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THE INFLUENCE OF INVESTIGATED FACTORS ON VISCOSITY OF STIRRED YOGURT

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Abstract: Skim milk was reconstituted to obtain milk with 8.44% DM, which was standardized with demineralized whey powder (DWP) to obtain milk sample A (9.71% DM) and milk sample B (10.75% DM). Milk samples were heat treated at 85ºC/20 min and 90ºC/10 min, respectively. Untreated milk was used as control. Milk samples were inoculated with 2.5% of commercial yogurt culture (containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in the ratio 1:1) at 43ºC. Samples were incubated until pH 4.6 was reached. Samples were immediately cooled to 4ºC and held at that temperature until analyses. Samples of acid casein gels were stirred after 1, 7 and 14 days of storage. Measurements of viscosity were done with Brookfield DV-E Viscometer. Spindle No 3 at 30 rpm was used for all samples.

Duration of fermentation decreased when DWP was used for standardization of milk dry matter content.

Yogurt samples produced from milk heat treated at 85ºC/20 min, obtained by stirring of gel 1 day after production had a higher viscosity than sample produced from milk heat treated at 90ºC/10 min. On the other hand, samples produced from milk heat treated at 90ºC/10 min had a greater viscosity after 7 and 14 days of storage, which indicates a greater hydrophilic properties and a more pronounced swelling of casein micelles.

Key words: demineralized whey powder, heat treatment, viscosity, stirred yogurt.

Introduction

The problem of dry matter standardization is present for long time in production of fermented milks. The most common ways of standardization are addition of milk powder, skim-milk powder and evaporated milk, as well as ultrafiltration of milk (Becker and Puhan, 1989, Denin-Djurdjević, 2001,

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Jelen et al., 1987, Maćej et al. 1997, Savello and Dargan, 1997, Tamime and Deeth, 1980, Tamime and Robinson, 1988). Also, an addition of stabilizers is used to obtain as good as possible rheological properties (caseinates, gelatin, carragenan etc.) (Maćej et al. 1994, 1995).

Over the last twenty years, an increase of healthy food consumptions has been observed, which practically initiates the application of whey proteins due to their high nutritive value (de Wit, 1998, Denin-Djurdjević, 2001, Djordjević, 1987, Hambraeus, 1986).

As elsewhere discussed, addition of whey proteins in milk changes technological properties of milk and has a great effect on the rheological properties of products. There are numerous articles that discuss the influence of whey protein addition on viscosity (Denin-Djurdjević et al., 2002, Lucey et al., 1998, Lucey et al., 1999), firmness (Jelen et al., 1987, Modler et al., 1983) and microstructure (Modler and Kalab, 1983, Modler et al., 1983, Tamime et al., 1984) of set-style yogurt. Also, the influence of whey proteins (Božanić et al., 2000) and whey powder addition (Abd El-Salam et al., 1991), Denin-Djurdjević, 2001, Todorić and Savadinović, 1973) on rheological properties of stirred yogurt is often investigated. However, according to general opinion, the addition of more than 2% of whey proteins induces undesirable sensory properties of yogurt (Denin-Djurdjević, 2001, Jelen et al., 1987, Modler et al., 1983, Tamime and Deeth, 1980, Tamime and Robinson, 1988).

The next crucial factor that influences viscosity of stirred yogurt is the application of heat treatment (Davies et al., 1978, Kalab et al., 1976, Labropoulos et al., 1984, Parnell-Clunies, et al., 1986, 1988a,b). The complex between casein and whey proteins is formed during heating of milk. According to Corredig and Dalgleish, 1999, the amount of ß-lactoglobulin is a significant factor that influences complex formation. However, the amount of α-lactalbumin associated with casein micelle influences hydrophilic properties of casein micelles at pH 4.60 (Mottar et al., 1989).

The aim of this work was to determine the influence of different amounts of added demineralized whey powder, applied heat treatments and storage period before stirring on the viscosity of stirred yogurt.

Materials and Methods

Skim milk powder was reconstituted to obtain milk with 8.44% DM, which was standardized with different amounts of demineralized whey powder (DWP) to obtain milk A (with 9.71% DM) and milk B (with 10.75% DM), respectively. Skim milk powder and DWP were obtained from the dairy "IMPAZ" Zaječar.

