Journal of Agricultural Sciences
Vol. 49, No 2, 2004
Pages 205-217

UDC: 637.334.2
Original scientific paper

INFLUENCE OF SELECTED FACTORS ON INDUCED SYNERESIS

Snežana Jovanović,[1] O. Maćej[1] and Jelena Denin-Djurdjević[1]

Abstract: Syneresis is the process of whey separation induced by gel contraction, resulting in rearranging or restructuring of casein matrix formed during enzymatic coagulation. Numerous factors can influence the process of syneresis.

The influences of pH, calcium concentration, temperature of coagulation of milk and applied heat treatment on the syneresis induced by different intensity of centrifugal force have been investigated. Coagulated samples were centrifuged at 1000, 2000 and 3000 rpm for 5 min, respectively. Reconstituted skim milk powder (*control sample*) and reconstituted non-fat milk heat treated at 87ºC/10 min (*experimental sample*) are coagulated at temperatures of 30ºC and 35ºC, at pH value of 5.8 and 6.2, and with the addition of 100, 200 and 400 mg/l of $CaCl_2$, respectively.

Centrifugation at 1000 rpm of both control and experimental samples didn't recover any sera, regardless of the applied coagulation conditions. This indicates that the intensity of centrifugal force wasn't strong enough to disrupt gel structure and cause syneresis. When the intensity of centrifugal force was increased up to 2000 rpm, the syneresis was induced, but the degree of syneresis depended on the applied factors of coagulation, primary on the applied heat treatments and temperature of coagulation. The amount of added $CaCl_2$ didn't have a significant influence on the induced syneresis at 2000 rpm. The induced syneresis was very significant for both control and experimental samples when the intensity of centrifugal force of 3000 rpm was applied. It was also noted that curd produced from heat treated milk in which milk protein coaggregates were formed, released less sera regardless of the applied coagulation factors.

Key words: milk, casein gel, coagulation factors, induced syneresis, sera.

---

[1]Snežana Jovanović, PhD., Assistant Professor, Ognjen Maćej, PhD., Professor, Jelena Denin-Djurdjević, M.Sc., Research Associate, Department of Food Technology and Biochemistry, Faculty of Agriculture, Nemanjina 6, 11081 Belgrade -Zemun, Serbia and Montenegro

*The article was financed by the Ministry of Science and Environmental Protection of the Republic of Serbia – project BTN.7.1.3.0713.B

Introduction

Gel structure formed by rennet has direct influence on texture, structure and chemical composition of cheese. Technological processes applied during the curd processing influence both the rate of water (sera) removal from the curd (syneresis) and total solid content of cheese. To be precise, the curd processing, composed of numerous operations such as cutting, stirring, cooking, drying, washing and whey removal, should also assure optimal conditions for the growth of microorganisms as well as for correct process of ripening (Green, 1987, Green and Grandison, 1993, Lawrence et al., 1984, Pejić, 1956, Pudja et al., 1996).

Basically, syneresis is removal of whey induced by gel contractions and doesn't represent the simple physical process. The casein matrix formed by enzymatic coagulation undergoes rearrangement or restructuring during the syneresis, which leads to the formation of more compact gel structure. In addition, the largest part of rennet or other enzymes used for coagulation of milk passes to the whey. Those enzymes remained in the curd would induce the so-called "non-specific proteolyses" of α_{s1}- i β-casein during ripening (Carić et al., 1998, Green and Grandison, 1993, Pudja and Obradović, 1994). The curd cutting increases total curd area and provides outside mechanical pressure on the curd, and consequently increases whey removal. Additional stirring of the curd as well as cooking of the curd and whey directly influence the increase of rate at which whey is removed. If the gel is cut too early, when it has lower firmness, the structure of the gel is disrupted more easily, partial destruction of gel may occur, as well as the formation of the cheese dust and loss of milk fat in the whey. If the gel is cut too late, when it has higher firmness, the whey removal from the surface of the curd is immediate which leads to the formation of membrane which, on the other hand, may decrease or completely stop further removal of the whey from the center of the curd (Scott, 1986, Walstra, 1993).

