Journal of Agricultural Sciences
Vol. 47, No 2, 2002
Pages 189-204

UDC: 637.146(147).3
Original scientific paper

# THE INFLUENCE OF DRY MATTER, APPLIED HEAT TREATMENT AND STORAGE PERIOD ON THE VISCOSITY OF STIRRED YOGURT

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

**Abstract**: Skim milk powder reconstituted to 8.44% TS, 9.65% TS and 10.84% TS, respectively was used for investigation.

Untreated milk and milk heat treated at 85ºC/20 min and 90ºC/10 min, respectively, were used for the investigation. Milk was inoculated with 2.5% of 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. Acid casein gel was stirred after 1, 7 and 14 days of storage. Measurements were done at 30 rpm during 2 min, at 20ºC.

According to the investigation, it could be concluded that both applied heat treatment and dry matter content influence viscosity of stirred yogurt. Viscosity increases when dry matter content increases. The smallest viscosity had yogurt produced from untreated milk with 8.44% TS, while samples produced from milk with 10.84% TS had the highest viscosity.

Applied heat treatments had significant influence on viscosity of yogurt gained by stirring of acid casein gels after 7 and 14 days of storage. Stirred yogurt produced from milk heat treated at 90ºC/10 min had a higher viscosity than samples produced from milk heat treated at 85ºC/20 min.

Storage period influenced average viscosity of stirred yogurt. Samples of stirred yogurt produced from milk with 8.44% TS showed a decrease of average viscosity during storage, regardless of the applied heat treatment of milk. The highest average viscosity had samples produced from milk with 10.84% TS.

**Key words**: stirred yogurt, viscosity, storage period, heat treatment.

---

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

## Introduction

Several factors, such as dry matter content, used starter culture, processing conditions, namely homogenisation, applied heat treatment, stirring, pumping, cooling and packing, influence rheological properties of stirred yogurt (Afonso and Maia, 1999, Maćej et al., 1997). Depending on intensity and duration of applied force (e.g. stirring, pumping), three-dimensional protein network is broken up, yielding smaller aggregates of casein micelles, which retain various elements of gel structure (Pudja and Obradović, 1993). Contrary to set-style yogurt, which represents three-dimensional network composed from chains and clusters of casein micelles, stirred yogurt has less chains and more clusters that are interconnected with thin fibres. According to Kalab et al., 1975, microstructure of stirred yogurt appears as flat clusters of casein micelles, composed from many small casein micelles clusters joined together by thin, short fibres (Kalab, 1979, Kalab et al., 1975).

The temperature of probe is another factor that influences viscosity of stirred yogurt. From the rheological viewpoint, stirred yogurt represents a very complex system for characterization of flow properties, because it shows both the thixotropic character (viscosity decreases during time of shearing as well as by increasing of shear rate), and the viscoelastic character due to structural breakdown during shearing and viscosity monitoring (Afonso and Maia, 1999, de Lorenzi et al., 1995, Guinee et al., 1995, van Marle et al., 1999).

Van Marle et al., 1999, concluded that volume fraction of gel particles as well as size of gel particles in stirred yogurt influence the viscosity of product. Afonso and Maia, 1999, described sharp decrease of viscosity during shearing by a model of formation acid casein gel. The proposed model assumed that casein particles during acidification form primary aggregates, which in turn forms so-called “super-aggregates”. The super-aggregates can be broken up to primary aggregates at lower shearing rates, while structure of primary aggregates can be disrupted at higher shearing rates. At the highest shearing rates, the primary aggregates are broken up to protein particles. Hess et al., 1997, assumed that bonds among casein micelles are the first bonds that are broken during shearing. Bonds between casein particles and exo-polysaccharides can be broken when bonds among casein particles are already broken. This postulation agrees well with those proposed by Kalab et al., 1975, and Tamime et al., 1984, who observed that the bacterium is linked to the protein matrix. Marshall and Rawson, 1999, concluded that the type of exo-polysaccharides has the greatest influence on the viscosity of final product.

De Lorenzi et al., 1995, classified yogurt as very weakly structured fluids according to marked strain sensitivity at lower frequency of oscillation ($\omega$). Also, the same authors concluded that the increase of strain has a greater effect on the decrease of elastic component (G') than of the viscous component (G") of yogurt. Guinee et al., 1995, concluded that different ingredients have various influence on gel structure formation (size of the aggregates, degree of protein aggregation). They also concluded that components formed during shearing oriented parallel with flow direction, which, on the other hand, influence exchange of yogurt structure.

