			alginate	chitosan			
A-1	LF-10/60 high-guluronic	0.00	100.0	0.0	2.72	17.1	16
A/Ch -1/1		0.15	98.6	1.4	2.84	16.1	14
A/Ch-1/2		0.30	97.5	2.5	2.87	13.5	11
A/Ch-1/3 <sup>1)</sup>		0.60	97.8	2.2	n.d.		
A/Ch-1/4 <sup>2)</sup>		0.30	96.9	3.1	2.93	14.7	13
A-2	LF-10/60 LS high-mannuronic	0.00	100.0	0.0	2.64	18.2	17
A/Ch -2/1		0.15	98.1	1.9	2.79	16.9	16
A/Ch -2/2		0.30	97.9	2.1	3.01	12.8	13

1) - large number of monofilaments glued together.

2) - coagulation bath including chitosan (II), in the remaining tests including chitosan (I).

**Table 2.** Influence of the chitosan concentration in the deposition bath on selected properties of alginate-chitosan fibres formed by method B.

Symbol of sample	Chitosan concentration in deposition bath, g/l	Polymer composition, %		WRV, %	Linear density, dtex	Tenacity, cN/tex	Elongation at break, %
		alginate	chitosan				
A-3	0.0	100.0	0.0	98	2.48	20.7	16
A/Ch-3/1	0.2	98.6	2.4	125	2.81	18.2	16
A/Ch-3/2	0.5	92.7	7.3	185	2.79	17.5	17
A/Ch-3/3	1.1	93.9	9.2	195	2.93	18.4	19
A-4 <sup>1)</sup>	0.0	100.0	0.0	134	2.57	21.8	19
A/Ch-4/1	0.2	98.9	2.3	141	2.79	19.2	17
A/Ch-4/2	0.5	98.7	4.3	165	3.01	18.3	18
A/Ch-4/3 <sup>2)</sup>	1.1	95.1	6.9	178	3.57	17.8	20

<sup>1)</sup> - chitosan (II) was used in the deposition bath, chitosan (I) in the remaining tests  
<sup>2)</sup> - alginate LF-10/60 LS was used for fibre formation in the tests from A-4 to A/Ch-4/3, alginate LF-10/60 in the remaining tests.

**Table 3.** Influence of the chitosan concentration in the deposition bath on selected properties of alginate-chitosan fibres formed by the method (B) from alginate containing 16% PVP in relation to sodium alginate.

Symbol of sample	Chitosan concentration in deposition bath, g/l	Polymer composition, %		WRV %	Linear density, dtex	Tenacity, cN/tex	Elongation at break, %
		alginate	chitosan				
A-5/P	0	100	0	251	3,57	15,8	10
A/Ch-5/P/1	0,2	88,3	11,7	1308	5,66	17,5	17
A/Ch-5/P/2	0,5	88,4	11,6	1125	5,01	22,2	19
A/Ch-5/P/3	0,8	85,9	14,1	827	6,33	15,6	17
A/Ch-5/P/4	1,1	81,4	18,6			- 1)	
A/Ch-5/P/5	1,1 <sup>2)</sup>	75,9	24,1	1220	6,89	15,2	21
A/Ch-6/P	1,5 <sup>3)</sup>	98,6	1,4	165	3,00	16,6	16

<sup>1)</sup> large number of monofilaments glued together  
<sup>2)</sup> chitosan (II) used in deposition bath  
<sup>3)</sup> chitosan (III) used in deposition bath, fibres taken up in the shape of monofilaments

chitosan fibres were characterised by appropriate mechanical properties: tenacity within the range of 17.5-19 cN/tex, and elongation at break of about 16 to 20%. The value of WRV increased with the

increase in chitosan content in the fibres, to about 195%.

