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VISCOSITY OF SET-STYLE YOGURT AS INFLUENCED BY HEAT TREATMENT OF MILK AND ADDED DEMINERALIZED WHEY POWDER

Jelena Denin Djurdjević, O. Maćej and Snežana Jovanović*

Abstract: Skim milk powder was reconstituted to obtain milk A (with 8.44% TS). Milk sample A was standardized with different amounts of demineralized whey powder (DWP) to obtain milk B (with 9.71% TS) and milk C (with 10.75% TS). 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. Measurements of viscosity were done with Brookfield DV-E Viscometer. Spindle No 3 at 20 rpm was used for all samples.

After 1 day of storage, set-style yogurt samples produced from untreated milk had the highest, while samples produced from milk heat treated at 90ºC/10 min the smallest initial viscosity, regadless of the dry matter content and composition. Average viscosity of set-style yogurts decreased with intensifying temperature of applied heat-treatment.

During storage, set-style yogurt samples produced from milk heat treated at 90ºC/10 min had the least pronounced decrease of viscosity during shearing.

After 14 days of storage, set-style yogurt samples produced from milk standardized with demineralized whey powder had higher viscosity than samples produced from basis milk.

Key words: demineralized whey powder, skim milk powder, heat treatment, viscosity, set-style yogurt.

* Jelena Denin Djurdjević, M.Sc., Research Associate, Dr Ognjen Maćej, Professor, Dr Snežana Jovanović, Assistant, Department of Food Technology and Biochemistry, Faculty of Agriculture, 11081 Belgrade-Zemun, Nemanjina 6, FR Yugoslavia

Introduction

The nutritive value of proteins is related to their amino-acid composition as well as to the availability of these amino-acids. Whey proteins represent non-casein proteins of milk. The nutritive value of major milk whey protein, namely ß-lactoglobulin and α-lactalbumin, is higher than egg's protein (Djordjević, 1987, Hambraeus, 1986). Whey protein products act as replacements for egg proteins in confectionary and bakery products, and as functional ingredients in milk industry. It is postulated that about 120 million tones of liquid whey is produced during cheese production (de Wit, 1998). Whey powder has 65-70% lactose, 11-15% proteins and 8-10% ash. To realize its potential as functional ingredient, whey has to be desalted and demineralized (Kinsella, 1984, Meriläinen and Dellaglio, 1990).

Addition of whey proteins and therefore modification of casein:whey protein ratio (CWR) predominantly influences heat stability of milk. Milk that was modified with acid whey proteins concentrate (WPC) to CWR of 20:80 or 40:60 coagulate during heat treatment at 93ºC and for that reason it cannot be used for yogurt production (Jelen et al., 1987). However, from the sensory standpoint, whey protein addition is permitted up to 1-2%, because a greater level of whey proteins induces unfavorable taste (Modler et al., 1983, Tamime and Deeth, 1980).

Modification of WCR influences firmness of acid casein gel only if WPC was used, but if sweet WPC was used there is not marked decrease of firmness. There is linear relationship between whey protein contents and reduction of viscosity (Buchheim et al., 1986, Tamime and Robinson, 1988). Nevertheless, sensory properties of yogurts produced from milk with modified CWR were changed, because an increase of whey proteins contents in milk leads to less smooth, clumpy appearance of yogurt and mouthfeel which is typical for heated whey proteins aggregates (Jelen et al., 1987).

WPC obtained by electrodialysis markedly reduced gel firmness, while WPC obtained by ultrafiltration did not alter gel firmness and could be compared with yogurt produced from milk fortified with skim milk powder (Kalab et al., 1983). Undenatured whey proteins have higher hydrofobicity than casein, which indicates that addition of undenatured whey proteins increases proteins hydrofobicity in the fermented milks. However, during heating, whey proteins denature and interact with casein to form coaggregates, which, on the other hand, improves properties of gel particles and leads to the formation of smoother product (Mottar et al., 1987).

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

Materials and Methods

Skim milk powder was reconstituted to obtain milk A (with 8.44% TS). Milk sample A was standardized with different amounts of demineralized whey powder (DWP) to obtain milk B (with 9.71% TS) and milk C (with 10.75% TS), 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.

Analyses and measurements

Dry matter content: AOAC method 16.032.
Nitrogen content: FIL/IDF 20B: 1993
Lactose content: FIL/IDF 28A: 1974
pH was determined by pH-meter Sentron 1001
Post-acidification: pH was recorded after 1st, 7th and 14th days of storage

Measurements of viscosity

Measurements of viscosity were done with Brookfield DV-E Viscometer. Spindle No 3 at 20 rpm was used for all samples, as formerly described by Denin Djurdjević et al., 2001.

