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THE INFLUENCE OF DRY MATTER AND HEAT TREATMENT ON THE VISCOSITY OF SET-STYLE YOGURT PRODUCED FROM RECONSTITUTED SKIM MILK POWDER

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Abstract: Skim milk powder was reconstituted in distilled water to obtain reconstituted milk A (8.44% TS), milk B (9.65% TS) and milk C (10.84% TS). The yogurts were produced from untreated milk and milk heat treated at 85°C/20 and 90°C/10 min, respectively. Milk samples were inoculated with 2.5% commercial yogurt culture and incubated at 43°C until pH 4.6 was reached.

Viscosity measurements were performed at 20°C after 1, 7 and 14 days of storage at 4°C. Brookfield DV-E Viscometer (spindle No 3 at 20 rpm) was used for measurement. Initial viscosity of yogurt samples produced from milk treated at 85°/20 were greater, but yogurt samples produced from milk treated at 90°C/10 min showed a smaller decrease of viscosity during time of shearing. Viscosity of stored samples showed the smaller reduction during time of shearing.

Key words: dry matter, heat treatment, set-style yogurt, skim milk powder.

Introduction

Fermented milks are very popular due to their good sensory characteristics. There are a great number of fermented products due to addition of different supplements such as fruits, cereals, vitamins, and macro elements etc as well as the products with longer shelf life (Maćej et al., 1994, Maćej et al., 1995a, Maćej et al., 1995b, Maćej et al., 1997, Maćej et al., 1998).

Set yogurt is a 3-dimensional network of chains and clusters of casein micelles in which water is entrapped. The gel structure of set-style yogurt is influenced by many factors which include milk composition, primary dry matter

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content (Becker and Puhan, 1989, de Lorenzi et al. 1995, Denin Djurdjević, 2001, Harwalkar and Kalab, 1986), protein content and composition (Denin Djurdjević, 2001, Jelen et al., 1987, Lucey et al., 1999, Mottar et al., 1987, Tamime et al., 1984), heat treatment of milk (Davies et al., 1978, Denin Djurdjević, 2001, Labropoulos et al., 1984, Lucey et al., 1998, Maćej et al., 1998, Mottar et al., 1989, Parnell-Clunies et al., 1988a, Pudja and Obradović, 1993, Savello and Dargan, 1997), addition of stabilizers (Maćej et al., 1995a, Maćej et al., 1995b, Maćej et al., 1998, Modler and Kalab, 1983, Modler et al., 1983), type of starter culture (ropy or non-ropy) used for manufacture (Hassan et al., 1996a, 1996b, Hess et al., 1997, Bouzar, et al., 1997), temperature of fermentation (Güzel-Seydim and Sezgin, 1998) and processing conditions during manufacture (Maćej et al., 1997).

Heat treatment plays a crucial role in yogurt manufacture and quality (Kalab et al., 1983, Kalab et al., 1976, Mottar et al., 1989, Parnell-Clunies et al., 1986). During heat treatments, complex between casein and whey protein is formed, which directly influences hydration of casein micelles (Parnell-Clunies et al., 1988b). It is generally accepted that set-style yogurt produced from unheated milk has weak gel, with worse rheological and sensory characteritics and pronounced syneresis (Guinee et al., 1993, Kalab et al., 1976, Tamime and Deeth, 1980, Tamime and Robinson, 1988). Also, as a result of insufficient heat treatments weak gel is formed (Parnell-Clunies et al., 1986), which easily releases whey (Kalab et al., 1983). According to Mottar et al., 1989, and Lucey et al., 1998, an optimum texture of yogurt was obtained with maximal hydration of protein, namely ß-lactoglobulin and α-lactalbumin associated with casein micelles determine the rheological properties of yogurt.

Besides heat treatment, important effects on overall yogurt quality have dry matter content and composition. Many investigations were performed during the last 20 years to increase dry matter content of milk and thus improve yogurt properties. Increasing of the dry matter in milk for yogurt production increase the firmness and viscosity of yogurt and decrease syneresis. The methods for increasing dry matter are evaporation, ultra-filtration, reverse osmosis, addition of skim milk powder, whey powder, whey protein concentrate etc (Becker and Puhan, 1989, Modler and Kalab, 1983, Modler et al., 1983, Savello and Dargan, 1997). Also, what is more important, all methods increase protein content of milk. It is well known that protein content of milk has the greatest influence on the gel strength, viscosity and syneresis. When casein to whey protein ratio is exchanged, the formed gel is softer and more susceptible to syneresis (Modler and Kalab, 1983, Modler et al., 1983).