## Materials and Methods

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

Untreated milk and milk heat treated at 85ºC/20 min and 90ºC/10 min, respectively, were used for the investigation. Milk was inoculated with 2.5% of 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.

Acid casein gel gained after fermentation was stirred after 1, 7 and 14 days of storage. Stirring of gel was done by electric stirrer during 30 sec. Samples of stirred yogurt obtained by stirring of acid casein gels produced from heat-treated milk were investigated after 1, 7 and 14 days. Samples of stirred yogurt obtained from untreated milk were investigated only after 1 day of storage. Those samples, in addition to intensive syneresis, showed small viscosity values which were below values suggested by producer of viscometer (less than 10% of maximal value of viscosity at a certain rate of spindle rotation).

#### Analyses and measurements

Dry matter content: AOAC method 16.032.
Nitrogen content: FIL/IDF 20B: 1993
Milk fat content: Gerber method (FIL/IDF 105:1981)

#### Measurements of viscosity

Measurements of viscosity were done with Brookfield DV-E Viscometer. Spindle No 3 at 30 rpm was used for all samples. Spindle was inserted at the side of samples cup and horizontally moved to the center of the sample. Spindle's speed was adjusted to 30 rpm, and readings were taken at 30 sec. intervals during 2 min. All measurements were done at 20ºC.

## Results and Discussion

### Milk and yogurt quality parameters

The composition of reconstituted skim milk used for the production of yogurt, as well as the composition of yogurt is given in Table 1.

Tab. 1. - Quality parameters of milk and yogurt

| Sample | | | Investigated parameters | | | |
|---|---|---|---|---|---|---|
| | | | DM % | MF % | NFDM % | Nitrogen % |
| 8.44% | Untreated | Milk x (n=5) | 8.44 | 0.13 | 8.31 | 0.4351 |
| | | Yogurt x (n=5) | 8.60 | 0.13 | 8.47 | 0.4151 |
| | 85ºC/20’ | Milk x (n=5) | 8.56 | 0.13 | 8.43 | 0.4335 |
| | | Yogurt x (n=5) | 8.75 | 0.13 | 8.62 | 0.4292 |
| | 90ºC/10’ | Milk x (n=5) | 8.62 | 0.13 | 8.49 | 0.4317 |
| | | Yogurt x (n=5) | 8.68 | 0.13 | 8.55 | 0.4227 |
| 9.65% | Untreated | Milk x (n=5) | 9.65 | 0.17 | 9.48 | 0.4973 |
| | | Yogurt x (n=5) | 9.52 | 0.17 | 9.35 | 0.4633 |
| | 85ºC/20’ | Milk x (n=5) | 9.70 | 0.17 | 9.53 | 0.4935 |
| | | Yogurt x (n=5) | 9.57 | 0.17 | 9.40 | 0.4865 |
| | 90ºC/10’ | Milk x (n=5) | 9.81 | 0.17 | 9.64 | 0.4910 |
| | | Yogurt x (n=5) | 9.60 | 0.17 | 9.43 | 0.4587 |
| 10.84% | Untreated | Milk x (n=5) | 10.84 | 0.21 | 10.63 | 0.5536 |
| | | Yogurt x (n=5) | 10.91 | 0.21 | 10.70 | 0.5248 |
| | 85ºC/20’ | Milk x (n=5) | 11.00 | 0.21 | 10.79 | 0.5564 |
| | | Yogurt x (n=5) | 10.88 | 0.21 | 10.67 | 0.5376 |
| | 90ºC/10’ | Milk x (n=5) | 10.95 | 0.21 | 10.74 | 0.5592 |
| | | Yogurt x (n=5) | 10.89 | 0.21 | 10.68 | 0.5407 |

DM – dry matter; MF – milk fat; NFDM – non-fat dry matter

As can be seen from results given in Table 1. dry matter content and non-fat dry matter content increased during heat treatment of milk. Yogurt samples produced from milk with 8.44% TS has larger DM content than milk, presumably due to the evaporation during the fermentation. Other yogurt samples showed decrease of dry matter content, which agrees with the results of Djordjević et al., 1988a, 1988b. Nitrogen content of all yogurt samples decreased, which indicates proteolitic activity of used LAB (Shah and Shihata, 1998, Laws and Marshall, 2001, Obradović, 2002).