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

Results and Discussion

Yogurt quality parameters

The composition of set-style yogurt samples A, B and C is shown in Table 1.

Nitrogen content of yogurt is lower than in milk (results are not given), which shows that applied LAB not only ferments lactose but also does proteolysis followed by deamination, as indicated by the results of Shah and Shihata, 1998. As could be seen from Table 1., protein content in dry matter (P in DM) was lower, while lactose content in dry matter (L in DM) was higher in yogurts B and C than in samples A.

Lactose content in yogurt samples produced from heat-treated milk was lower than in samples produced from untreated milk, which agrees with the results of Lee et al., 1988. These results are expected due to decrease of lactose content during heating, as indicated in works of Jovanović, 2001, Jovanović et al., 1997, Niketić et al., 2000, Denin Djurdjević, 2001, and Denin Djurdjević et al., 2001.

Tab. 1. - Yogurt quality parameters

Sample	HT	Investigated parameters						
		DM %	NFDM %	N %	P %	P in DM (%)	L %	L in DM %
A	untreated	8.60	8.47	0.4151	2.65	30.79	4.18	48.60
	85ºC/20’	8.75	8.62	0.4292	2.74	31.29	4.15	47.43
	90ºC/10’	8.68	8.55	0.4227	2.70	31.07	4.12	47.47
B	untreated	9.57	9.40	0.4377	2.79	29.18	5.33	55.69
	85ºC/20’	9.81	9.64	0.4410	2.81	28.68	5.21	53.11
	90ºC/10’	9.79	9.62	0.4533	2.89	29.54	5.26	53.73
C	untreated	10.58	10.41	0.4647	2.96	28.02	5.92	55.95
	85ºC/20’	10.68	10.51	0.4547	2.90	27.16	5.75	53.84
	90ºC/10’	10.70	10.53	0.4677	2.98	27.89	5.87	54.86

HT – applied heat treatment of milk; DM – dry matter; NFDM – non-fat dry matter
N – nitrogen matter; P – proteins; L – lactose

Duration of fermentation of milk A, untreated and heat treated at 85ºC/20 min was 210 min. Duration of fermentation of milk A heat treated at 90ºC/10 min was the longest due to slower pH decrease between 210 and 300 min.

Average duration of fermentation of milk samples B and C was 210 and 180 min, respectively, regardless of the applied heat treatment. The shortest duration of fermentation of milk C could be attributed to the amount of lactose that was the highest in this sample. Gained results agree well with those of Todorić and Savadinović, 1973, who investigated the influence of different amounts of whey powder added in milk on duration of fermentation, and concluded that increase of whey powder decreased duration of fermentation as well as that greater values of titratable acidity were achieved.

Changes of viscosity of set-style yogurt during storage

The influence of added demineralized whey powder and applied heat treatment on viscosity of set-style yogurt after 1 day of storage

The influence of added demineralized whey powder and applied heat treatments on the change of viscosity during time of shearing is shown in Fig. 1.

During heat treatments, complex between casein and whey protein is formed, but the degree of complex formation depends on the temperature and time of heat treatment, as well as on the amount of whey proteins present in milk (Corredig and Dalgleish, 1999). On the other hand, applied heat treatment determines the amount of α-lactalbumin that associates with casein micelle and thus influences hydrophilic properties and hydration of casein micelle at pH 4.6, and therefore rheological properties of acid casein gel (Mottar et al., 1989, Lucey et al., 1998).

All samples showed decrease of viscosity during shearing, as expected on the basis of investigations of Labropoulos et al., 1984, Denin Djurdjević, 2001, and Denin Djurdjević et al., 2001.

