



EFFECT OF MOLECULAR MASS AND SURFACE CHARGE OF ANIONIC POLYACRYLAMIDE ON PECTIN PRECIPITATION

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ABSTRACT: In sugar industry, separation of undesirable compounds in sugar beet juice is done mostly by CaO and carbon dioxide. In order to reduce the amount of lime, a new method of pectin separation based on the application CaSO₄ with the addition of various types of anionic polyacrylamides (PAMs) is presented. The effects of molecular weight (MW) and the surface charge type of anionic polyacrylamides on the pectin precipitation were investigated. These compounds cause the process of charge neutralization of pectin macromolecules, followed by two mechanisms of polymeric bridging effect: Ca²⁺ bridges between anionic polymer molecules and pectin particles that promote the coagulation of pectin and Ca²⁺ bridges between anionic polymers that hinder coagulation of pectin. The aim of this paper was to examine the effect of CaSO₄ mixture and anionic PAMs of different molecular weights and degree of ionization to increase the efficiency of removal of pectin from sugar beet juice.

Two pectin preparations were isolated from sugar beet pulp. CaSO₄ was added to 100 cm³ (0.1 % wt) pectin solution. Studies were performed with 10 different concentrations of CaSO₄ solution (50-500 mg/dm³) with the addition of anionic PAM with two ionization degree and three molecular weight, concentrations of 3 mg/dm³. The efficiency of pectin precipitation was monitored by measuring the zeta potential. The bridging effect of Ca²⁺ ions between anionic PAMs and pectin has increased with an increase in the MW of the anionic PAMs. Using anionic PAM of the largest MW (1500 · 10⁶g/mol) and a lower degree of ionization (30%), the optimal amounts of CaSO₄ were measured: 340-355 mg/dm³. These optimal concentrations were achieved at the zero value of the potential zeta when the pectin particles were discharged.

Key words: *pectin, CaSO₄, anionic polyacrylamide, molecular weight, ionic degree*

INTRODUCTION

Removal of impurities (consisting of both soluble and insoluble non-sugar compounds) from sugar beet juice by clarification is an essential part of the process of raw sugar manufacture.

Traditional inorganic salts of polyvalent metals and their polymers have been used for decades as coagulants in various pro-

cesses of separation due to their advantages, above all, due to low prices.

With various coagulation-flocculation processes, the multivalent metals are adsorbed onto negatively charged colloidal particles (Yang et al., 2016). In the recent papers (Kuljanin et al., 2015a; Kuljanin et al., 2015b), a new method for separating

pectin from sugar beet juice was presented based on the application of CaSO_4 as well as cationic/anionic polymers. Pectins are classified as hydrocolloids due to their high molecular weight coupled with the abundance of polar and ionic groups on their sidechains.

One of the crucial properties of any food hydrocolloid is its ability to interact with water. In the mentioned papers (Kuljanin et al., 2015a) and (Kuljanin et al., 2015b), Ca^{2+} ions were used in the form of CaSO_4 due to the known effect of dehydration of SO_4^{2-} ions. This is, in addition to the charge neutralization of negatively charged pectin particles, a precondition for more rapid coagulation and precipitation hydrophilic pectin macromolecules (Garnier et al., 1994; Kuljanin et al., 2016). The main lack of inorganic coagulants is a high sensitivity to pH, inefficiency in the separation of very fine particles and applicability to only a few dispersive systems (Yang et al., 2016).

It has been proved that the metal salts in the presence of small amounts of synthetic organic polymers (concentrations of 2 - 3 mg/dm^3 of solution) achieve greater efficiency in separation of organic matter from wastewater (Pattabi et al., 2000). Synthetic organic polymers are macromolecules of chain structure with side chains at the ends of which are charged ionized groups. They can be anionic, cationic and neutral, depending on what kind of ions they bind to themselves. Polyacrylamide, which is most commonly used for purification of water, is effective at a concentration of 0.15-2 mg/dm^3 in an aqueous environment having a pH of 3-7 (Karlovič, 2002).