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

Samples of acid casein gels were stirred during 30 sec after 1, 7 and 14 days of storage. Samples gained by stirring of acid casein gels after 1 day of storage are named as samples of stirred yogurt after 1 day of storage. Samples gained by stirring of acid casein gels after 7 days of storage are named as samples of stirred yogurt after 7 days of storage. Samples gained by stirring of acid casein gels after 14 days of storage are named as samples of stirred yogurt after 14 days of storage.

Analyses and measurements

Dry matter content: AOAC method 16.032.
Nitrogen content: FIL/IDF 20B: 1993
Milk fat content: Gerber butyrometric method (FIL/IDF 105:1981)
pH was determined by pH-meter Sentron 1001

Measurements of viscosity

Measurements of viscosity were done with Brookfield DV-E Viscometer. Spindle No 3 at 30 rpm was used for all samples, as formerly described by Denin-Djurdjević et al., 2002a.

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

Results and Discussion

Quality parameters of milk and yogurt

Chemical composition of milk A and B as well as yogurt samples are shown in Table 1. Chemical composition of milk and yogurt with 8.44% DM was shown in the results of Denin-Djurdjević et al., 2002a.

Tab. 1. - Quality parameters of milk and yogurt

Sample			Investigated parameters			
			DM %	MF %	NFDM %	Nitrogen %
Milk A	Untreated	Milk □ (n=5)	9.71	0.17	9.54	0.4605
		Yogurt □ (n=5)	9.57	0.17	9.40	0.4377
	85ºC/20’	Milk □ (n=5)	9.85	0.17	9.68	0.4682
		Yogurt □ (n=5)	9.81	0.17	9.64	0.4410
	90ºC/10’	Milk □ (n=5)	9.88	0.17	9.71	0.4560
		Yogurt □ (n=5)	9.79	0.17	9.62	0.4533
Milk B	Untreated	Milk □ (n=5)	10.75	0.17	10.58	0.4816
		Yogurt □ (n=5)	10.58	0.17	10.41	0.4647
	85ºC/20’	Milk □ (n=5)	10.96	0.17	10.79	0.4788
		Yogurt □ (n=5)	10.68	0.17	10.51	0.4547
	90ºC/10’	Milk □ (n=5)	10.89	0.17	10.72	0.4792
		Yogurt □ (n=5)	10.70	0.17	10.53	0.4677

As can be seen from the results shown in Table 1., nitrogen content of yogurt samples is lower than in milk, which indicates that applied LAB carries out proteolysis (Denin-Djurdjević et al., 2002a., Shah and Shihata, 1998).

The influence of added demineralized whey powder on the fermentation process

The fermentation process of milk A and B as well as of milk with 8.44% DM is shown in Fig. 1., 2. and 3.

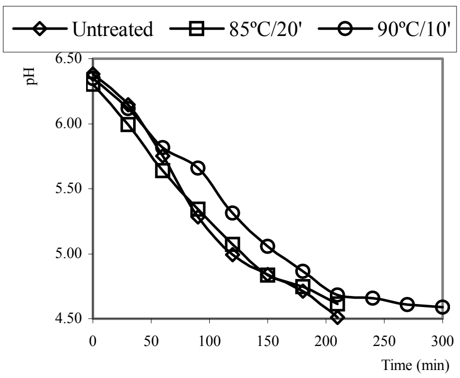

Fig. 1. - Exchange of pH value during fermentation of milk with 8.44% TS as influenced by applied heat treatment

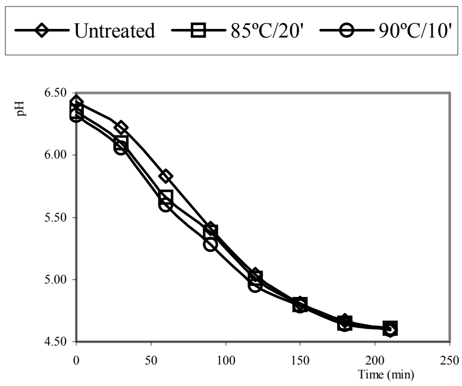

Fig. 2. - Exchange of pH value during fermentation of milk A as influenced by applied heat treatment

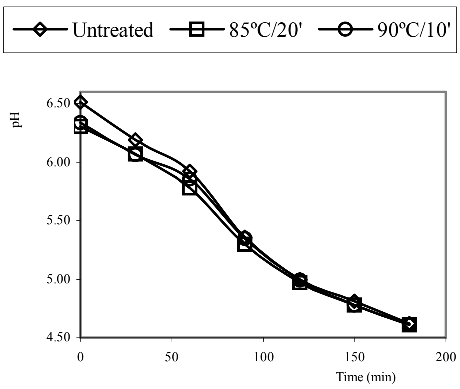

Fig. 3. - Exchange of pH value during fermentation of milk B as influenced by applied heat treatment