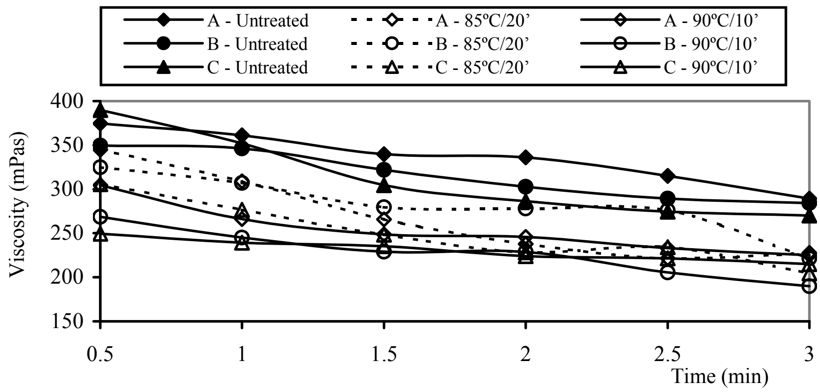

Fig. 1. - The influence of dry matter content and composition on the change of viscosity of set-style yogurts produced from untreated milk (full symbol, full line), milk heat treated at 85ºC/20 min (dashed line, empty symbol) and milk heat treated at 90ºC/10 min (full line, empty symbol), after 1 day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

As Fig. 1. shows, yogurt samples produced from untreated milk had the highest, while samples produced from milk heat treated at 90ºC/10 min had the smallest viscosity.

After 0.5 min, sample C had the highest viscosity. However, a sharp structure breakdown occurred during the investigated period, so this sample had the smallest viscosity after 3.0 min. On the other hand, yogurt B had less pronounced decrease of viscosity during time of shearing, so this sample had similar values of viscosity after 3.0 min as yogurt A.

The highest viscosity after 0.5 min of yogurt samples produced from milk heat treated at 85ºC/20 min had samples A, while samples C had the smallest viscosity. Yogurt B had higher viscosity than samples A between 1.5 and 2.5 min, while yogurt C had higher viscosity than samples A after 2.5 min.

Yogurt samples B and C produced from milk heat treated at 90ºC/10 min had smaller viscosity than sample A during the whole shearing time. Yogurt B had higher viscosity than yogurt C after 0.5 min. Nevertheless, yogurt C showed less pronounced decrease of viscosity during the investigated period, so this sample showed markedly higher viscosity after 2.5 and 3.0 min than sample B.

The influence of applied heat treatment, dry matter content and composition on average viscosity after 1 day of storage is shown in Table 2.

Tab. 2. - Influence of dry matter content and applied heat treatment on the average viscosity of set-style yogurt after 1 day of storage

HT	Yogurt sample A	B	C
	Average viscosity		
Untreated	336.04	315.76	312.92
85ºC/20’	267.72	281.17	249.63
90ºC/10’	253.91	227.27	230.7

HT – applied heat treatment of milk

As could be seen from Table 2., average viscosity decreased with increase of temperature of heat treatment, which well agrees with the results shown in Fig. 1.

The influence of storage period on change of acidity and viscosity of set-style yogurt

Exchange of pH value during storage of yogurt is shown in Fig. 2.

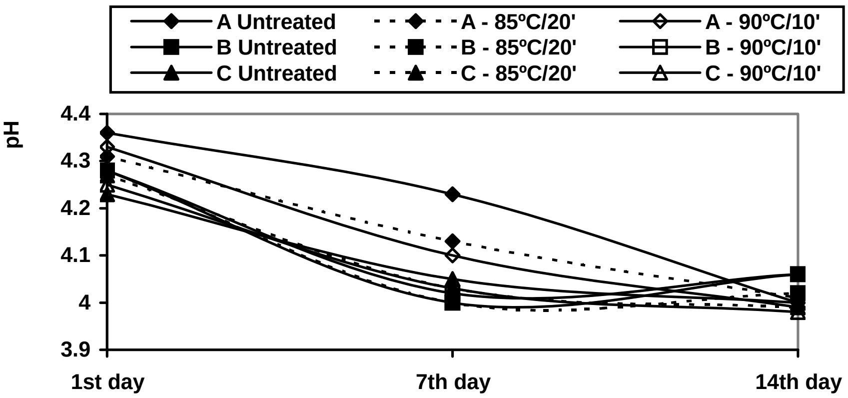

Fig. 2. - The influence of applied heat treatment and amount of added DWP on pH value of yogurt during storage

According to the results shown in Fig. 2., it can be seen that samples A had the highest, while samples B the smallest pH value.

Exchange of pH value during storage directly influences rheological properties of set-style yogurt. Voluminosity of casein micelle increases at lower pH value due to increased hydration, while positive net charge inside of casein micelle arises, which, on the other hand, induces molecular repulsion. As a result of molecular repulsion, increases of pore diameter occurs, which favors syneresis induced by drainage method (Harwalkar and Kalab, 1986). Partial breakdown of gel structure occurs during the application of external force (shearing, pumping), which influences split of links inside protein matrix and consequently syneresis. Depending on intensity and time of external force, casein matrix is transformed into smaller casein aggregates, which hold elements of unforced gel structure, but show finite syneresis (Pudja and Obradović, 1993).