Poly-N-vinylpyrrolidone (PVP) was added to the sodium alginate solution

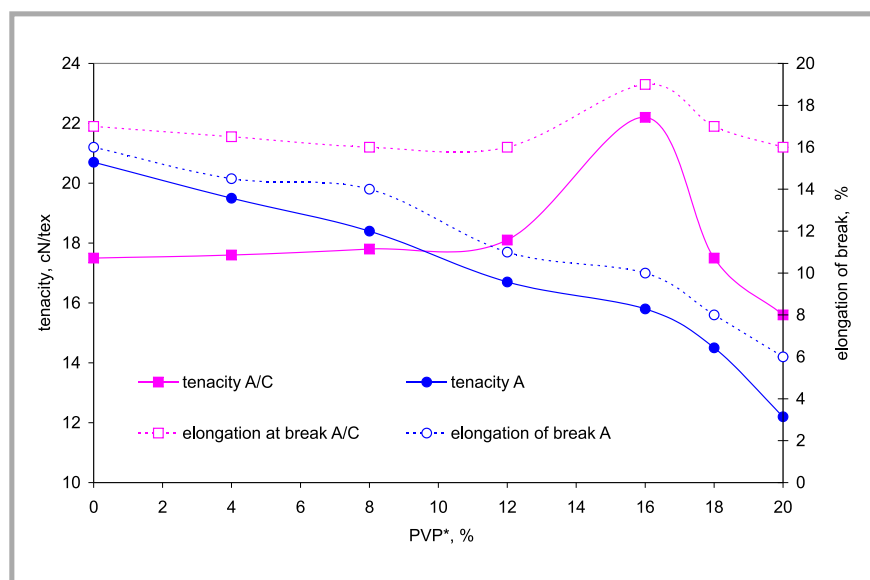
in order to increase the chitosan content in alginate-chitosan fibres. This polymer is widely applied in the processes of manufacturing filtration membranes, as an agent among others, which increases the porosity and enables a micro-porous structure to be obtained [25, 26]. PVP is readily soluble in water, and therefore can to a significant degree be rinsed out during the processes of alginate-chitosan fibre formation and finishing.

A series of tests with different contents of PVP in the LF-10/60 sodium alginate solution was carried out. Figure 1 presents the dependency of tenacity and elongation at break of alginate and alginate-chitosan-fibres formed by method B on the concentration of PVP in the spinning solution. The chitosan (I) concentration in the deposition bath was maintained at the level of 0.5%. The amount of the PVP added was calculated as a percentage in relation to sodium alginate.

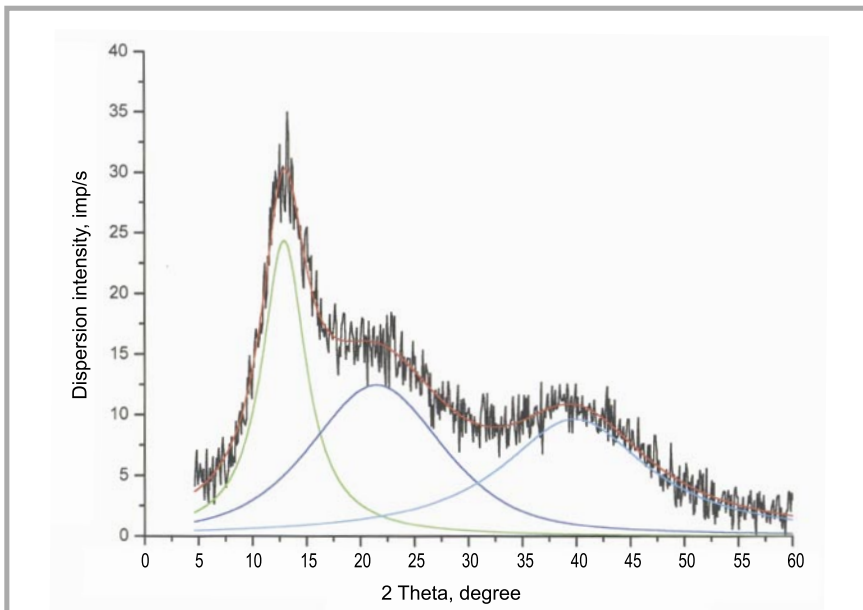
We noted that the increase in PVP concentration in the spinning solution causes a distinct decrease in the tenacity and elongation at break of one-component alginate fibres. In the case of alginate-chitosan fibres, no essential influence of the PVP concentration increase on the evaluated parameters was noted, with the exception of the 16% concentration, at which tenacity and elongation at break achieved their maximum values.

Table 3 presents the influence of chitosan concentration in the deposition bath on selected properties of the alginate-chitosan fibres, formed from a spinning solution containing an addition of PVP. Alginate LF-10/60 was used for the tests. The PVP addition to the spinning solution was 16% in relation to sodium alginate.