### The influence of applied heat treatment and storage period of acid casein gel before stirring on the viscosity of stirred yogurt

Change of viscosity of stirred yogurt produced from reconstituted skim milk with 8.44% TS is shown in Table 2. and Fig. 1.

As can be seen from Table 2. and Fig. 1., stirred yogurt produced from untreated milk with 8.44% TS had remarkably lower viscosity than samples produced from heat-treated milk. Viscosity of yogurt produced from untreated milk with 8.44% TS decreased by 11.47 mPas during time of shearing. Yogurt samples produced from milk heat treated at 90ºC/10 min, had greater viscosity values than samples produced from milk heat treated at 85ºC/20 min. During the investigated time of shearing, viscosity of yogurt samples produced from milk heat treated at 85ºC/20 min and 90ºC/10 min decreased for 12.33 mPas and 14.03 mPas, respectively.

T a b . 2. - The influence of applied heat treatment and storage period of acid casein gel before stirring on viscosity change of stirred yogurt produced from reconstituted skim milk with 8.44% DM

| Applied heat treatment | Storage period (days) | Calculated parameters | Time (min) 0.5 | 1.0 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|
| | | | Viscosity (mPas) | | | |
| Untreated milk | 1 day | x (n=3) | 28.77 | 23.10 | 19.90 | 17.30 |
| | | Sd | 2.4583 | 0.3000 | 0.1732 | 0.1732 |
| | | Cv | 8.55 | 1.30 | 0.87 | 1.00 |
| 85ºC/20’ | 1 day | x (n=3) | 45.50 | 40.03 | 36.27 | 33.17 |
| | | Sd | 2.9513 | 1.9009 | 1.1372 | 1.0017 |
| | | Cv | 6.49 | 4.75 | 3.14 | 3.02 |
| | 7 days | x (n=3) | 42.00 | 36.67 | 33.33 | 30.73 |
| | | Sd | 1.6371 | 1.2897 | 0.9238 | 0.5132 |
| | | Cv | 3.90 | 3.52 | 2.77 | 1.67 |
| | 14 days | x (n=3) | 37.10 | 32.63 | 29.27 | 26.77 |
| | | Sd | 4.2532 | 3.4962 | 2.6102 | 2.6102 |
| | | Cv | 11.46 | 10.71 | 8.92 | 9.75 |
| 90ºC/10’ | 1 day | x (n=3) | 51.90 | 46.53 | 41.90 | 37.87 |
| | | Sd | 3.3601 | 3.7820 | 3.3601 | 2.4583 |
| | | Cv | 6.47 | 8.13 | 8.02 | 6.49 |
| | 7 days | x (n=3) | 44.50 | 39.80 | 36.27 | 33.77 |
| | | Sd | 2.7185 | 2.9309 | 2.2745 | 2.3714 |
| | | Cv | 6.11 | 7.36 | 6.27 | 7.02 |
| | 14 days | x (n=3) | 42.10 | 37.07 | 34.07 | 31.27 |
| | | Sd | 3.9000 | 3.1182 | 2.4947 | 2.2745 |
| | | Cv | 9.26 | 8.41 | 7.32 | 7.27 |

Also, results show that viscosity of stirred yogurt produced from milk with 8.44% TS heat treated at 85ºC/20 min decreased when storage period of acid casein gel before stirring was increased. The viscosity values of stirred yogurt gained by stirring of acid casein gel after 7 and 14 days of storage was after 30 sec smaller for 3.50 mPas and 8.40 mPas than the viscosity value of stirred yogurt gained by stirring of gel after 1 day of storage. Overall decreases of viscosity during shearing were 11.27 mPas and 10.33 mPas, respectively, for stirred yogurts gained by stirring of gels after 7 and 14 days of storage.