Change of viscosity of set-style yogurt during shearing as influenced by applied heat treatment and amount of added DWP after 7 days of storage is shown in Fig. 3.

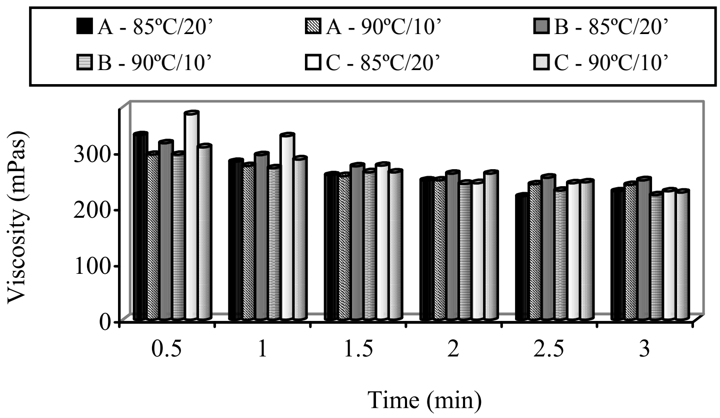

Fig. 3. - The influence of applied heat treatment and amount of added DWP on the change of yogurt viscosity after 7 days of storage

As Fig. 3. shows, after 7 days of storage, sample C produced from milk heat treated at 85ºC/20 min had the highest viscosity after 0.5 min. However, sample C showed significant decrease of viscosity during shearing, so this sample had the same viscosity as sample A after 3.0 min. On the other hand, yogurt B produced from milk heat treated at 85ºC/20 min, despite having smaller viscosity after 0.5 min, had the highest viscosity after 3.0 min due to a less pronounced decrease of viscosity.

Yogurt samples produced from milk heat treated at 90ºC/10 min had smaller viscosity than the same samples produced from milk heat treated at 85ºC/20 min. However, yogurt samples produced from milk heat treated at 90ºC/10 min had less pronounced decrease of viscosity during shearing, which indicates that lesser viscosity at the beginning of shearing leads to lesser decrease of viscosity during the investigated time of shearing.

Change of viscosity of set-style yogurt during shearing as influenced by applied heat treatment and amount of added DWP after 14 days of storage is shown in Fig. 4.

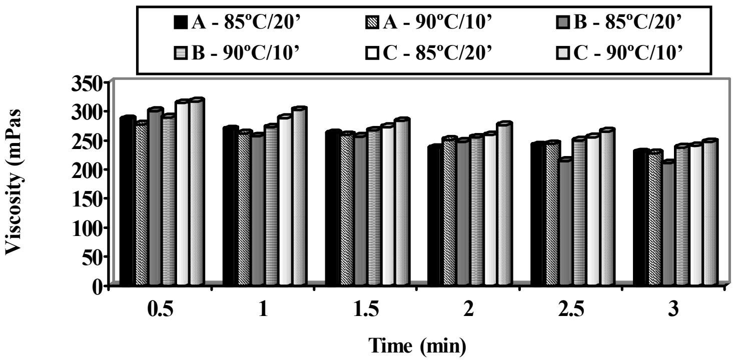

Fig. 4. - The influence of applied heat treatment and amount of added DWP on the change of yogurt viscosity after 14 days of storage

Yogurt sample C produced from milk heat treated at 90ºC/10 min had the highest viscosity during investigated shearing time, as could be seen from Fig. 4. Even after 14 days of storage, yogurt samples produced from milk heat treated at 90ºC/10 min had less pronounced decrease of viscosity during shearing than samples produced from milk heat treated at 85ºC/20 min. This indicates that yogurt produced from milk heat- treated at 90ºC/10 min had structure that is more resistant to deformations.

Gained results agree with those of Modler and Kalab, 1983, Modler et al., 1983, who concluded that set-style yogurt produced from milk standardized with whey proteins had smaller firmness than yogurt produced from milk standardized by casein-based products. Kalab et al., 1983, stated that yogurt produced from milk standardized with either skim milk powder or WPC had similar gel firmness, while microstructure of these gels had pronounced differences. In acid casein gels produced from milk standardized with WPC, casein micelles are linked with each to other via thin flocculated whey proteins.