The factors influencing the rate of whey removal i.e. syneresis as well as macro and microstructure of cheese are numerous, though the most significant ones are pH, temperature, gel permeability, milk composition and the degree of concentration, calcium and other ions concentration, ionic strength, milk homogenization, cooling of milk, severe heat treatments of milk, degree and the way of agitation and stirring, degree and the way of curd pulverization during cutting as well as the surface of the curd, the amount of the whey surrounding the curd, washing of the cheese curd, drying, whey removal, molding, pressing and salting of cheese (Fox and Cogan,1990, Fox and Cogan., 2000, Green, 1987, Green and Grandison, 1993, Guinee et al., 1992, Pearse and Mackinlay, 1989, Pudja and Guinee, 1998, Pudja and Maćej, 1996, Pudja et al., 1996, van den Bijgaart, 1989, Walstra,1993, Zoon et al., 1988).

Material and Method

The influences of pH, calcium concentration, temperature of coagulation of milk and applied heat treatment on the syneresis induced by different intensity of centrifugal force have been investigated. Coagulated samples were centrifuged at 1000, 2000 and 3000 rpm for 5 min, respectively. Syneresis was determined by measuring the amount of sera segregated from the gel.

In order to eliminate the influence of chemical composition of raw milk, reconstituted instant non-fat milk powder regularly used for determining rennet strength, has been used in this experiment. Heat treatment applied during production of this kind of instant milk powder gives the product of good solubility, which after reconstitution still has high sensitivity toward rennet and other proteolytic enzymes.

Total solid content of reconstituted skim milk was 9.0% which was used as a control sample. Reconstituted skim milk heat treated at 87ºC/10 min has been used as an experimental sample.

The conditions of coagulation were as follows:

- Temperature of coagulation: 30^0C and 35^0C;
- pH value of milk: 6.2 and 5.8;
- The amount of added $CaCl_2$ (mg/l): 100, 200 and 400.

Statistical analysis was performed. All data for the investigated parameters are shown as mean values (X). Also, the analyses of variance for all data were performed (Standard deviation - Sd and coefficient of variation - Cv) (Stanković et al., 1989).

Results and Discussion

Results of investigation are shown in Tables 1., 2. and 3., and Figures 1 and 2.

As can be seen from tables, there was no sera removal from gels centrifuged at 1000 rpm, which indicates that the intensity of applied centrifugal force wasn't high enough to destroy gel structure and induce syneresis. It could be explained by the fact that at this intensity of centrifugal force even control samples coagulated at the lowest concentration of $CaCl_2$, at coagulation temperature of 30^oC and at pH 6.2, had casein matrix strong enough to maintain gel integrity and prevent whey removal. It means that pH value of 6.2, which is considerably lower than pH of fresh milk, plays a significant role and has big influence on the improvement of the rheological characteristics of gels gained from experimental samples under the same conditions.

T a b. 1. - The influence of the intensity of centrifugal force on the amount of recovered sera when 100 mg/l of $CaCl_2$ is added

Centrifugal force (rpm)	Coagulation temperature (ºC)	pH value of milk	Amount of added $CaCl_2$-100 mg/l Control sample Amount of recovered serum (%) Calculated parameters x (n=6)	min.	max.	Sd	Cv (%)
1000	30	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
	35	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
2000	30	6.2	5.40	1.90	8.71	2.8720	53.16
		5.8	17.39	11.37	24.17	4.7294	27.20
	35	6.2	46.95	41.52	54.75	5.4730	11.66
		5.8	21.85	16.44	29.64	4.3120	19.73
3000	30	6.2	63.52	61.79	65.42	1.3384	2.11
		5.8	62.30	56.70	65.37	3.0684	4.92
	35	6.2	65.88	63.71	68.05	1.7433	2.64
		5.8	59.81	55.65	66.44	5.0298	8.41
Centrifugal force (rpm)	Coagulation temperature (ºC)	pH value of milk	Experimental sample Amount of recovered serum (%) Calculated parameters x (n=6)	min.	max.	Sd	Cv (%)
1000	30	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
	35	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
2000	30	6.2	3.63	2.45	8.12	2.2474	61.98
		5.8	1.28	0.71	2.72	0.7290	56.95
	35	6.2	22.03	15.93	26.72	4.9689	22.56
		5.8	18.37	13.89	23.20	3.4628	18.85
3000	30	6.2	60.08	57.58	63.06	1.9493	3.24
		5.8	34.97	24.84	41.55	6.6399	18.98
	35	6.2	62.31	59.85	65.41	2.0348	3.26
		5.8	59.98	55.32	62.68	3.4955	5.83