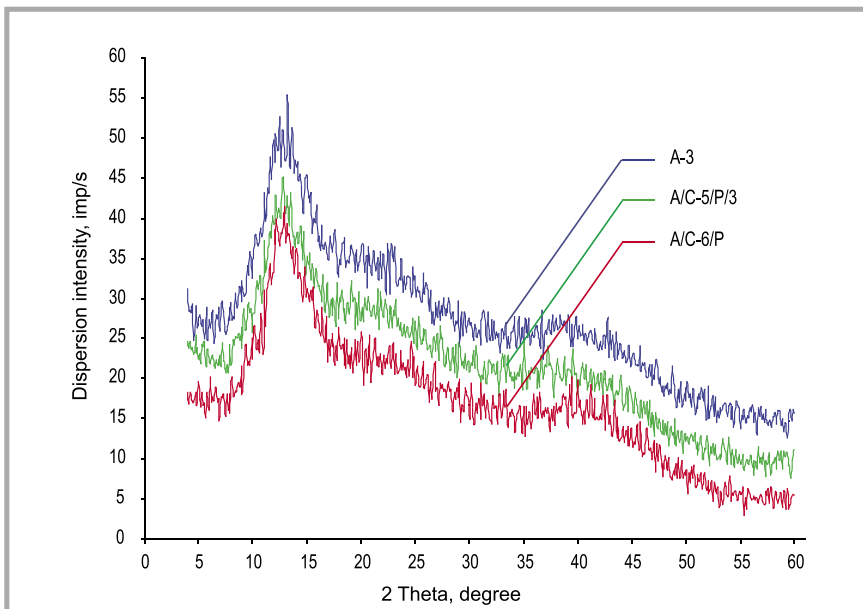
A sample from the control test of spinning alginate fibres with a PVP addition (A-5/P) was characterised by a tenacity of 15.8 cN/tex and elongation at break of 10%, i.e. values which were evidently lower than those for the sample from the control test of spinning without a PVP addition (Table 2, A-3). We believe that the simultaneous increase in the WRV-value from 98% to 251% results to a great degree from the more developed surface of these fibres. On the basis of the results obtained, it can also be assumed that the PVP addition advantageously influences the mechanical properties of the alginate-chitosan fibres. The fibres obtained,



**Figure 1.** Dependency of the PVP amount added to the spinning solution on the tenacity and elongation at break of the alginate (A) and alginate/chitosan (A/C) fibres; PVP\* - PVP concentration in relation to sodium alginate, in per cent.



**Figure 2.** Decomposition of the WAXS diffractograms for alginate fibres.



**Figure 3.** Comparison of the WAXS diffractograms for alginate and alginate-chitosan fibres; for better visualisation, the curves for the samples A/C-5/P/3 and A/C-6/P were shifted by about 7 imp/s along the y-axis.

depending on their composition, were characterised by tenacities at the level of 15-22% and relatively high elongations at break of 17-21%. The linear density of the alginate-chitosan fibres increased in comparison to the control test, and amounted to between 5.0 and 6.9 dtex.

At the same time, we noted that the addition of PVP to the solution of sodium alginate enabled us to obtain fibres with about twice as much chitosan content in relation to fibres formed without this addition. The chitosan concentration in the deposition bath at the level of 0.5% enabled us to

**Table 4.** Results of investigating the alginate-chitosan fibres obtained by the WAXS method.

Symbol of samples	Kind of fibres	Polymer composition, %		Degree of crystallinity, %	Crystallite dimension, Å
		alginate	chitosan		
A-3	staple fibre	100.0	0.0	29.2	12.5
A/Ch-5/P/3	staple fibre	85.9	14.1	19.9	14.9
A/Ch-6/P	multifilament	98.6	1.4	14.5	16.7

obtain two-component fibres with the best characteristics, i.e. with a chitosan content of 11.6% wt, linear density of 5.01 dtex, tenacity of 22.2 cN/tex, elongation at break of 19%, and a water retention value (WRV) over 1100%. An increase in the chitosan concentration up to 0.8% enables an increase in chitosan content in the fibre to 14.1%, but at the same time a distinct lowering of the fibre tenacity was noted, down to the level characterised by the fibres from the control test. In contrast, a further increase in the chitosan concentration in the deposition bath increased the number of elementary fibres which had become glued together. The two-component fibres manufactured by method B with PVP addition were characterised by very high WRV (the samples from the A/Ch-5/P/1 test by a WRV of up to 1308%). For comparison, the one-component alginate fibres were characterised by a WRV at the level of 100-130%, whereas the WRV of two-component fibres spun without PVP did not exceed 200% (see Table 2).

Using chitosan with a lower molecular weight of 120 kD and a concentration of 1.1% in the deposition bath caused an increase in the chitosan content in the fibres to 24.1%, although after drying, the fibre stream was difficult to separate.

The fibres formed in the shape of a multifilament (test A/Ch-6/P) are characterised by a relatively low content (1.4%) of chitosan in the fibres, which was caused by the short finish processing time.