The aim of this work was to determine the influence of different dry matter content, different heat treatments and storage period on the viscosity of set-style yogurt produced from reconstituted skim milk powder.

Materials and Methods

Skim milk powder was reconstituted to obtain milk A (with 8.44% TS), milk B (with 9.65% TS) and milk C (with 10.84% TS). Skim milk powder was obtained from the dairy "IMPAZ" Zaječar.

For the experiments untreated milk and milk heat treated at 85°C/20 min and 90°C/10 min, respectively were used. Milk was inoculated with 2.5% of commercial yogurt culture (containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in ratio 1:1) at 43°C. Samples were incubated until pH 4.6 was reached. Samples were immediately cooled to 4°C and held at that temperature during 14 days.

Analyses and measurements

Dry matter content: AOAC method 16.032.

Nitrogen content: FIL/IDF 20B: 1993

Fat content: Gerber butyrometric method (FIL/IDF 105:1981)

Lactose content: FIL/IDF 28A: 1974

pH was determined by pH-meter Sentron 1001

Titratable acidity: (Carić et al., (2000))

Post-acidification: pH and titratable acidity were recorded after 1st, 7th and 14th days of storage

Measurement of viscosity

Measurements of viscosity were done with Brookfield DV-E Viscometer. Spindle No 3 at 20 rpm was used for all samples. To avoid disturbing of gel structure, spindle was inserted at the side of samples cup, and gently moved horizontally to the center of the sample. Since the temperature affects the rheological properties of yogurt, all measurements were done at 20°C.

Before reading, all samples were undergone shearing at shear rate of 100 rpm for 30 s. After initial shearing, spindle speed was adjusted to 20 rpm, and readings were taken at 30 s intervals during 3 min. For each treatment three replicates were used and a new sample was used for each measurement, because shearing disrupts linkages in protein matrix.

Viscosity was monitored during storage at 4°C after 1, 7 and 14 days.

Results and Discussion

Milk quality parameters

The composition of milk used for the production of yogurt, untreated and treated at different temperatures, as well as pH value and value for titratable acidity are given in Table 1.

T a b . 1. - The composition of different milk used for yogurt production

Sample	Heat treatment	Dry matter (%)	Fat (%)	NFDM (%)	Protein (%)	Lactose (%)	pH	°SH
Milk A	Untreated	8.44	0.13	8.31	2.77	4.50	6.50	6.80
	85°C/20min	8.56	0.13	8.43	2.81	4.42	6.44	6.90
	90°C/10min	8.62	0.13	8.49	2.81	4.45	6.44	7.40
Milk B	Untreated	9.65	0.17	9.48	3.17	5.50	6.50	7.80
	85°C/20min	9.70	0.17	9.53	3.17	5.25	6.42	7.80
	90°C/10min	9.81	0.17	9.64	3.18	5.24	6.41	7.80
Milk C	Untreated	10.84	0.21	10.63	3.53	5.98	6.45	8.60
	85°C/20min	11.00	0.21	10.79	3.60	5.89	6.37	8.80
	90°C/10min	10.95	0.21	10.74	3.60	5.81	6.39	8.80

Results given in Table 1. show that with increase of NFDM both protein and lactose content increase. During heat treatment of milk, pH decreased, while titratable acidity increased. Also, lactose content decreases during heat treatment, which is in agreement with data of Andrews, 1987, Jovanović, 2001, Jovanović et al., 1997, Morrissey, 1985, Niketić et al., 2000, and Vukićević et al., 1998. Untreated milk samples B and C had by 13.87% and 25.18% higher protein content, respectively, than untreated milk sample A.

Dynamics of acidity of set-style yogurt during storage

Changes of pH and titratable acidity during storage at 4°C are shown in Table 2.

After storage at 4°C, during 24h, all samples had good appearance, without whey separation. All samples showed drop of pH value during first day of storage. After 7 and 14 days, some whey separation occurred in samples produced from heat treated milk A, while samples produced from milk with C i D, didn't show syneresis during storage period. All samples produced from untreated milk showed syneresis during storage.