Control sample – reconstituted skim milk powder
Experimental sample- reconstituted skim milk powder heat treated at 87^oC/10 min

T a b. 2. - The influence of the intensity of centrifugal force on the amount of recovered sera when 200 mg/l of $CaCl_2$ is added

Amount of added $CaCl_2$-200 mg/l							
Centrifu gal force (rpm)	Coagulation temperature (ºC)	pH value of milk	Control sample Amount of recovered serum (%) Calculated parameters x (n=6)	min.	max.	Sd	Cv (%)
1000	30	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
	35	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
2000	30	6.2	-	-	-	-	-
		5.8	13.79	4.75	31.25	9.3269	67.63
	35	6.2	57.13	53.36	61.54	3.5472	6.21
		5.8	17.58	13.01	21.04	3.2889	18.71
3000	30	6.2	59.24	56.32	62.58	2.3163	3.91
		5.8	67.46	65.72	70.23	2.1245	3.15
	35	6.2	69.94	67.65	72.11	1.7446	2.49
		5.8	69.31	68.18	70.70	0.8920	1.29
Centrifu gal force (rpm)	Coagulation temperature (ºC)	pH value of milk	Experimental sample Amount of recovered serum (%) Calculated parameters x (n=6)	min.	max.	Sd	Cv (%)
1000	30	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
	35	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
2000	30	6.2	26.09	10.10	39.01	12.3621	47.38
		5.8	1.42	1.13	1.58	0.1639	11.49
	35	6.2	6.01	2.62	11.00	2.7844	46.36
		5.8	4.26	1.94	6.45	1.7865	41.92
3000	30	6.2	55.01	48.36	62.77	6.8290	12.41
		5.8	26.82	25.10	29.49	1.7065	6.36
	35	6.2	57.63	51.81	66.25	6.6046	11.46
		5.8	64.41	61.09	67.55	2.1936	3.40

Control sample – reconstituted skim milk powder
Experimental sample- reconstituted skim milk powder heat treated at 87^{o}C/10 min

T a b. 3. - The influence of the intensity of centrifugal force on the amount of recovered sera when 400 mg/l of $CaCl_2$ is added

Amount of added $CaCl_2$-400 mg/l							
			Control sample				
Centrifugal force (rpm)	Coagulation temperature (°C)	pH value of milk	Amount of recovered serum (%) Calculated parameters				
			x (n=6)	min.	max.	Sd	Cv (%)
1000	30	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
	35	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
2000	30	6.2	8.74	1.49	12.47	3.8231	43.71
		5.8	27.59	13.52	37.82	8.8454	32.06
	35	6.2	53.89	51.04	55.64	1.9246	3.57
		5.8	2.60	1.52	3.42	0.6196	23.79
3000	30	6.2	65.30	64.34	67.02	1.0432	1.60
		5.8	61.61	56.91	65.36	3.3256	5.40
	35	6.2	66.75	62.03	74.36	5.7620	8.63
		5.8	67.00	64.67	71.25	3.0445	4.54
			Experimental sample				
Centrifugal force (rpm)	Coagulation temperature (°C)	pH value of milk	Amount of recovered serum (%) Calculated parameters				
			x (n=6)	min.	max.	Sd	Cv (%)
1000	30	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
	35	6.2	-	-	-	-	-
		5.8	-	-	-	-	-
2000	30	6.2	1.05	0.47	1.45	0.3266	31.17
		5.8	0.44	0.28	0.65	0.1640	37.29
	35	6.2	1.49	1.24	1.77	0.1942	13.01
		5.8	0.75	0.35	1.06	0.2906	38.64
3000	30	6.2	52.67	41.82	62.86	7.9139	15.02
		5.8	36.45	27.79	42.58	5.4610	14.98
	35	6.2	53.93	49.88	58.75	3.9185	7.27
		5.8	54.92	49.97	62.43	4.3016	7.83