Fig. 1. shows that average duration of fermentation of milk with 8.44% DM, untreated and heat treated at 85ºC/20 min was 210 min, while duration of

fermentation of milk heat treated at 90ºC/10 min was the longest (300 min). Duration of fermentation of milk A, untreated and heat treated was 210 min, while milk B had the shortest duration of fermentation (180 min). The shortest duration of fermentation of milk B can be attributed to the highest amount of lactose, which increases the amount of material for fermentation. Gained results agree with those Denin-Djurdjević, 2001, and Todorić and Savadinović, 1973, who added different amounts of whey powder in milk and concluded that increase of whey powder concentration leads to increase of fermentation rate.

Changes of viscosity of stirred yogurt at steady spindle rotation

The influence of applied heat treatment and storage period before stirring on viscosity change of stirred yogurt produced from milk A is shown in Table 2. and Fig. 4.

Tab. 2. - The influence of applied heat treatment and storage period of acid casein gel before stirring on viscosity change of stirred yogurt produced from milk A

Applied heat treatment	Storage period (days)	Calculated parameters	Time (min)			
			0.5	1.0	1.5	2.0
			Viscosity (mPas)			
Untreated milk	1 day	□ (n=3)	28.33	23.87	21.03	19.60
		Sd	1.4012	1.5631	1.1060	0.9165
		Cv	4.95	6.55	5.26	4.68
85ºC/20’	1 day	□ (n=3)	49.37	45.10	43.27	41.47
		Sd	2.1572	1.7521	1.7098	1.7898
		Cv	4.37	3.89	3.95	4.32
	7 days	□ (n=3)	50.23	45.53	42.20	40.20
		Sd	7.5235	5.8046	4.5924	3.6497
		Cv	14.98	12.75	10.88	9.08
	14 days	□ (n=3)	44.03	40.93	38.77	36.90
		Sd	1.3650	0.5774	0.3512	0.5196
		Cv	3.10	1.41	0.91	1.41
90ºC/10’	1 day	□ (n=3)	50.93	44.80	40.77	37.40
		Sd	1.7243	2.4269	2.6652	2.3065
		Cv	3.39	5.42	6.54	6.17
	7 days	□ (n=3)	56.47	50.53	46.17	43.00
		Sd	1.8877	0.6807	0.2309	0.3464
		Cv	3.34	1.35	0.50	0.81
	14 days	□ (n=3)	61.50	54.27	48.93	45.83
		Sd	2.5239	2.9872	3.1501	2.9484
		Cv	4.10	5.50	6.44	6.43

Table 2. and Fig. 4. show that stirred yogurt produced from untreated milk A had the smallest viscosity values (28.33 mPas at the beginning and 19.60 mPas at

the end) after 1 day of storage. Decrease of viscosity during time of shearing was 8.73 mPas.

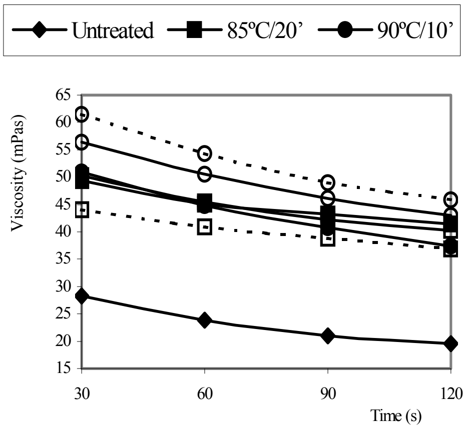

Fig 4. - The influence of applied heat treatment and storage period before stirring (gels were stored 1 day (full symbol, full line); 7 days (empty symbol, full line) and 14 days (empty symbol, dashed line)) on viscosity of stirred yogurt produced from milk A

Stirred yogurt produced from milk A heat treated at 85ºC/20 min had after 30 sec smaller viscosity than yogurt produced from milk heat treated at 90ºC/10 min. However, yogurt produced from milk A heat treated at 85ºC/20 min had higher viscosity during the rest of shearing. Decrease of viscosity during time of shearing was 7.90 mPas and 13.53 mPas, respectively, for samples produced from milk heat treated at 85ºC/20 min and 90ºC/10 min.