#### X-ray investigations of the alginate-chitosan fibres

Only a single peak originated in the crystalline regions, and two amorphous peaks were distinguished on the WAXS curves for the alginate and alginate-chitosan fibres (Figure 2). The single peak is composed from interference effects originating from different net planes, of the mannuron and the guluron acids. Therefore it is impossible to determine the Miller indicator for the reflection plan for this peak, and the crystallite dimensions determined on the basis of the Scherrer equation inform us of the true dimensions of the ordered regions in the fibres in only a very approximate way. The first, mostly sharp peak should be treated as a peak originated from the ordered regions, whereas the two remaining are the amorphous halo.

The WAXS curves for alginate and alginate-chitosan fibres are compared in

Figure 3. The dependencies presented are almost identical, but the crystalline peaks are smaller and smaller, ranging from these for alginate fibres (A-3), to those of multifilament alginate-chitosan fibres (A/C-6/P), and so an increase in the crystallite dimensions is observed for these samples (Table 4).

#### Evaluation of the alginate-chitosan fibres by scanning electron microscopy

The cross-sections of the alginate fibres are irregular, similar to an oval with distinctly marked flat indentations. Figure 5 presents SEM photos of the cross-sections and the surfaces of alginate fibres marked by the symbol A-5/P, obtained from a spinning solution with a 16% content of PVP related to alginate. The envelope of the cross-section of these fibres is even more developed than that of alginate fibres spun without a PVP addition. The surface of the monofilaments is characterised by distinct flat indentations, which were not observed on the surface of alginate fibres formed without a PVP addition. On the cross-section,

flat indentations of dimensions below 1  $\mu\text{m}$  are visible (Figure 4b).

Figure 5 presents SEM photos of the cross-sections and surfaces of the alginate-chitosan fibres marked A/C-5/P/3 formed by method B with the same PVP addition as for the control test A-5/P. Significant differences of the view of cross-sections and fibre surfaces are clearly visible when comparing the alginate fibres and alginate chitosan fibres formed with a PVP addition. The flat indentations in the case of two-component fibres are significantly smaller than in alginate fibres, and their cross-sections are more rounded.

It is evident that the chitosan deposited on the alginate fibres filled the flat indentations, which were visible on the SEM photos of the fibres taken from the alginate fibres' control test (Figure 4, A-5/P fibres). It is safe to assume that the distinct increase in the percentage content of chitosan in the alginate-chitosan fibres formed by method B with PVP addition

was caused by a higher porosity and a more developed envelope of the alginate fibres' cross-section.

#### Conclusions

- Fibres containing 3.1% of chitosan were obtained by a method for forming alginate-chitosan fibres which consisted in introducing chitosan into the coagulation bath.
- A method for forming alginate-chitosan fibres consisting in applying chitosan at the stage of finishing the processing is more effective, and enables producers to obtain alginate-chitosan fibres containing 9.2% of chitosan. This content depends on the kind of the polymers used, the chitosan and the sodium alginate. Alginate-chitosan fibres obtained in this way are characterised by good mechanical properties, namely tenacity within the range of 17.5-19.0 cN/tex, and elongation at break from 16% to 20%.
- Polyvinylpyrrolidone introduced into the spinning solution of sodium

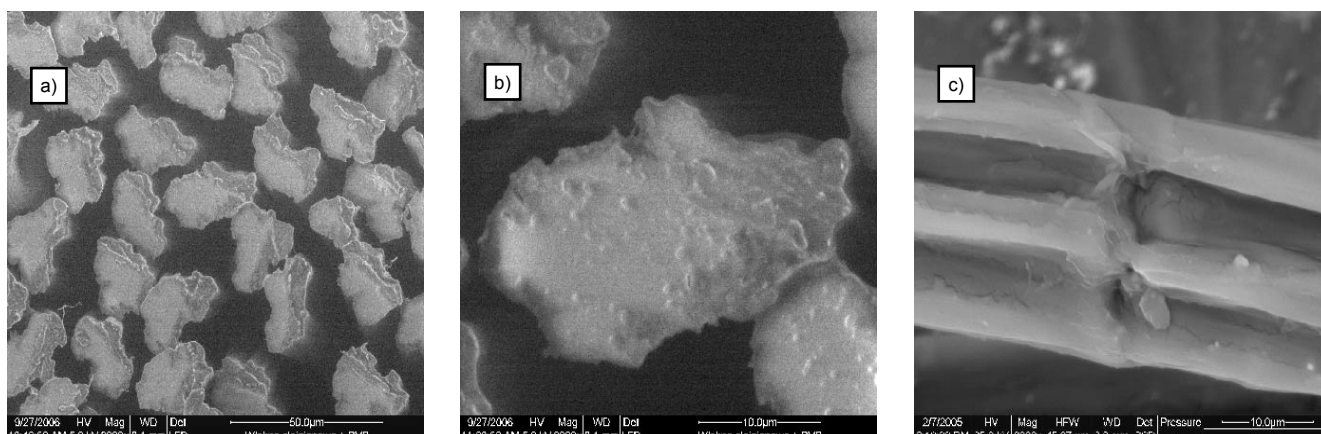


Figure 4. SEM photos of alginate fibres marked A-5/P formed from a spinning solution including 16% of PVP in relation to alginate; a, b) – cross-sections, c) – surface of the monofilaments.