Control sample – reconstituted skim milk powder
Experimental sample- reconstituted skim milk powder heat treated at 87°C/10 min

As can be seen from shown tables and Figure 1., when the intensity of centrifugal force was increased up to 2000 rpm, the syneresis was induced, but the degree of syneresis depended on applied factors of coagulation, primarily on the applied heat treatments and temperature of coagulation, whereas the amount of added $CaCl_2$ didn't have a significant influence on the induced syneresis at 2000 rpm.

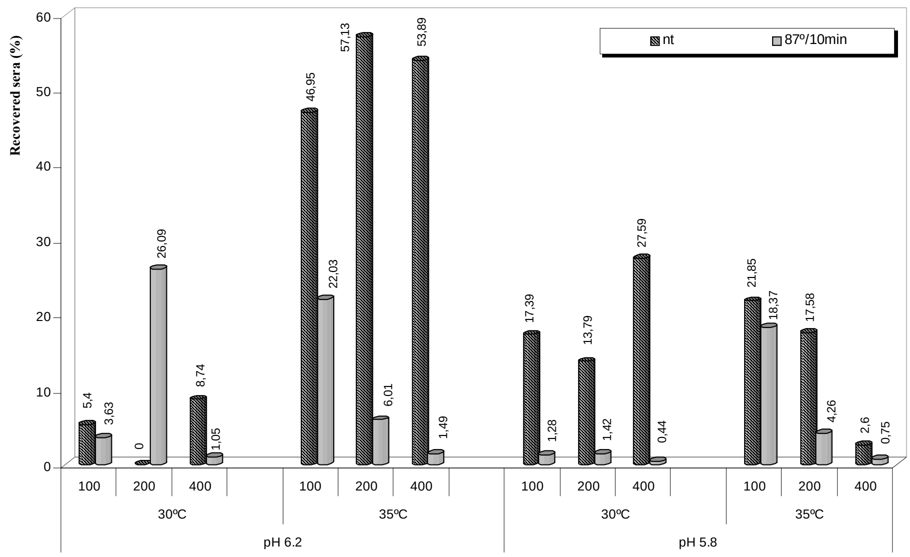

Fig. 1. – The influence of investigated coagulation factors on the amount of recovered sera by centrifuging at 2000 rpm

The amount of recovered sera of control samples coagulated at pH 6.2 was greatly influenced by the temperature of coagulation. It can be seen from Figure 1. and Table 1. that the amount of recovered sera from samples coagulated at 30°C and with 100 mg/l of added $CaCl_2$ was only 5.40% of milk volume, while the amount of recovered sera from samples coagulated at the same conditions but at the temperature of 35°C was 46.95%.

From data shown in Table 2. it can be seen that at the temperature of 30ºC syneresis at 2000 rpm wasn't induced because of an increase in $CaCl_2$ to 200 mg/l. It could be explained by the formation of network structure of gel capable to withstand such intensity of centrifugal force and avert induced syneresis. However, the amount of recovered sera from samples coagulated at the same concentration of $CaCl_2$ and at 35°C had an average value of 57.13%, which indicates that not only temperature of coagulation but also concentration of Ca^{2+} ions has an influence on rheological properties of gel.

The results regarding the amount of sera recovered from gel produced from milk in which 400 mg/l of $CaCl_2$ was added are shown in Table 3. Samples coagulated at 30°C, recovered a little bit higher volume of sera than the same samples produced from milk in which 100 mg/l of $CaCl_2$ was added. However, the influence of coagulation temperature was significant and as a result the amount of sera recovered from samples coagulated at 35ºC was 53.89% and was insignificantly lower than for samples coagulated with 200 mg/l of $CaCl_2$.