T a b . 2. - The changes of pH and titratable acidity of yogurts, during storage at 4°C

		Storage period (days)					
		1	7	14	1	7	14
Sample[1]	Heat treatment		pH			°SH	
Milk A	Untreated	4.36	4.23	4.00	35.11	37.45	40.01
	85°C/20min	4.31	4.13	4.01	35.46	38.10	39.57
	90°C/10min	4.33	4.10	3.99	34.04	37.72	38.89
Milk B	Untreated	4.39	4.08	4.00	34.78	40.96	43.38
	85°C/20min	4.35	4.09	4.03	34.13	37.31	40.62
	90°C/10min	4.42	4.13	4.11	33.56	37.54	40.14
Milk C	Untreated	4.27	3.93	4.06	40.19	46.75	49.87
	85°C/20min	4.36	4.07	4.14	39.29	42.71	44.53
	90°C/10min	4.28	4.00	4.09	41.43	45.92	46.03

[1] - Milk sample used for yogurt production

After initial drop, pH value decreased slowly during storage period of samples produced from milk A and B. However, samples produced from milk C showed decrease of pH during first storage period of 7 days and increase during second storage period, which could be associated with slow proteolitic activity of LAB. On the other hand, titratable acidity of all samples increased during storage. It could be concluded that the greater protein content the greater yogurt buffer capacity.

Changes of viscosity of set-style yogurt during storage

The influence of dry matter content and heat treatment on viscosity of set-style yogurt after 1 day of storage

The influence of dry matter content and heat treatment of milk on the viscosity of yogurt samples after 1 day of storage is shown in Figure 1.

As expected greater total solids and protein content of samples gave greater viscosity. The set-style yogurt samples produced from untreated milk had the greatest viscosity, regardless of dry matter content. After 0.5 min, the viscosity of samples produced from milk treated at 85°C/20 min was higher compared with samples produced from milk treated at 90°C/10 min, which could be associated with the degree of whey protein denaturation and association with casein micelles. Parnell-Clunies et al., 1986, assumed that viscosity is the function of aggregate size. On the other hand, aggregate size is the result of SH/SS interactions which arise from denaturation and unfolding of the globular whey protein. Corredig and Dalgleish, 1999, found that not only time and temperature of heating, but also the amount of whey protein present in skim milk affect the quantity of formed complex; as well as that casein micelle possess only a certain number of site which are available for the interaction with ß-lactoglobulin. Maćej and Jovanović, 1998, investigated the nitrogen matter content of milk sera and concluded that almost the same quantities of coaggregates are formed during heating at 87°C/10min and 90°C/10 min.

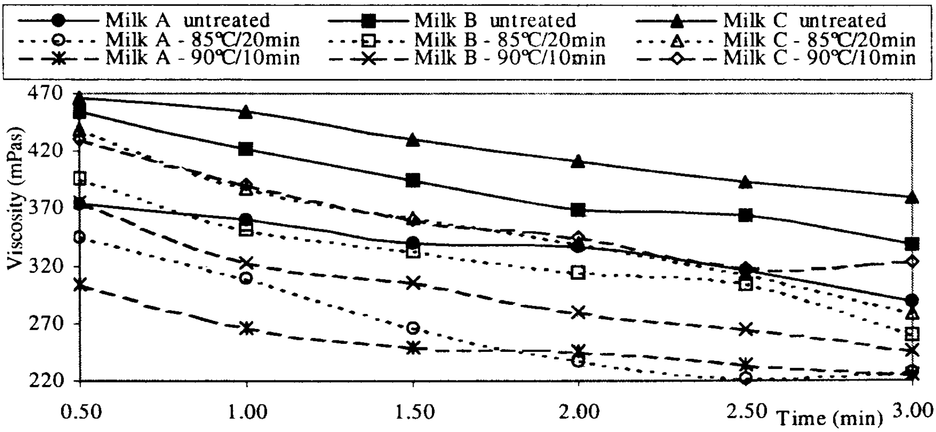

Fig. 1. - The influence of dry matter content on the change of viscosity of set-style yogurts produced from untreated milk (full symbol, full line), milk heat treated at 85°C/20 min (dashed line) and 90°C/10 min (empty symbol - dashed line), after 1 day of storage at 4°C

All samples showed decrease of viscosity during the time of shearing. All samples treated at 85°C/20 min had greater decrease of viscosity with time of shearing, when compared with samples treated at 90°C/10 min. It could be hypothesized that different forces participate in protein matrix or that coaggregates formed at different temperature have different degree of hydration at pH $\leq$ 4.6. The least pronounced reduction of viscosity is noticed for sample produced from milk A treated at 90°C/10 min. Labropoulos et al., 1984, assumed that shearing of gels caused some loss of water by lyophoresis, which resulted in lower viscosity. Becker and Puhan, 1989, found that viscosity of stirred yogurt produced from skim milk increases with increasing of non-fat dry matter. Harwalkar and Kalab, 1986, investigated microstructure of acid casein gels and concluded that the casein chains become shorter and matrix density increases when the total solids increase. These facts could be explained by greater casein content, as well as by larger number of linkages between micelles in formed gel. Also, during heat treatment whey protein associated with casein micelles alters properties of micelles, so they become more hydrated than natural casein micelles (Torado de la Fuente and Alais, 1975). Whey proteins participate in gel structure due to formed coaggregates, and in this way contribute to the flow behavior of gels.