As can be seen from Table 2. and Fig. 4. stirred yogurt produced from milk heat treated at 85ºC/20 min had higher viscosity after 7 than after 14 days of storage. Decrease of viscosity during time of shearing was 10.03 mPas and was by 2.13 mPas greater than after 1 day. Viscosity value of stirred yogurt after 14 days of storage was 44.03 mPas after 30 sec and 36.90 mPas after 120 sec. Decrease of viscosity during time of shearing was 7.13 mPas.

Table 2. and Fig. 4. show that viscosity values of stirred yogurt produced from milk heat treated at 90ºC/10 min were between 56.47 mPas (after 30 sec) and 43.00 mPas (after 120 sec). Decrease of viscosity during time of shearing was 13.47 mPas and was approximately such as decrease of viscosity after 1 day of storage.

After 14 days of storage, yogurt samples produced from milk A heat treated at 90ºC/10 min had a highest viscosity values, which ranged from 61.50 mPas, after 30 sec, to 45.83 mPas, after 120 sec. Decrease of viscosity during time of shearing was 15.67 mPas, which was the greatest decrease in this group.

The influence of applied heat treatment and storage period before stirring on viscosity change of stirred yogurt produced from milk B is shown in Table 3. and Fig. 5.

T a b . 3. - The influence of applied heat treatment and storage period of acid casein gel before stirring on viscosity change of stirred yogurt produced from milk B

Applied heat treatment	Storage period (days)	Calculated parameters	Time (min) 0.5	1.0	1.5	2.0
			Viscosity (mPas)			
Untreated milk	1 day	$\bar{x}$ (n=3)	30.53	26.77	24.27	22.40
		Sd	0.6807	0.9609	1.2583	1.7521
		Cv	2.23	3.59	5.19	7.82
85ºC/20’	1 day	$\bar{x}$ (n=3)	50.53	47.50	45.53	43.87
		Sd	3.6005	4.2579	4.3547	4.0550
		Cv	7.12	8.96	9.56	9.24
	7 days	$\bar{x}$ (n=3)	51.47	46.97	44.17	42.20
		Sd	1.1060	1.1015	0.8021	0.9000
		Cv	2.15	2.35	1.82	2.13
	14 days	$\bar{x}$ (n=3)	47.50	44.17	41.77	40.00
		Sd	0.9000	0.6807	1.0214	0.3000
		Cv	1.89	1.54	2.45	0.75
90ºC/10’	1 day	$\bar{x}$ (n=3)	49.17	44.07	40.63	38.07
		Sd	6.1647	4.5347	3.8371	3.0600
		Cv	12.54	10.29	9.44	8.04
	7 days	$\bar{x}$ (n=3)	55.30	50.30	47.50	45.40
		Sd	4.6119	4.6119	4.3405	4.4193
		Cv	8.34	9.17	9.14	9.73
	14 days	$\bar{x}$ (n=3)	57.83	52.30	49.30	46.60
		Sd	5.8072	5.3028	4.8508	4.5574
		Cv	10.04	10.14	9.84	9.78

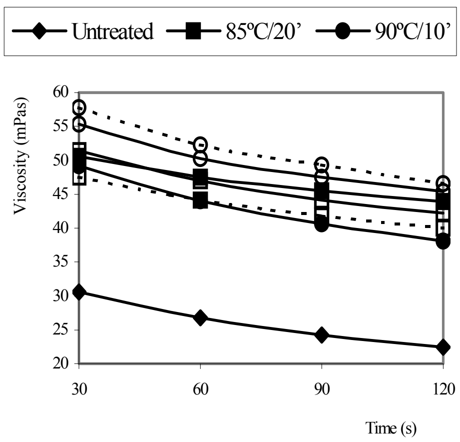

Fig 5. - The influence of applied heat treatment and storage period before stirring (gels were stored 1 day (full symbol, full line); 7 days (empty symbol, full line) and 14 days (empty symbol, dashed line) on viscosity of stirred yogurt produced from milk B

As results show, stirred yogurt produced from untreated milk B had the smallest viscosity, ranging from 30.53 mPas after 30 sec, to 22.40 mPas after 120 sec. Viscosity decreased by 8.13 mPas during shearing.

Yogurt samples produced from heat treated milk had a higher viscosity after 1 day of storage. Viscosity ranged from 50.53 mPas and 49.17 mPas after 30 sec to 43.87 mPas and 38.07 mPas, after 120 sec, for yogurt samples produced from milk heat treated at 85ºC/20 min and 90ºC/10 min, respectively.