By studying the conventional processing of sugar cane, it has been proven that after liming, adding anion flocculants (a high molecular weight copolymer of acrylamide and sodium acrylate) improves the sedimentation of non-sucrose particles in the juice. Also, the reduction of clarified juice turbidity by 50% was significant (Doherty et al., 2003). Authors found out that the anionic flocculants are more effective in the presence of cationic polymers to aid flocculation of the cane sugar juice particles. Studies on silica present in cane su-

gar juice, suggesting that the uncharged polar amide groups in anionic flocculant (copolymer of acrylamide) are important in binding to silica (Mühle and Dobias, 1993). Industrial research on the classic cleaning raw sugar beet juice, using anion flocculants based on polyacrylamide, confirmed the technological and economic feasibility of this process (Loseva, 1990). Also, anionic polyelectrolyte proved to be very efficient for separation of proteins from crop (Baraniak et al., 2009). In the paper (Kuljanin et al., 2015a), the efficiency of the cationic and anionic polymers in the presence of CaSO_4 was compared. The anionic polymers, which had less molecular weights (10^6 – $7 \cdot 10^6$ g/mol), showed a somewhat weaker effect of purifying pectin solutions than cationic polymer of higher molecular weight ($5 \cdot 10^6$ – $1.5 \cdot 10^7$ g/mol). For the cationic polymer, the charge neutralization mechanism it is considered to be predominant since most colloidal particles in aqueous solutions are negatively charged (Duan and Gregory, 2003; Kuljanin et al., 2015b). However, it has been established, both for non-ionic as well as for linear ionic polymers with large molecular weights and low charge charges, that the main mechanism for binding with colloidal particles is interparticle bridging (Ghimici and Nichifor, 2018). Anionic polyelectrolytes must have a large molecular weight (minimum of 10^6 g/mol) to obtain a high enough kinetic energy to overcome the energy barrier between the negatively charged particles by mechanism of interparticle bridging (Koper, 2007; Kuljanin et al., 2016). The charge density (which depends on the degree of ionization) of polyelectrolyte has been studied so far only in the treatment of water and wastewater/sludge. In the reference (24), the influence of the charge density and the molecular weight of different polyelectrolytes on the precipitation of bentonite in wastewater were revealed. In the Results and Discussion section, references (Fraj, 2016) and (Yang et al., 2016) refer to the influence of the molecular weight of the polyelectrolyte (i.e. the length of their molecular chains) and their relationship with the degree of ionization at the molecular level during the treatment of water. *Shaikh et al., 2017,*

were investigated the influence of surface charge density and molecular weight of anionic polyacrylamide (PAM) on the zeta potential and adsorption/flocculation behavior of highly stable bentonite dispersions. Authors found out that molecular weight was an essential factor influencing sedimentation and flocculation. Also it was concluded that flocculation decreased with increasing anionic surface charge density. To measure the charge of the surface of pectin particles, in this paper a method of measuring of the zeta potential was used. In the earlier works, a less precise method was used: a "jar" test based on measuring the time required for sediment sedimentation. Zeta potential is an electrokinetic parameter by which the charge of the surface of the colloidal particles can be measured. When the zeta potential reaches a value of 0 ± 5 mV, the surface of the particles becomes discharged, allowing their precipitation (Koper, 2007; Kuljanin et al., 2016).

The main objective of this research was to investigate the effects of anionic flocculants with different molecular weight and ionization degree on pectin separation by Ca^{2+} ions. A series of anionic PAMs with different charge densities and molecular mass were used as a model compounds for synthetic anionic polyelectrolytes.