Lucey et al., 1999, concluded that addition of WPC in untreated milk results in lesser elasticity module, because undenatured whey proteins act as "filler" without practical role in gel formation. Nevertheless, applied heat treatment of milk with or without added WPC, reduces gel shear deformation at yielding, namely gels becomes more brittle. However, since brittleness is more associated with the size of deformation, it is more properly to assume that such gels are less firm. This could explain different viscosity values of set-style yogurts produced from heat-untreated and heat-treated milk gained in our investigation.

Jelen et al., 1987, produced set-style yogurt from milk with modified CWR and concluded that an increase of whey protein content decreased viscosity and firmness of products, which agrees with our results gained after 1 day of storage.

Hugunin, 1999, assumed that standardization of milk with demineralized whey powder improves consistency of yogurt.

Conclusion

According to all aforementioned, it could be concluded:

Yogurt samples produced from milk standardized with demineralized whey powder had lower content of protein in dry matter and higher lactose content in dry matter than samples produced from basis milk.

The shortest duration of fermentation had milk with the highest amount of lactose, namely milk sample C.

Yogurt sample C produced from untreated milk standardized with demineralized whey powder had higher viscosity after 0.5 min than sample B, but sample B had higher viscosity after 1.5 min due to a more pronounced viscosity reduction during shearing of sample C.

Yogurt sample B produced from heat-treated milk had higher initial viscosity than sample C, while sample C had less pronounced viscosity decrease during shearing. Yogurt sample C produced from milk heat treated at 90ºC/10 min had higher viscosity values after 2.5 and 3.0 min than sample B.

After 7 days of storage, set-style yogurt C had the highest initial viscosity. However, yogurt sample C produced from milk heat treated at 85ºC/20 min had more pronounced viscosity reduction during shearing than samples produced from milk heat treated at 90ºC/10 min. On the other hand, yogurt samples produced from milk heat treated at 85ºC/10 min had higher initial viscosity.

After 14 days of storage, yogurt samples produced from milk heat treated at 90ºC/10 min had less pronounced viscosity reduction during shearing than samples produced from milk heat treated at 85ºC/10 min.

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UTICAJ TERMIČKOG TRETMANA I DODATE DEMINERALIZOVANE SURUTKE U PRAHU NA VISKOZITET ČVRSTOG JOGURTA

Jelena Denin Djurdjević, O. Maćej i Snežana Jovanović*

Rezime

Obrano mleko u prahu je rekonstituisano i dobijeno je mleko A (sa 8.44% SM). Mleku A je dodavana demineralizovana surutka u prahu i dobijeni su uzorci mleka B (sa 9.71% SM) i mleka C (sa 10.75% SM). Svi uzorci su termički tretirani na 85ºC/20 min i 90ºC/10 min. Kao kontrolni uzorak korišteno je termički netretirano mleko. Svi uzorci su inokulisani na 43ºC sa 2.5% tečne

* Mr Jelena Denin Djurdjević, saradnik, dr Ognjen Maćej, redovni profesor, dr Snežana Jovanović, docent, Institut za prehrambenu tehnologiju i biohemiju, Poljoprivredni fakultet 11081 Beograd- Zemun, Nemanjina 6, 11081 Zemun, SR Jugoslavija

jogurtne kulture (*Lactobacillus delbrueckii* subsp. *bulgaricus* i *Streptococcus thermophilus* u odnosu 1:1) i inkubirani do postizanja pH 4.6. Nakon fermentacije uzorci su ohladjeni na 4ºC i držani na toj temperaturi do analize.

Viskozitet je određivan nakon 1., 7. i 14. dana skladištenja pomoću Brookfield-ovog viskozimetra DV-E pri brzini rotacije spindla od 20 o/min.

Nakon 1. dana skladištenja, uzorci čvrstog jogurta proizvedeni od netretiranog mleka imali su najveće a uzorci proizvedeni od mleka termički tretiranog na 90ºC/10 min najmanje inicijalne vrednosti viskoziteta, bez obzira na sastav i sadržaj suve materije. Ujedno, srednja vrednost viskoziteta čvrstog jogurta se smanjuje sa povećanjem temperature primenjenog termičkog tretmana.

Tokom skladištenja uzorci čvrstog jogurta proizvedeni od mleka termički tretiranog na 90ºC/10 min imaju najmanje izraženo smanjenje viskoziteta tokom vremena.

Nakon 14 dana skladištenja, uzorci jogurta proizvedeni od mleka standardizovanog DSUP imaju veće vrednosti viskoziteta od uzoraka proizvedenih od mleka A.

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