Table 3. and Fig. 5. show that after 7 days stirred yogurt produced from milk B heat treated at 85ºC/20 min, had the highest viscosity (51.47 mPas after 30 sec), which was by 0.94 mPas greater than of that after 1day. However, viscosity decreased by 9.27 mPas during shearing, which resulted in smaller viscosity after 120 sec by 1.67 mPas than after 1 day. Stirred yogurt produced from milk B heat treated at 85ºC/10 min had the smallest viscosity after 14 days of storage. Decrease of viscosity during shearing was 7.50 mPas.

As Table 3. and Fig. 5. show, viscosity of yogurt samples produced from milk B heat treated at 90ºC/10 min was influenced by storage period of gel before stirring. Also, these samples had higher viscosity after 7 and 14 days than samples produced from milk heat treated at 85ºC/20 min.

Samples of stirred yogurt produced from milk B heat treated at 90ºC/10 min had the highest viscosity after 14 days of storage and the smallest after 1 day of storage. After 7 days, viscosity values of stirred yogurt ranged from 55.30 mPas after 30 sec. to 45.40 mPas after 120 sec. Viscosity decreased by 9.90 mPas during shearing. After 14 days of storage, viscosity values of stirred yogurt ranged from 57.83 mPas after 30 sec. to 46.60 mPas after 120 sec. Viscosity decreased by 11.23 mPas during shearing.

Gained results agree with the results of Božanić et al., 2000, Denin-Djurdjević et al., 2001, Denin-Djurdjević et al., 2002, Labropoulos et al., 1984, and indicate that stirred yogurt shows thixotropic behaviour.

According to the gained results, it could be concluded that hydrophilic properties of acid casein gel produced from milk heat treated at 90ºC increase during storage, which has positive influence on the viscosity of stirred yogurt. However, in view of the fact that manufacturers stir yogurt immediately after fermentation and cooling, a better solution is heat treatment at 85ºC/20 min.

The influence of added demineralized whey powder on the viscosity of stirred yogurt

The influences of added demineralized whey powder and applied heat treatment on viscosity changes of stirred yogurt, after 1 day of storage, compared with viscosity of stirred yogurt produced from milk with 8.44% DM, are shown in Figs. 6., 7. and 8.

Fig. 6. shows that yogurt samples produced from untreated milk standardized with DWP had less pronounced decrease of viscosity during shearing. Also, these

samples had higher viscosity values. Contrary to set-style yogurt, where addition of DWP leads to decrease of viscosity (Denin-Djurdjević et al., 2002), addition of DWP in milk for the production of stirred yogurt leads to increase of viscosity, which agrees with the results of Denin-Djurdjević, 2001, and Todorić and Savadinović, 1973.

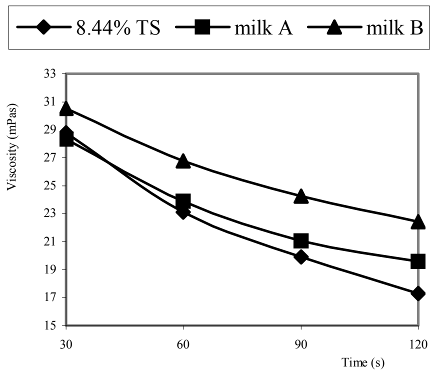

Fig. 6. - The influence of added demineralized whey powder on viscosity of stirred yogurt produced from untreated milk

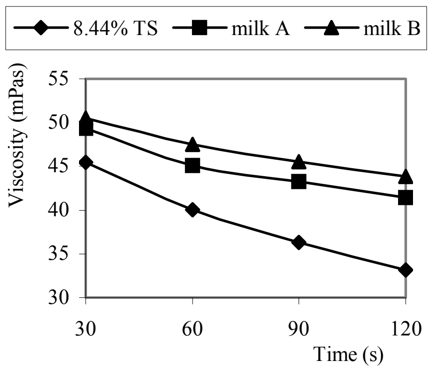

Fig. 7. - The influence of added demineralized whey powder on viscosity of stirred yogurt produced from milk heat treated at 85ºC/20'