MATERIALS AND METHODS

Two pectin preparations are isolated from the pressed sugar beet pulp (*Beta vulgaris* L. ssp. *Vulgaris* var. *Sacchariferra*) after the industrial processing of sugar beet in sugar factory Šajkaška, Žabalj, Serbia. For the experiment, coagulant calcium sulfate in crystalline hydrate form ($\text{CaSO}_4 \times 7\text{H}_2\text{O}$) as an aqueous solution, produced in Zorka Pharma, Šabac, Serbia was used. Purity of this salt was 99.0% w/w. As a flocculant, anionic polyelectrolyte, polyacrylamide, PAM, formula: $[-\text{CH}_2-\text{CH}(\text{CONH}_2)]_n$ was used. The main technical parameters of the flocculant used are: purity, 90%; middle degree of ionization were 30% and 60%; values of mean molecular weight were $500 \cdot 10^6$, $1000 \cdot 10^6$ and $1500 \cdot 10^6$ g/mol. Manufacturer: Zhengzhou Jing Lian; *Water Purification Materials Co.*, Ltd., Henan, China (Mainland). The pH of

the solutions was measured on a pH Meter MA 5740, "Iskra", Kranj, Slovenia.

Pectin extraction

As in previous work (Kuljanin et al., 2015a and Kuljanin et al., 2015b), 2 or 3 types of pectin preparations with different degrees of methyl esterification (DE) were used. Due to these differences, preparations P1 and P2 differed in the number of free COOH^- groups (third column in Table 2) which depends on the charge of the surface of the pectin particles and therefore of the binding capacity of the Ca^{2+} ions. In this way, two pectic preparations with different coagulation capabilities were obtained. Pectin preparations P1 and P2 were isolated by extraction by standard laboratory procedure, AOAC (2000). Two types of preparations were isolated by extraction in acidic conditions. The pH, temperature and duration of the extraction were made for preparation P1: pH = 1.0, $t = 75^\circ\text{C}$, $\tau = 1.0$ h, while for preparation P2: pH = 3.5, $t = 95^\circ\text{C}$, $\tau = 1.5$ h.

The extraction procedure is described in the previous paper (Kuljanin et al., 2014). The extraction of each preparation was carried out 3 times in order to obtain as precise as possible results of the measurement of the mean value of the dry matter content, the mean value of preparation purity (i.e. the galacturonic acid content), etc. The analysis of the basic parameters was performed in accordance with the standard method AOAC (2000). The degree of esterification of the obtained pectin preparations was calculated using the equivalents of free (X) and esterified carboxyl groups (Y) (Kuljanin, 2008).

Experiment plan

The experiment examined the model solutions of pectin preparations of a concentration of 0.1% (w/w). The working solutions were obtained by dissolving 1 g of the pectin preparation in 250 cm^3 of distilled water and allowed to swell overnight. After that, they were complemented by distilled water up to 1 dm^3 and each measurement was separated by 50 cm^3 . After dissolving 1 g of CaSO_4 in 200 cm^3 of distilled water, the appropriate amount was taken with pipette and added

to a 50 cm³ pectin solution (0.1% by weight).

The resulting concentrations of CaSO₄ are in the range of 50 to 500 mg/dm³. All measurements were carried out at pH = 7. After adding CaSO₄ coagulant to a solution of pectin preparations and adjusting the pH, the solution was mixed intensively for 30 min using a magnetic stirrer (Tehnica, Železniki, MM-520, Slovenia).

After dilution of the solution for 5 min, the zeta potential of the clear part of the

solution was measured (Table 3).

In the second phase of the experiment, after addition of CaSO₄, flocculant - anionic polyacrylamide (PAM), concentration 3 g/dm³ was added. The mean molecular weight of PAM was determined refractometrically and spectrophotometrically by the Kar and Arslan method (Kar and Arslan, 1999). The mean molecular weight was obtained from experimental measurements for five different PAM concentrations.