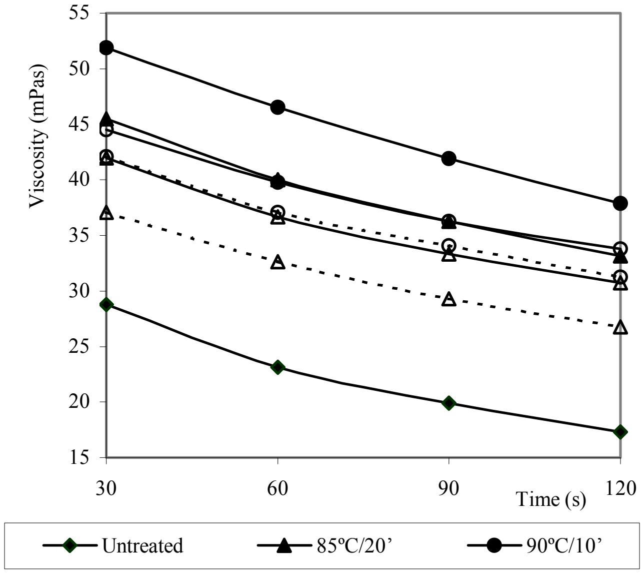


Fig 1. - The influence of applied heat treatment and storage period before stirring (gels were stored 1 day (full symbol, full line); 7 days (empty symbol, full line) and 14 days (empty symbol, dashed line) on the viscosity of stirred yogurt with 8.44% TS

Stirred yogurt gained by stirring of acid casein gel produced from milk with 8.44% TS heat treated at 90ºC/10 min after 7 days of storage, had considerably smaller viscosity than samples after 1 day of storage. The viscosity value after 30 sec was by 7.40 mPas smaller than viscosity of samples gained by stirring of gel 1 day after production. Overall decrease of viscosity during shearing was 10.73 mPas. Stirred yogurt gained by stirring of acid casein gel after 14 days of storage had the smallest viscosity. After 30 sec, the viscosity values were smaller by 9.80 mPas and 2.40 mPas, respectively, than viscosity of samples gained by stirring of gel after 1 and 7 days of storage. Viscosity decreased by 10.83 mPas during investigated time of shearing.

It could be assumed that stirred yogurt produced from milk with 8.44% TS heat treated at 90ºC/10 min have higher viscosity than stirred yogurt produced from milk heat treated at 85ºC/20 min, gained by stirring of acid casein gel after the same storage period.

Change of viscosity of stirred yogurt produced from reconstituted skim milk with 9.65% TS is shown in Table 3. and Fig. 2.

Results show that yogurt produced form untreated milk has the smallest, while yogurt produced from milk heat treated at 90ºC/10 min has the highest viscosity. Overall decreases of viscosity were 13.44 mPas, 13.67 mPas and 13.44 mPas, respectively, for samples produced from untreated milk and milk heat-treated at 85ºC/20 min and 90ºC/10 min.

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 reconstituted skim milk with 9.65% DM

| Applied heat treatment | Storage period (days) | Calculated parameters | Time (min) 0.5 | 1.0 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|
| | | | Viscosity (mPas) | | | |
| Untreated milk | 1 day | x (n=3) | 36.57 | 30.20 | 26.17 | 23.13 |
| | | Sd | 1.0970 | 0.9644 | 0.7506 | 0.8327 |
| | | Cv | 3.00 | 3.19 | 2.87 | 3.60 |
| 85ºC/20’ | 1 day | x (n=3) | 49.60 | 44.97 | 40.27 | 35.93 |
| | | Sd | 5.3226 | 5.6163 | 7.0216 | 5.4243 |
| | | Cv | 10.73 | 12.49 | 17.44 | 15.10 |
| | 7 days | x (n=3) | 54.17 | 47.50 | 43.47 | 40.13 |
| | | Sd | 2.3671 | 2.7074 | 2.7791 | 3.5642 |
| | | Cv | 4.37 | 5.70 | 6.39 | 8.88 |
| | 14 days | x (n=3) | 50.63 | 44.40 | 40.53 | 37.60 |
| | | Sd | 0.8505 | 0.6000 | 0.6807 | 1.5133 |
| | | Cv | 1.68 | 1.35 | 1.68 | 4.02 |
| 90ºC/10’ | 1 day | x (n=3) | 53.67 | 47.77 | 43.47 | 40.23 |
| | | Sd | 3.5921 | 6.5072 | 6.9580 | 6.9644 |
| | | Cv | 6.69 | 13.62 | 16.01 | 17.31 |
| | 7 days | x (n=3) | 66.47 | 58.57 | 53.53 | 50.13 |
| | | Sd | 4.0673 | 3.9501 | 3.3232 | 3.1182 |
| | | Cv | 6.12 | 6.74 | 6.21 | 6.22 |
| | 14 days | x (n=3) | 64.60 | 55.00 | 49.90 | 46.57 |
| | | Sd | 7.3627 | 4.0951 | 3.9950 | 3.6896 |
| | | Cv | 11.40 | 7.45 | 8.01 | 7.92 |