It is visible from results shown in Tables 1., 2., 3. and Figure 1. that the amount of recovered sera from all experimental samples, except the samples coagulated at pH 6.2, at the temperature of 30°C and with 200 mg/l of added $CaCl_2$, was considerably lower than from control samples, which is a result of the applied heat treatment of milk and formation of milk protein coaggregates.

For control samples, the amount of recovered sera was the biggest (26.09%) for samples coagulated at pH 6.2, at 30ºC and with 200 mg/l of added $CaCl_2$. It could be explained by the formation of gel with uneven rheological properties, which was easily broken by applied centrifugal force, which, on the other hand, induced a big amount of recovered sera. Such conclusion is supported by a high coefficient of variation of 47.38%. However, the influence of Ca^{2+} ions on induced syneresis is evident at the temperature of coagulation of 35ºC and at pH 6.2. Also, the regularity of recovered sera is noticeable. With an increase of $CaCl_2$ concentration, the gel firmness is increased and rheological properties of gel are improved, casein matrix is more structured and gained gel structure is more even than the structure of gels produced at the same pH value but at lower temperature of coagulation. It is confirmed with smaller values of coefficient of variations, the smallest value being 13.01% for samples produced from milk in which 400 mg/l of $CaCl_2$ was added.

The amount of recovered sera was considerably reduced when pH value was decreased from 6.2 to 5.8. The amount of recovered sera is higher for control samples, but the difference is smaller than for samples coagulated at pH 6.2.

That is the reason why the influence of the intensity of centrifugal force of 3000 rpm on the induced syneresis has been investigated. The results are shown in Tables 1., 2., 3. and Figure 2.

The results gained for control and experimental samples show that the applied intensity of centrifugal force of 3000 rpm had a considerable effect on the amount of recovered sera. It is visible from Figure 2. that all selected coagulation factors had similar effect on the induced syneresis of control samples, regardless of the pH, temperature of coagulation and concentration of $CaCl_2$. However, it does not mean that gels with similar or the same rheological characteristics were formed at selected coagulation parameters, regardless of the similar amount of recovered sera, as could be initially concluded. The differences are especially noticeable at pH 5.8 and with 200 mg/l and 400 mg/l of added $CaCl_2$. On the other hand, relatively low pH value of 6.2 (not commonly used in the traditional cheese production) had a significant effect, which diminished the influence of coagulation temperature and $CaCl_2$ concentration on the differences in the rheological properties of casein gels. Those differences would be more pronounced during coagulation of milk with lower acidity commonly used during traditional production of cheeses.

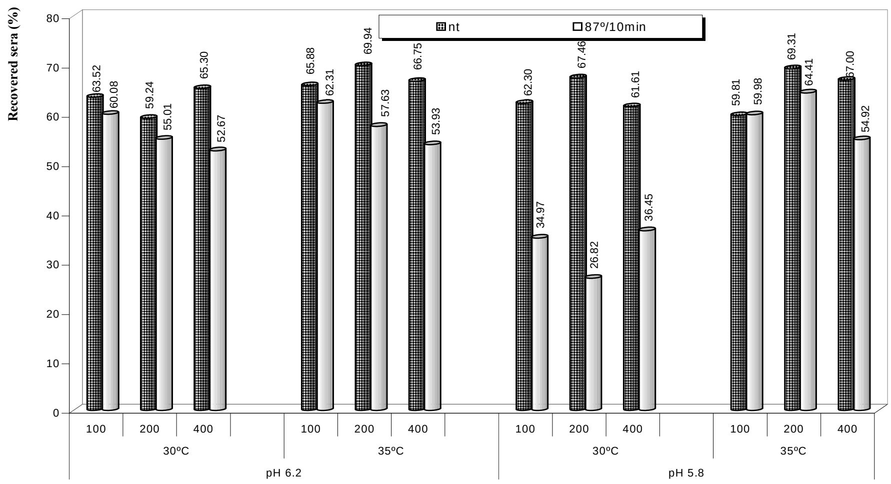

Fig. 2. – The influence of investigated coagulation factors on amount of recovered sera by centrifuging at 3000 rpm

It can be seen from data shown in Tables 1., 2., 3. and Figure 2. that there is less sera recovery from gels produced of milk in which coaggregates were formed than from the control samples. There is practically no difference in the amount of recovered sera at pH 6.2, regardless of the coagulation temperature and concentration of $CaCl_2$. However, at pH 5.8, the amount of recovered sera was smaller for samples coagulated at 30ºC than at 35ºC. The amount of added $CaCl_2$ didn't have a significant influence, as can be seen from Figure 2.