Table 1.
Experiment plan

Pectin solutions P1 and P2		Volume: 50 cm ³ ; conc.: 1g/dm ³			No. of measurement: 140
100% CaSO ₄		20 flasks (pH = 7)			10 concentrations: 50 - 500 mg/dm ³
CaSO ₄ + anionic PAM 3 mg/dm ³	40 flasks: MW _{PAM} 500 · 10 ⁶ (g/mol)	120 flasks (pH = 7)	40 flasks: MW _{PAM} 1000 · 10 ⁶ (g/mol)	40 flasks: MW _{PAM} 1500 · 10 ⁶ (g/mol)	10 concentrations: 50 - 500 mg/dm ³

Table 2.
Physical-chemical properties of pectin preparations

Type of pect.	Solid content SC (g/100g)	Equivalent of free COOH groups X · 10 ⁵	Equivalent of ester. COOH groups Y · 10 ⁵	Content of galacturonic acid (%)	Degree of esterification DE (%)
P1	81.55	16.83	19.74	63.45	53.98
P2	80.35	24.58	16.05	72.24	39.50

Table 3.
Measured zeta potentials (mV) of pectin solutions with CaSO₄, treated with different MW and ionic degree of anionic PAMs

Conc. CaSO ₄ (mg/dm ³)	Pure CaSO ₄ (mV)		CaSO ₄ + anionic PAM		MW: 500 · 10 ⁶ (g/mol)		CaSO ₄ + anionic PAM		MW: 1000 · 10 ⁶ (g/mol)		CaSO ₄ + anionic PAM		MW: 1500 · 10 ⁶ (g/mol)	
	P1	P2	Ionic degree 60% (mV)		Ionic degree 30% (mV)		Ionic degree 60% (mV)		Ionic degree 30% (mV)		Ionic degree 60% (mV)		Ionic degree 30% (mV)	
			P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
50	-22	-21	-20	-20	-20	-19	-19	-20	-20	-20	-20	-19	-20	-19
100	-18	-17	-18	-17	-17	-16	-17	-18	-19	-18	-18	-18	-17	-17
150	-17	-13	-15	-14	-15	-15	-15	-16	-16	-16	-16	-15	-15	-13
200	-16	-12	-12	-12	-14	-13	-11	-12	-15	-13	-12	-13	-11	-9
250	-13	-11	-11	-10	-11	-10	-10	-10	-11	-9	-8	-8	-7	-5
300	-10	-8	-8	-7	-8	-6	-7	-6	-9	-7	-7	-5	-4	-1*
350	-7	-6	-5	-3	-4	-3	-3*	-3*	-2*	-1*	-1*	0*	0*	+1*
400	-3	-1*	-3	-1*	-1*	-1*	+6*	+4*	+4*	+2*	+1*	2	+1	+2
450	-1*	+3*	0*	+2*	+1*	+4*	+7	+5	+5	+5	+3	+3	+4	+3
500	+4*	+5	+2	+5	+4	+6	+8	+6	+7	+6	+5	+5	+6	+5

The numbers marked with * represent the interval of the zeta potential: 0 ± 5 mV

The basic solution was obtained by dissolving 0.5 g of PAM in 100 cm³ of distilled water and allowed to swell overnight at room temperature. From this solution, a solution of 3 mg/dm³ concentration was prepared. This solution was added to the solution of the pectin preparation according to the method described in the paper (Kuljanin et al., 2014).

Measurement of the zeta potential

The zeta potential of particles in a pectin solution was evaluated by means of electrophoresis using a Zeta Meter ZM-77 (Riddick, 1968). The process of measuring of zeta potential and general arrangement of Zeta Meter Unit was explained in the work (Alkan et al., 2005).

RESULTS AND DISCUSSION

Due to differences in the extraction conditions (pH, temperature and duration of the extraction), two types of preparations were isolated. The pectin preparations were of different composition and degree of esterification. The results of the analysis of the basic physical-chemical properties of the pectin preparations are given in Table 2. The content of galacturonic acid (degree of purity) and degree of esterification in the tested preparations corresponds to the average value of the pectin content and degree of esterification in the raw juice of the sugar beet.

The results of measurement of the zeta potential of pectin solutions P1 and P2 which have been treated with CaSO₄, with different types of anionic PAMs (three MW and two ionic degree), are given in Table 3. The results represent the mean value of 3 measurements.