Contrary to results gained for yogurt with 8.44% TS, viscosity of stirred yogurt produced from milk 9.65% TS heat treated at 85ºC/20 min increased for 4.57 mPas after 7 days of storage of acid casein gel compared with yogurt after 1 day of storage. Viscosity decreased for 14.04 mPas during shearing. Further storage of acid casein gel before stirring resulted in the decrease of viscosity, thus stirred yogurt produced by stirring of acid casein gel after 14 days of storage had viscosity of 50.63 mPas after 30 sec, which is smaller by 3.54 mPas than viscosity of samples after 7 days of storage. Viscosity decreased by 13.03 mPas during shearing.

Stirred yogurt produced from milk with 9.65% TS heat treated at 90ºC/10 min gained by stirring of acid casein gel 7 days after production shows pronounced increase of viscosity compared to the samples after 1 day. Viscosity after 30 sec was 66.47 mPas and was higher by 12.80 mPas and 1.87 mPas, respectively, than viscosity of stirred yogurt gained by stirring of acid casein gel after 1 and 14 days of storage. Decrease of viscosity during shearing was 16.34 mPas. Yogurt gained by stirring of acid casein gel after 14 days of storage had smaller viscosity, which after 30 sec was 64.60 mPas. Decrease of viscosity during shearing was small and adds up 8.03 mPas.

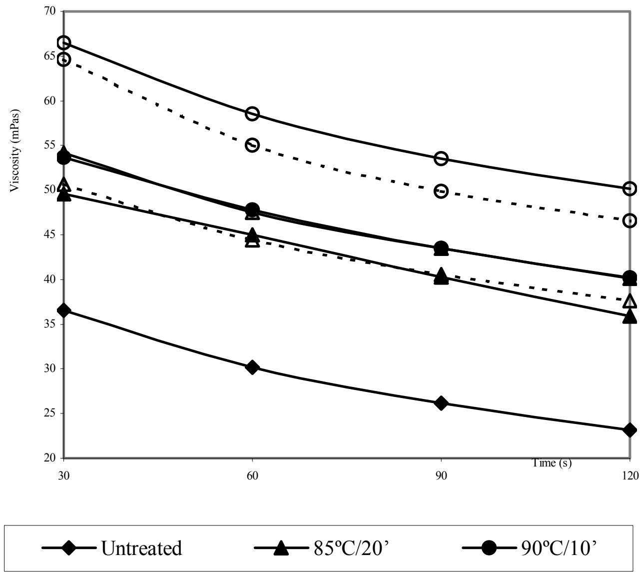


Fig 2. - The influence of applied heat treatment and storage period before stirring (gels were stored 1 day (full symbol, full line); 7 days (empty symbol, full line) and 14 days (empty symbol, dashed line)) on the viscosity of stirred yogurt with 9.65% TS.

Similarly to the samples produced from milk with 8.44% TS, stirred yogurt produced from milk with 9.65% TS heat treated at 90ºC/10 min had higher viscosity than samples produced from milk heat treated at 85ºC/20 min, gained by stirring of acid casein gel after identical storage period.

Change of viscosity of stirred yogurt produced from reconstituted skim milk with 10.84% TS is shown in Table 4. and Fig. 3**.**

Results show that after 30 sec stirred yogurt, gained by stirring of acid casein gel 1 day after production, produced from untreated milk with 10.84% TS had the smallest, while samples produced from milk heat treated at 85ºC/20 min had the highest viscosity. Viscosity of stirred yogurt produced from milk heat treated at 90ºC/10 min was 78.97 mPas after 30 sec of shearing and was only 0.60 mPas smaller than viscosity of samples produced from milk heat treated at 85ºC/20 min. Overall decrease of viscosity during shearing were 15.53 mPas, 15.50 mPas and

18.24 mPas, respectively, for samples produced from untreated milk, milk heat treated at 85ºC/20 min and 90ºC/10 min.