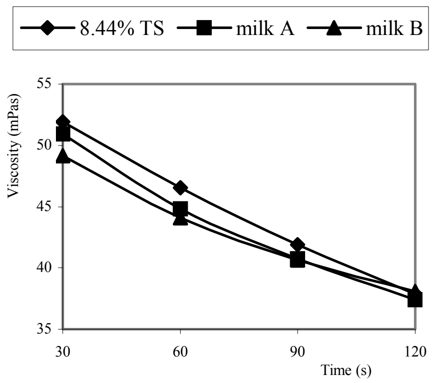

Fig. 8. - The influence of added demineralized whey powder on viscosity of stirred yogurt produced from milk heat treated at 90ºC/10'

Fig. 7. shows that samples of stirred yogurt produced from milk A and B heat treated at 85ºC/10 min had remarkably higher viscosity than samples with 8.44% DM. On the other hand, when heat treatment at 90ºC/10 min was used, viscosity

values of stirred yogurt samples A and B were similar to those of yogurt with 8.44% DM as Fig. 8. shows.

Gained results indicate that aport from the amount of added DWP, applied heat treatment has a great influence on rheological properties of stirred yogurt after 1 day of storage. Contrary to set-style yogurt samples produced from milk standardized with DWP (Denin-Djurdjević et al., 2002), which had a greater viscosity if heat treatment at 90ºC/10 min had been used, stirred yogurt samples had a higher viscosity if heat treatment at 85ºC/10 min had been used. Our results indicate that DWP could be used for milk standardization, but selection of heat treatment depends on the type of yogurt, namely, is the milk designed for production of stirred or set-style yogurt.

Conclusion

According to all aforementioned, it could be concluded:

Standardization of milk dry matter content with DWP leads to shorter duration of fermentation with lactic acid bacteria, which effects costs of production. Milk samples standardized with 2% DWP had shorter fermentation than milk samples standardized with 1% DWP did.

Samples of stirred yogurt produced from milk heat treated at 85ºC/20 min obtained by stirring of acid casein gel stored 1 day had a greater viscosity than samples produced from milk heat-treated at 90ºC/10 min, regardless to the amount of added DWP.

Samples produced from milk heat treated at 90ºC/10 min had a greater viscosity after 7 and 14 days of storage, which indicates greater hydrophilic properties as well as a more pronounced swelling of casein micelles during storage.

Samples of stirred yogurt produced from milk heat treated at 85ºC/20 min had a greater viscosity than samples produced from milk without added DWP. It can be concluded that DWP could be used for milk dry matter standardization.

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UTICAJ ODABRANIH FAKTORA NA PROMENU VISKOZITETA TEČNOG JOGURTA

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R e z i m e

Obrano mleko u prahu je rekonstituisano tako da se dobije mleko sa 8.44% SM, koje je zatim standardizovano dodatkom različite količine demineralizovane surutke u prahu (DSUP), pri čemu su dobijeni uzorci mleko A (sa 9.71% SM) i mleko B (sa 10.75% SM). Svi uzorci mleka su termički tretirani na 85ºC/20 min i 90ºC/10min, respektivno, a kao kontrolni uzorak je korišćeno termički netretirano mleko. Nakon termičkog tretmana, mleko je ohlađeno do 43ºC i inokulisano sa 2.5% komercijalne jogurt kulture (*Lb. delbrueckii* subsp. *bulgaricus* i *Str. thermophilus* u odnosu 1:1). Uzorci su inkubirani na 43ºC do postizanja pH 4.6. Uzorci su zatim brzo ohlađeni na 4ºC i držani na toj temperaturi do analize. Uzorci kiselog kazeinskog gela su razbijani pomoću električne mešalice u toku 30 sekundi nakon 1, 7 i 14 dana skladištenja. Merenje viskoziteta je vršeno pomoću viskozimetra Brookfield DV-E. Upotrebljen je spindl No 3, pri 30 obrt/min.

Fermentacija traje kraće kada se za standardizaciju suve materije mleka koristi DSUP. Uzorci tečnog jogurta proizvedeni od mleka termički tretiranog na 85ºC/10 min, dobijeni razbijanjem gela 1 dan nakon proizvodnje imaju veće vrednosti viskoziteta od uzoraka proizvedenih od mleka termički tretiranog na 90ºC/10 min. Nakon 7 i 14 dana skladištenja, veće vrednosti viskoziteta su imali uzorci tečnog jogurta proizvedeni od mleka termički tretiranog na 90ºC/10', što ukazuje na jaču hidrofilnost i više izraženo bubrenje kazeinskih čestica tokom skladištenja.

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