The influence of storage period on the viscosity of set-style yogurt

The rheological properties of set-style yogurt are influenced by storage period, as described elsewhere (Becker and Puhan, 1989, Denin Djurdjević, 2001, Kalab et al., 1976, Maćej et al., 1998, Mikuljanac, 1997).

The influence of the storage period on the viscosity of set-style yogurt is shown in Fig. 2-4. The influence of storage period and dry matter content on the average viscosity is shown in Table 3 and Fig. 5.

Tab. 3. - The influence of storage period, heat treatment and dry matter content on average viscosity

Sample[1]	Heat treatment	Storage period (days) 1	7	14
		Average viscosity (mPas)		
Milk A	85°C/20 min	267.72	261.44	254.28
	90°C/10 min	253.91	259.77	253.68
Milk B	85°C/20 min	326.28	329.04	328.98
	90°C/10 min	299.11	299.11	277.02
Milk C	85°C/20 min	353.29	364.92	367.47
	90°C/10 min	361.02	350.07	360.76

[1] - Milk sample used for yogurt production

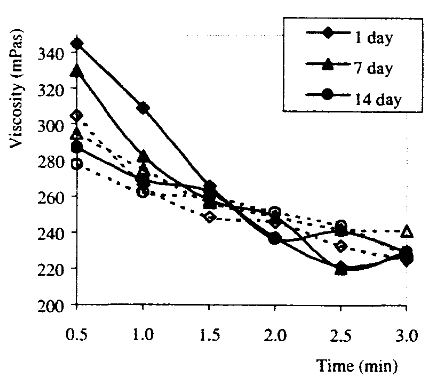

Fig. 2. - The influence of storage period on the change of viscosity of yogurts, produced from milk A, heat treated at 85°C/20 min (full symbol, full line) and 90°C/10 min (empty symbol, dashed line)

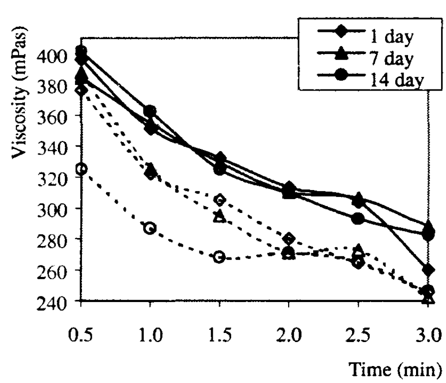

Fig. 3. - The influence of storage period on the change of viscosity of yogurts, produced from milk B, heat treated at 85°C/20 min (full symbol, full line) and 90°C/10 min (empty symbol, dashed line)

During storage at 4°C the initial viscosity of sample produced from milk A, heat treated at 85°C/20min, showed slight decrease as Fig. 2. shows. Since the decrease of viscosity during time of shearing is less pronounced in the case of samples stored at 4°C during 7 and 14 days, it could be concluded that there occurred structural changes on the protein network during storage. Also, average viscosity of those samples dropped from 267.72 mPas after 1st day to 254.28 mPas after 14th day of storage. On the other hand, the sample produced from milk A, heat treated at 90°C/10 min, didn't show the same trends. The less pronounced decrease of the viscosity during shearing is noticed for the sample stored 7 days, so these samples show the greatest value of average viscosity (259.77 mPas). The average viscosity of samples stored 1 and 14 days were 253.91 mPas and 253.68 mPas, respectively.

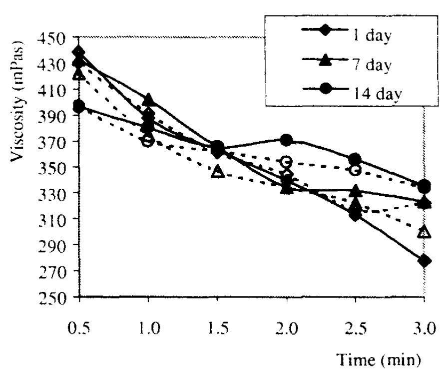

Fig. 4. - The influence of storage period on the change of viscosity of yogurts, produced from milk C, heat treated at 85°C/20 min (full symbol, full line) and 90°C/10 min (empty symbol, dashed line)