T a b . 4. - The influence of applied heat treatment and storage period of acid casein gel before stirring on viscosity change of stirred yogurt produced from reconstituted skim milk with 10.84 DM

| Applied heat treatment | Storage period (days) | Calculated parameters | Time (min) 0.5 | 1.0 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|
| | | | Viscosity (mPas) | | | |
| Untreated milk | 1 day | x (n=3) | 47.20 | 40.20 | 35.63 | 31.67 |
| | | Sd | 1.0817 | 0.7550 | 0.9504 | 1.4434 |
| | | Cv | 2.29 | 1.88 | 2.67 | 4.56 |
| 85ºC/20’ | 1 day | x (n=3) | 79.57 | 71.47 | 66.97 | 64.07 |
| | | Sd | 9.9681 | 8.1990 | 7.4447 | 6.5912 |
| | | Cv | 12.53 | 11.47 | 11.12 | 10.29 |
| | 7 days | x (n=3) | 69.83 | 61.33 | 56.70 | 53.43 |
| | | Sd | 1.5373 | 1.8877 | 1.9313 | 1.7243 |
| | | Cv | 2.20 | 3.08 | 3.41 | 3.23 |
| | 14 days | x (n=3) | 62.40 | 56.03 | 51.97 | 49.20 |
| | | Sd | 1.9079 | 1.1060 | 0.9238 | 0.4583 |
| | | Cv | 3.06 | 1.97 | 1.78 | 0.93 |
| 90ºC/10’ | 1 day | x (n=3) | 78.97 | 70.20 | 64.50 | 60.73 |
| | | Sd | 3.1533 | 2.0518 | 1.5716 | 1.5373 |
| | | Cv | 3.99 | 2.92 | 2.44 | 2.53 |
| | 7 days | x (n=3) | 87.60 | 78.23 | 72.40 | 68.03 |
| | | Sd | 5.9908 | 3.5642 | 2.8160 | 2.0526 |
| | | Cv | 6.84 | 4.56 | 3.89 | 3.02 |
| | 14 days | x (n=3) | 87.50 | 77.63 | 71.33 | 66.47 |
| | | Sd | 4.8590 | 3.4962 | 3.7807 | 2.8989 |
| | | Cv | 5.55 | 4.50 | 5.30 | 4.36 |

Stirred yogurt produced from milk with 10.84% TS heat treated at 85ºC/20 min, gained by stirring of acid casein gel 7 days after production, had after 30 sec viscosity of 69.83 mPas, which was by 9.74 mPas smaller than viscosity of yogurt after 1 day of storage. Viscosity of yogurt gained by stirring of gel after 14 days of storage was still smaller (62.40 mPas). Overall decrease of viscosity during shearing were 16.40 mPas and 13.20 mPas, respectively, for samples gained by stirring of acid casein gel after 7 and 14 days of storage.

As can be seen from results, viscosities of stirred yogurt produced from milk with 10.84% TS heat treated at 90ºC/10 min, gained by stirring of acid casein gels 7 and 14 days after production were similar and did not differ significantly from each other. The smallest viscosity had samples gained by stirring of gel 1 day after production, while the highest viscosity had samples gained by stirring of gel 7 days after production. Overall decrease of viscosity during shearing were 19.57

mPas and 21.03 mPas, for samples gained by stirring of acid casein gel after 7 and 14 days of storage, respectively.

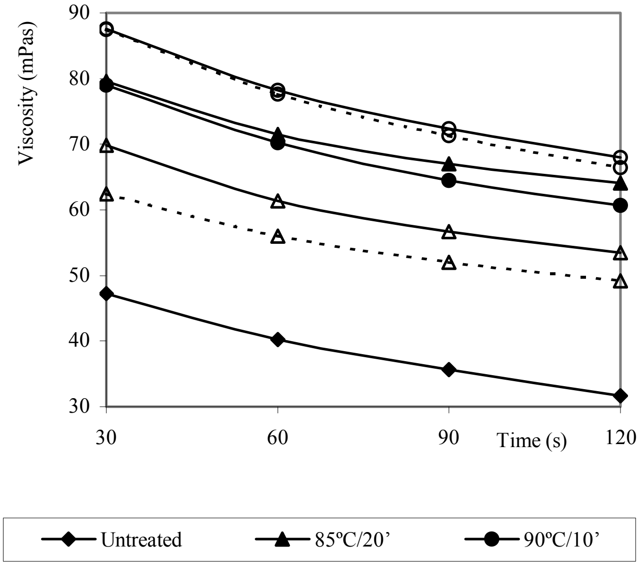


Fig 3. - The influence of applied heat treatment and storage period before stirring (gels were stored 1 day (full symbol, full line); 7 days (empty symbol, full line) and 14 days (empty symbol, dashed line) on the viscosity of stirred yogurt with 10.84% TS