Visual evaluations of gained gels and sera have been done after centrifuging.

Sera recovered from control samples were transparent. When centrifugal force of 2000 rpm has been applied, gained gel was partially separated into layers, unevenly packed whit sera entrapped within the holes. The gels produced from samples coagulated at pH 5.8, with 400 mg/l of added $CaCl_2$ and at 35^oC had the most compact structure. Even after sera were decanted, gels continued to spontaneously release sera. Gels gained after centrifuging at 3000 rpm were compact, had good network with more or less manifested granular structure.

Sera recovered from experimental samples had characteristic yellow-green colour and was more transparent than those gained from control samples. Gels gained after centrifuging at 2000 rpm were separated into layers with sera entrapped in between the layers. After sera have been decanted, gels showed the tendency to spontaneous syneresis. Samples centrifuged at 3000 rpm had compact gel with spreadable consistency, which could be connected with the influence of sera proteins incorporated into structure as a result of the formation of milk protein coaggregates.

The results of investigation gained in this phase match the results of other authors. When treated with rennet, milk in which coaggregates were formed by severe heat treatments forms gel with smaller firmness and higher density, which releases serum more slowly due to impaired ability to contraction (Ghosh et al., 1996, Green and Grandison, 1993, Pearse and Mackinlay, 1989, Walstra, 1993). Gel firmness is connected with gel permeability. As a rule, the more porous gels were built from thicker chains, and consequently were more resistant to mechanical influences from surroundings, namely are characterized with superior rigidity (Guinee et al., 1993, Walstra and Jenness, 1984). According to Pudja (1992), who investigated the coagulation of concentrated milk, samples treated with severe heat treatments (85^{o}C/2 min and 100^{o}C/2 min) had an impaired ability of coagulation. Protein matrix is characterized with thinner chains, while serum was evenly distributed. According to Mottar et al. (1989) gel formed from milk heat treated with severe heat treatment has lower firmness, dismembered structure, which is explained with partial covering of casein micelles with sera proteins. Lower syneresis of gels containing sera proteins is explained by the influence of β-lactoglobulin aggregates on the ability to bond water as well as with the formation of complex between κ-casein and β-lactoglobulin (Pearse et al., 1985). According to Walstra (1993) and Green (1987), the rate of syneresis is increased at lower pH values because the gel has a higher ability of contractions.

Conclusion

Selected factors of coagulation (pH, temperature of coagulation, the amount of added $CaCl_2$ and applied heat treatments) have a big influence on the amount of recovered sera by the application of various intensities of centrifugal force (induced syneresis);

According to the gained results, it could be concluded that the best rheological properties had gels produced by milk coagulation at pH 5.8, at the temperature of coagulation of 35^{o}C and with added 400 mg/l $CaCl_2$;

Lastly, it can be concluded that the results regarding the time of the gel formation and induced syneresis cannot provide the answer to the fundamental question: what combination of coagulation factors is optimal for the production of the gel from milk in which coaggregates were formed, with good rheological properties similar to those gained during traditional production of semi-hard cheeses?

Further investigation should involve the investigation of chemical composition of sera gained by induced syneresis, dry matter content and nitrogen content, nitrogen matter content in dry matter, as well as the distribution of nitrogen matter from gel to sera. These investigations should provide more precise data the conclusions of gels characteristics would be drawn upon, and the coagulation factors for the production of semi-hard cheese from milk protein coaggregates would be defined too.