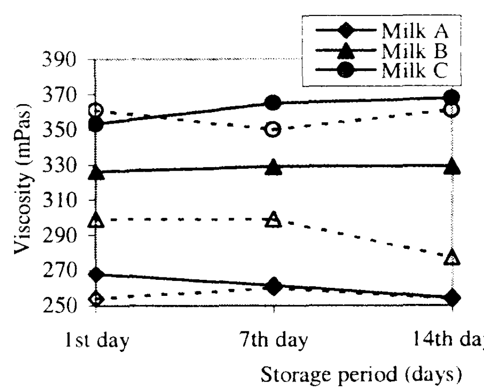

Fig. 5. - The influence of dry matter content and storage period on the change of average viscosity of yogurts, produced from milk sample heat treated at 85°C/20 min (full symbol, full line) and 90°C/10 min (empty symbol, dashed line)

Samples produced from milk B, heat treated at 85°C/20min, had similar average viscosity after 7 and 14 day of storage. The influence of the storage on the change of viscosity is shown in Fig. 3. The reduction of viscosity is less pronounced than reduction of viscosity after 1 day of storage. Samples produced from milk B, heat treated at 90°C/10min (Fig. 5.), stored 7 days, show the greatest reduction of viscosity, while samples stored 14 days, show the least pronounced decrease. The average viscosity of samples stored 1 and 7 days is the same (299.11 mPas), while samples stored 14 days have the smallest average viscosity (277.02 mPas).

Samples produced from milk C, heat treated at 85°C/20min, after 14 days of storage at 4°C, show a deviation in thixotropic behavior (Fig. 4.), which indicates that protein matrix of these samples possesses a large number of bonds that resist to flow. The least decrease of viscosity during shearing was noticed after 14 days of storage regardless of used heat treatment.

These lower reductions of viscosity indicate that drop of pH value (table 2.) influences shrinkage and rearrangements of protein network in all samples regardless of dry matter content and used heat treatment. Harwalkar and Kalab, 1986, assumed that pH value of yogurts influence firmness and susceptibility to syneresis as well as pore size. They also hypothesized that the formation of larger pores is caused by higher net positive charge of casein micelles at lower pH value, which in turn influence the swelling and higher hydration of casein micelles.

It could be concluded that the samples produced from milk C had the greatest, while samples produced from milk A had the smallest values of average viscosity during storage period, as table 3 and Fig. 5. show.

Conclusion

According to all aforementioned, it could be concluded that dry matter and protein content influence the rheological behavior of yogurt. Increasing of dry matter content increase viscosity of yogurt produced from reconstituted skim milk powder treated at both heat treatments, namely 85°C/20 min and 90°C/10 min. All yogurt samples produced from milk A and B, heat treated at 85°C/20 min, showed the greater initial viscosity compared with samples produced from milk heat treated at 90°C/10 min. On the other hand, yogurt samples treated at 90°C/10 min showed a smaller reduction of viscosity during shearing. This indicates that used heat treatments have different influence on the formation and physical properties of coaggregates and that different forces participate in the formation of casein gels as well as on viscosity behavior of yogurt measured at 20 rpm.

The smaller reduction of viscosity during shearing is noticed during 14-day storage at 4°C. That indicates that drop of pH value influences the structural rearrangement of protein network and hydration of casein micelles.

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UTICAJ SUVE MATERIJE I TERMIČKOG TRETMANA NA VISKOZITET ČVRSTOG JOGURTA PROIZVEDENOG OD REKONSTITUISANOG OBRANOG MLEKA U PRAHU

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Rezime

Obrano mleko u prahu je rekonstituisano sa destilovanom vodom da bi se dobilo mleko A (sa 8.44% SM), B (sa 9.65% SM) i C (sa 10.84% SM). Ogledi su

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vršeni sa termički netretiranim mlekom i mlekom termički tretiranom na 85°C/20 min i 90°C/10 min, respektivno.

Viskozitet je odredjivan pomoću viskozimetra Brookfield DV-E, na temperaturi od 20°C, nakon 1., 7. i 14. dana skladištenja. Vrednost viskoziteta je nakon 1. dana skladištenja bila najveća kod uzoraka proizvedenih od termički netretiranih mleka. Početna vrednost viskoziteta uzoraka čvrstog jogurta proizvedenih od mleka termički tretiranih na 85°C/20 min, bila je nešto veća, u odnosu na uzorke proizvedene od mleka termički tretiranih na 90°C/10 min. S druge strane uzorci čvrstog jogurta proizvedeni od mleka termički tretiranog na 90°C/10 min, imali su manje izraženo smanjenje viskoziteta tokom vremena delovanja sile smicanja.

Kod uzoraka koji su skladišteni 14 dana, smanjenje viskoziteta je bilo najmanje izraženo.

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