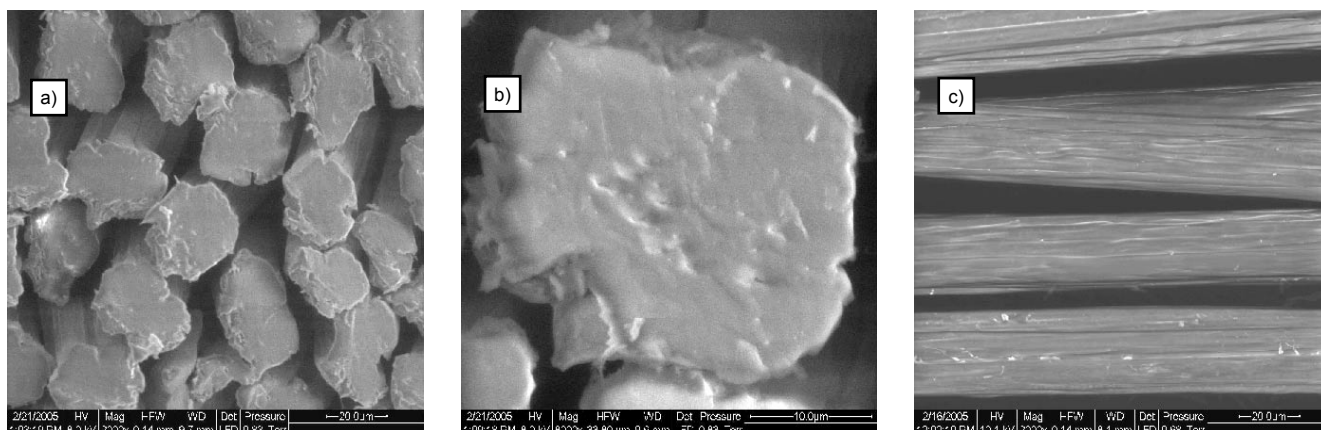


Figure 5. SEM photos of alginate-chitosan fibres marked A/Ch-5/P/3 formed by method B from a spinning solution including 16% of PVP in relation to alginate; a, b) – cross-sections, c) – surface of the monofilaments.

alginate secure better penetration of the chitosan solution into the alginate fibres, an increase in the total amount of chitosan deposited on the fibres, and better binding of the chitosan skin with the alginate core. Furthermore, the addition of PVP enables us to obtain two-component fibres with about twice as much chitosan content than fibres formed without PVP. The fibres manufactured under these conditions were characterised by 11.6% chitosan content in the composite, a tenacity of 22.2 cN/tex, elongation at break of 19%, and a WRV of 1125%.

- The mechanical properties of the alginate-chitosan fibres, as well as their very high WRV values within the range of 1000 to 1300%, make the fibres developed suitable for manufacturing a new generation of dressings.

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## The 2007 International Chemical Fibre Products Purchase Meeting

sponsored by the  
China Chemical Fibre Association

will be held from  
March 26<sup>th</sup> to 30<sup>th</sup> of 2007

in Cixi city, China, which is a principal manufacturing base for polyester staple fibre. The relevant manufacturers and buyers from all over the world will be invited to the purchase meeting. The organiser will also match the demands of each of the attendees beforehand.

The purchase meetings for buyers/sellers of chemical fibre products have been held during the past 2 years in China, and concerned polyester, acrylic, nylon and spandex fibres. These meetings have been the most professional and the most effective productpurchase meetings in the chemical fibre industry in the world for some time now. Contracts for 200,000 tons of PES fibres, 40,000 tons of acrylic fibre, 50,000 tons of nylon fibre products and 10,000 tons of spandex fibre products have been signed. More than 300 companies have been involved in these meetings; the attendees came from America, Canada, Mexico, India, Pakistan, Iran, Turkey, Singapore, Switzerland, Poland, Saudi Arabia, Egypt, Brazil, South Korea, Italy, Germany, Russia, Hungary, Malaysia, Vietnam, Thailand, Morocco, Spain, Denmark and China.

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