REFERENCES

1. Carić, M., Milanović, S., Vucelja, D. (1998): Nutritivne karakteristike sira i topljenog sira. Preh. ind. Mleko i mlečni proizvodi 9 (1-2), 7-16.
2. Fox, P.F., Cogan, T.M. (1990): Production and metabolism of lactate during cheese manufacture and ripening. 2nd Cheese symposium. Ed. by Cogan, T.M., Moorepark, 63-70.
3. Fox, P.F., Cogan, T.M. (2000): Cheese: scientific highlights of the 20th century. 6th Cheese symposium. Ed. by Cogan, T.M., McSweeney, P.L.H. and Guinee, T.P., Moorepark, 83-121.
4. Ghosh, B.C., Steffl, A., Kessler, H.-G. (1996): Rennetability of milk containing different heat-denatured whey protein. Milchwissenschaft 51 (1), 28-31.
5. Green, M.L. (1987): Effect of manipulation of milk composition and curd-forming conditions on the formation, structure and properties of milk curd. J. Dairy Res. 54 (2), 303-313.
6. Green, M.L., Grandison, A.S. (1993): Secondary (non-enzymatic) phase of rennet coagulation and post-coagulation phenomena in Cheese: chemistry, physics and microbiology. Volume 1, Chapter 4, 101-140. Second edition. Ed. by Fox, P.F., Chapman & Hall, London.
7. Guinee, T. P., Pudja, P. D., Farkye, N. Y. (1993): Fresh acid-curd cheese varieties in Cheese: Chemistry, Physics and Microbiology. Vol. 2., Major Cheese Groups. Ed. Fox, P. F., Chapman & Hall, London.
8. Guinee, T.P., Pudja, D.P., Mulholland, E.O., Reville, W.J. (1992): Ultrafiltration in cheesemaking, 3rd Cheese Symposium. Ed. by Cogan, T.M., Moorepark, 49-59.
9. Lawrence, R.C., Heap, H.A., Gilles, J. (1984): A controlled approach to cheese technology. J. Dairy Sci. 67 (8), 1632-1645.
10. Mottar, J., Bassier, A., Joniau, M., Baert, J. (1989): Effect of heat-induced association of whey proteins and casein micelles on yogurt texture. J. Dairy Sci. 72 (9), 2247-2256.
11. Pearse, M.J., Mackinlay, A.G. (1989): Biochemical aspects of syneresis: a review. J. Dairy Sci. 72 (6), 1401-1407.
12. Pearse, M.J., Linklater, P.M., Hall, R.J., Mackinlay, A.G. (1985): Effect of heat induced interaction between β-lactoglobulin and κ-casein on syneresis. J. Dairy Res. 52 (1), 159-165.
13. Pejić, O. (1956): Mlekarstvo II deo. Tehnologija mlečnih proizvoda. Naučna knjiga, Beograd.
14. Pudja, P. (1992): Karakteristike tvrdih sireva izradjenih od mleka koncentrovanog ultrafiltracijom u zavisnosti od termičke obrade mleka. Doktorska disertacija, Univerzitet u Beogradu.