After measuring the molecular weight of samples of anionic PAM, using refractometric and spectrophotometric methods, fractions with a mean molecular weight of approximately 500 · 10⁶ g/mol, 1000 · 10⁶ g/mol and 1500 · 10⁶ g/mol were isolated.

Figures 1 and 2 are presented optimal concentrations of CaSO₄ to achieve the zero value of the zeta potential. Measurements were performed with different types of anionic PAMs (three MW and two

ionic degree) for pectin solution P1 and P2.

This type of anionic flocculant (PAM) of large molecular weight is being used, both in the treatment of various industrial wastewaters and in the treatment of wastewaters of sugar factories. In the experiments, the used concentration of the anionic PAMs was 3 mg/dm³ since the highest efficiency of clarification was noticed in previous works by applying polyelectrolytes of this concentration (Kuljanin et al., 2015a, Kuljanin et al., 2015b).

Around the zero value of the potential zeta, the surface of the pectin particles is discharged, which allows their coagulation and precipitation. The measured optimal amount of CaSO₄ coagulant prior to the addition of anionic polyelectrolytes required to achieve the zero value of zeta potential was 460 mg/dm³ for preparation P1 and 440 mg/dm³ for preparation P2 (into the header of Figure 1 and 2). In this case, there is a simple charge neutralization mechanism. With the use of anionic flocculants, less quantities of this coagulant were required, which can be seen from Figures 1 and 2. The minimum amount of CaSO₄ needed to achieve the zero value of the zeta potential was measured using the anionic PAM with the highest MW (1500 million g/mol) and a lower degree of ionization (30%). These optimal amounts of CaSO₄ were: 355 mg/dm³, for preparation P1 and 340 mg/dm³, for preparation P2. Comparing the results from Figures 1 and 2, it can be concluded that MW of this type of polymer has a more significant effect on the precipitation of pectin than the impact of the degree of PAM ionization. Observed at the molecular level, as explained in the text below, with an increase in the molecular weight of the PAM, the number of binding sites with Ca²⁺ ions increases.

This is explained with the extended conformation of the polymeric chains of PAM (Yang et al, 2016), which enables a greater "bridging effect", thereby improving the precipitation of pectin. In this case comes to an increase in the number of H-connections with the COO- groups, which reduces the degree of PAM ionization.

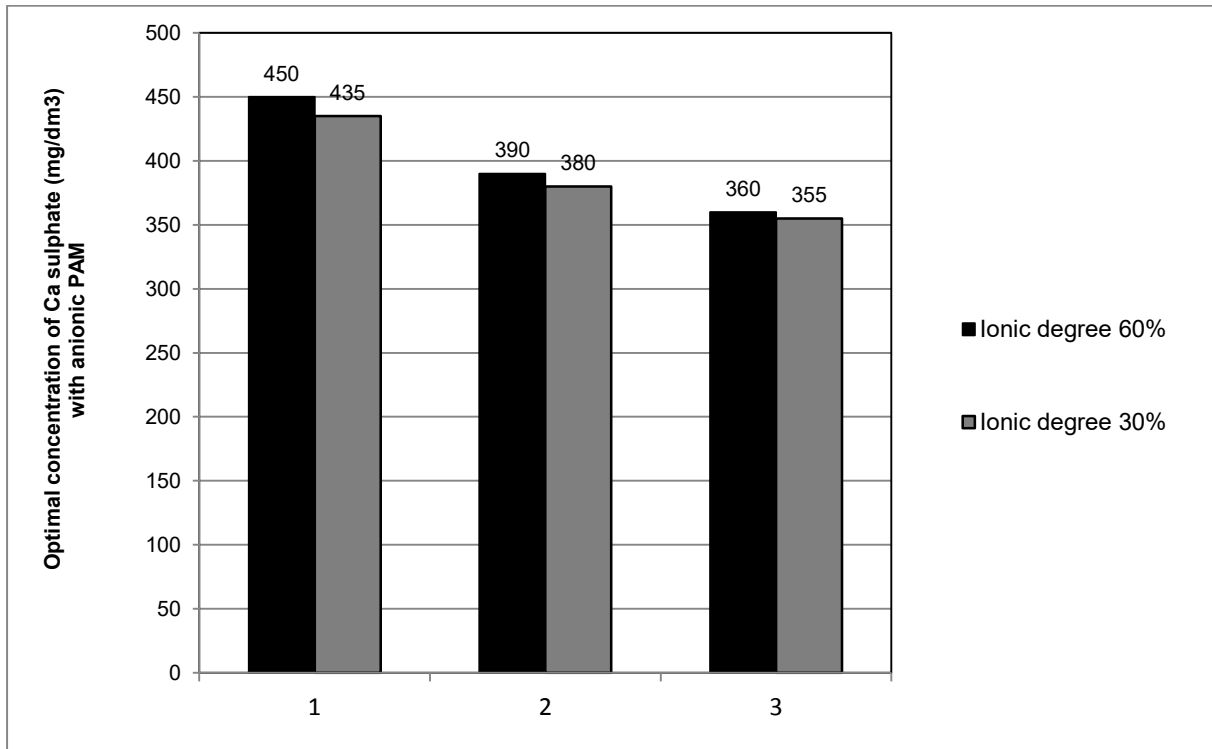


Figure 1. Optimal concentration of pure CaSO_4 and CaSO_4 with various types of anionic PAMs for pectin solution P1

Pure CaSO_4 : 460 mg/dm^3

Molecular weight of anionic PAMs: 1 - $500 \cdot 10^6 \text{ g/mol}$; 2 - $1000 \cdot 10^6 \text{ g/mol}$; 3 - $1500 \cdot 10^6 \text{ g/mol}$