15. Pudja, P.D., Guinee, T.P. (1998): Koagulacija mleka: značaj koncentracije kazeina i termičkog tretmana. Zbornik radova III Jugoslovenskog simpozijuma prehrambene tehnologije. Sveska IV, Beograd, 66-70.
16. Pudja, P.D., Maćej, O.D. (1996): Savremena proizvodnja sireva i perspektive razvoja. Monografija "Sirarstvo". Ur. Pudja, P. D., Beograd, 50-63.
17. Pudja, P., Obradović, D. (1994): Uzajamna povezanost tehnoloških i mikrobioloških faktora u proizvodnji sireva. Zbornik radova III Medjunarodnog simpozijuma "Savremeni trendovi u mlekarstvu". Ur. Krunić, M. i Čurić, M. Kopaonik, 57-60.
18. Pudja, P., Maćej, O., Dozet, N., Jovanović, S., Mikuljanac, A. (1996): Uticaj sadržaja proteina mleka na reološke karakteristike sireva. Biotehnologija u stočarstvu 12 (1-2), 37-44.
19. Scott, R. (1986): Cheesemaking practice. Second edition. Elsevier Applied Science Publishers Ltd, London and New York.
20. Stanković, J., Ralević, N., Ljubanović-Ralević, I. (1989): Statistika sa primenom u poljoprivredi. Savremena administracija, Beograd.
21. Van den Bijgaart, H.J.C.M. (1989): Syneresis of rennet -induced milk gels as influenced by cheesmaking parameters. Dissertation abstract. Neth. Milk Dairy J. 43, 92-94.
22. Walstra, P. (1993): The syneresis of curd in Cheese: chemistry, physics and microbiology. Volume 1, Chapter 5, 141-191. Second edition. Ed. by Fox, P.F., Chapman & Hall, London.
23. Walstra, P., Jenness, P. (1984): Dairy chemistry and physics. Ed. by: John Willey & Sons, New York.
24. Zoon, P., van Vliet, T., Walstra, P. (1988): Rheological properties of rennet-induced skim milk gels. 2. The effect of temperature. Neth. Milk Dairy J. 42, 271-294.

Received May 12, 2004
Accepted September 16, 2004

UTICAJ ODABRANIH FAKTORA KOAGULACIJE NA INDUKOVANI SINEREZIS

Snežana Jovanović,[1] O. Maćej[1] i Jelena Denin Djurdjević[1]

R e z i m e

Sinerezis je proces izdvajanje surutke usled kontrakcije gruša, pri čemu dolazi do rearanžiranja, ili prestruktuiranja kazeinske mreže, koja je nastala tokom enzimske koagulacije, na koji utiče veliki broj faktora.

U ovom radu je ispitivan uticaj pH, koncentracije Ca^{2+}, temperature koagulacije mleka i uticaj termičkog tretmana na indukovani sinerezis pod uticajem različitog intenziteta centrifugalne sile. Koagulisani uzorci mleka centrifugirani su pri 1000, 2000 i 3000 o/min u vremenu od 5 minuta. Rekonstituisano obrano mleko u prahu (kontrolni uzorak) i rekonstituisano obrano mleko termički tretirano na temperaturi 87^0C/10 minuta (ogledni uzorak) je koagulisalo pri različitim temperaturama 30ºC i 35ºC, pH vrednostima 5.8 i 6.2, kao i pri dodatku 100, 200 i 400 mg/l $CaCl_2$.

Centrifugiranjem kontrolnih i oglednih uzoraka pri 1000 o/min, bez obzira na uslove koagulacije nije dovelo do izdvajanja seruma iz gela, pa se može zaključiti da intenzitet primenjene centrifugalne sile nije bio dovoljno veliki da naruši strukturu gela i izazove sinerezis. Sa povećanjem intenziteta centrifugalne sile (2000 o/min), dolazi do većeg, ili manjeg stepena pojave indukovanog sinerezisa, a uočava se uticaj ispitivanih faktora koagulacije, pre svega primenjenih termičkih tretmana, pH vrednosti, temperature koagulacije, a u manjoj meri i količine dodatog $CaCl_2$ na količinu izdvojenog seruma. Pri delovanju centrifugalne sile većeg intenziteta (3000 o/min), kod kontrolnih i kod oglednih uzoraka u znatno većoj meri je uticalo na količinu izdvojenog seruma. Takodje je uočeno da gel dobijen od mleka u kojem su obrazovani koagregati, pri svim ispitivanim faktorima koagulacije, izdvaja manju količinu seruma u odnosu na kontrolne uzorke.

Primljeno 12. maja 2004.
Odobreno 16. septembra 2004.

[1] Dr Snežana Jovanović, docent, dr Ognjen Maćej, redovni profesor, mr Jelena Denin Djurdjević, saradnik, Poljoprivredni fakultet, 11081 Beograd-Zemun, Nemanjina 6, Srbija i Crna Gora

*Rad je finansiran od strane Ministarstva nauke i zaštite životne sredine R. Srbije za projekat BTN.7.1.3.0713.B