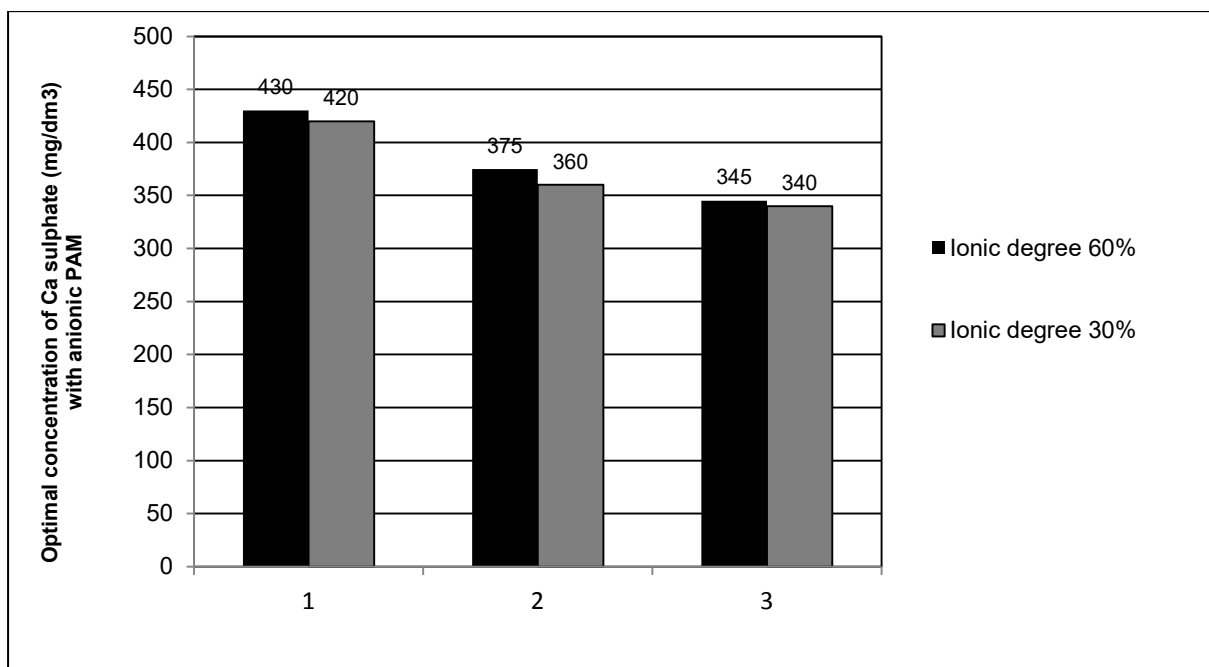


Figure 2. Optimal concentration of pure CaSO_4 and CaSO_4 with various types of anionic PAMs for pectin solution P2

Pure CaSO_4 : 440 mg/dm^3

Molecular weight of anionic PAMs: 1 - $500 \cdot 10^6 \text{ g/mol}$; 2 - $1000 \cdot 10^6 \text{ g/mol}$; 3 - $1500 \cdot 10^6 \text{ g/mol}$

Namely, the optimal amounts of CaSO_4 coagulants with the application of PAM of the same molecular weight and of a different degree of ionization, differed from 5 to 15 mg/dm^3 . The measured difference in the amount of coagulants with the application of PAM of different molecular weights and the same degree of ionization was in a significantly larger interval, from 100 to 105 mg/dm^3 .

The presence of Ca^{2+} ions suppresses the dissociation of functional groups of anionic polyelectrolytes and pectin macromolecules. Since Ca^{2+} ions have high efficiency in reducing electrostatic reflections between anionic polyelectrolytes and colloidal particles, they provide anchoring and bridging sites for anionic polymer molecules (Lee et al., 2012). In our case, Ca^{2+} ions build divalent cationic bridges between anionic polymer molecules and pectin particles. This can be schematically shown as: Pectin $\cdots^+\text{Ca}^+\cdots^-$ PAM $\cdots^+\text{Ca}^+\cdots^-$ Pectin.

In accordance with the literature data (Yang et al., 2016), only for large-MW flocculants is typical bridging mechanism. This “bridging effect” is strongly related to the structure of the polymer chains in water (i.e., the chain morphology and conformation). Increasing the MW of polymer usually results in a larger hydrodynamic size and a more extended conformation of the polymer chain. In our case, the bridging effect of Ca^{2+} ions (from CaSO_4) will be enhanced with an increase in the molecular weight of the anionic polymer (Figure 1 and 2). Extended conformation of the polymer chains of PAMs allows for a higher number of H-connections. The H bond is achieved when the H^+ ions from the amide group of polyacrylamide binds to the functional COO^- groups at the surface of the pectin particles. More amide groups on large-MW anionic PAM molecules allow stronger bonding between PAM and pectin macromolecules.

From literature (Fraj, 2016), it is known that the expansion of polymeric polyelectrolyte polymers occurs only to a certain value of the degree of ionization. In this experiment, in examined levels of ionization (30% and 60%), the expansion of

the polymer chain of PAMs was most likely negligible. This can explain the low impact of the degree of ionization of anion flocculant on the effect of coagulation and pectin flocculation.

Based on the literature data (Lee et al., 2012), it has been established that under certain conditions the opposite effect can be achieved that is, to increase the stabilization of the colloidal solution. In this case, are formed polymers – binding Ca^{2+} bridges, between PAM molecules. This can be schematically shown as: PAM $\cdots^+\text{Ca}^+\cdots^-$ PAM $\cdots^+\text{Ca}^+\cdots^-$ PAM. This increased steric stabilization by developing polymer layers covering the pectin surface.

In addition to the two flocculation models described here, at local sites on the surface of the pectin particles where a charge inversion due to the excess of adsorbed Ca^{2+} ions on the surface of macromolecules pectin (zeta potential ~ 0 mV) was present, adsorption of the anionic PAM is also performed (Mpofy et al., 2005). Then, there is a chemical reaction between the reactive COO^- group on the surface of the polyacrylamide and the adsorbed Ca^{2+} ions on the surface of macromolecules of pectin. Since the anionic PAMs of high molecular weight have a large length of polymer chains, after adsorption of anionic PAM, it also comes to a known “bridging effect”. From Table 2, it is evident that pectin P2, with lower DE, has a higher flocculating activity. This may be due to the fact that low DE pectin have higher amount of negatively charged carboxyl group (COO^-) and could provide more effective sites for Ca^{2+} ions to form bridge that binds pectin particles and anionic PAM.

CONCLUSIONS

The effects of the surface charge type and molecular weight of anionic polyacrylamides (PAMs) on the zeta potential of different pectin solutions with Ca^{2+} ions were investigated. This work has been successful in establishing the link between electrokinetic behavior pectin solutions with Ca^{2+} ions, the surface charge and MW of anionic PAMs. The results indicate that some flocculation/coagulation process is

of potential interest for the removal of pectin during sugar beet juice clarification. The main mechanism has been described by forming Ca^{2+} ionic bridges between anionic polymer and pectin particles. Optimum concentrations of CaSO_4 (340-355 mg/dm^3) were obtained with addition of anionic PAM of the highest molar weight ($1500 \cdot 10^6$ g/mol) and ionization degree of 30%. These concentrations are many times lower compared to the conventional CaO coagulant (9 g CaO/g pectin) used for purification of sugar beet juice. By using CaSO_4 with the addition of this type of high molecular weight flocculant, the cost of removing pectin and other non-sucrose matter as well as the amount of waste sludge in the vicinity of the sugar factory would be reduced. This would be significant from an economic and environmental point of view.

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УТИЦАЈ МОЛСКЕ МАСЕ И ПОВРШИНСКОГ НАЕЛЕКТРИСАЊА АНЈОНСКОГ ПОЛИАКРИЛАМИДА НА ТАЛОЖЕЊЕ ПЕКТИНА

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Сажетак: Изнета је теоријска основа нове методе чишћења сировог сока шећерне репе базирана на примени CaSO_4 уз додатак анјонског флокуланта, полиакриламида (ПАМ). Проучаван је утицај различитих молекулских тежина и површинског наелектрисања (степен јонизације) овог типа флокуланта на таложење пектина. Мерењем зета потенцијала, установљена је неутрализација наелектрисања пектинских макромолекула и процес међучестичног повезивања. Процес међучестичног повезивања је описан преко два механизма: стварање Ca^{2+} “мостова” између анјонских полимерних ланаца и пектинских макромолекула и стварање Ca^{2+} “мостова” само између анјонских полимера. Испитивано је 10 концентрација CaSO_4 уз додатак ПАМ-а молекулских тежина: $500 \cdot 10^6$; $1000 \cdot 10^6$ и $1500 \cdot 10^6$ g/mol, концентрације 3 mg/dm^3 . Установљено је, да се са порастом молекулске тежине анјонског полимера, интензивира стварање Ca^{2+} “мостова” између ПАМ-а и пектинских макромолекула чиме се побољшава њихова коагулација.

Оптималне концентрације CaSO_4 ($340\text{-}355 \text{ mg/dm}^3$), постижу се у тренутку разелектрисања површине пектинских макромолекула када је достигнута нулта вредност зета потенцијала. Најбољи резултати добијени су применом CaSO_4 уз анјонски ПАМ највеће молске масе ($1500 \cdot 10^6$ g/mol) и степена јонизације 30%.

Количина CaSO_4 уз додатак овог типа флокуланта велике молекулске тежине, била би вишеструко мања у поређењу са употребљеном количином класичног коагуланта CaO (око 9 g/g пектина у соку шећерне репе). Самим тим, смањили би се трошкови уклањања пектина и других несхарозних материја из сока шећерне репе као и количина отпадног муља у непосредној близини фабрике шећера.

Кључне речи: пектини, CaSO_4 , анјонски полиакриламид, молекулска тежина, степен јонизације

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