It is clear from showed results that applied heat treatment has a great influence on the viscosity of stirred yogurt. The influence of applied heat treatment is attributed to the amount of denatured and with casein micelle associated $\alpha$-lactalbumin, because this amount determines hydrophilic properties of casein particles after fermentation (Denin-Djurdjević, 2001, Mottar et al., 1989). According to the results shown in Fig. 1., 2. and 3., it can be concluded that applied heat treatment at 90ºC/10 min resulted in higher viscosity of stirred yogurt gained by stirring of acid casein gel after 7 and 14 days of storage than the 85ºC/20 min heat treatment did. These results indicate that storage period of acid casein gel has influence on the increase of hydrophilic properties of casein particles, as well as on swelling of particles, which in turn influences spatial distribution and viscosity.

Results gained by investigation of viscosity change agree with those of other authors (Afonso and Maia, 1999, Labropoulos et al. 1984, Hellinga et al., 1986). Afonso and Maia, 1999, concluded that after 10 min of shearing all yogurt samples showed similar viscosity, namely, yogurt samples with a higher viscosity at the beginning of shearing had a greater decrease of viscosity during shearing, while samples with a smaller viscosity at the beginning of shearing had less pronounced decrease of viscosity during shearing.

**The influence of milk dry matter content on the viscosity of stirred yogurt**

The influence of dry matter content and applied heat treatment on viscosity of stirred yogurt gained by stirring of acid casein gel after 1 day of storage is shown at Fig. 4., 5. and 6.

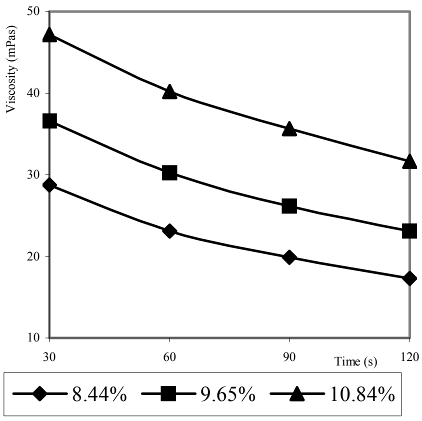


Fig. 4. - The influence of dry matter content on the viscosity of stirred yogurt produced from untreated milk

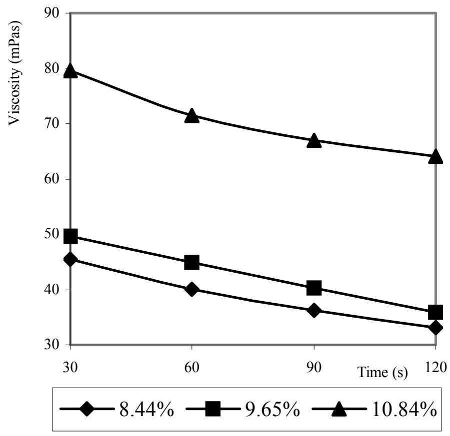


Fig. 5. - The influence of dry matter content on the viscosity of stirred yogurt produced from milk heat treated at 85ºC/20'

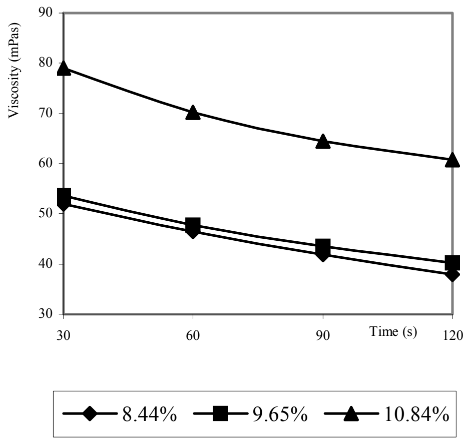


Fig. 6. - The influence of dry matter content on the viscosity of stirred yogurt produced from milk heat treated at 90ºC/10'

As Fig. 4., 5. and 6. show, stirred yogurt produced from milk with 10.84% TS had the greatest, while stirred yogurt produced from milk with 8.44% TS had the smallest viscosity, regardless of the applied heat treatment of milk. The difference between viscosity values of stirred yogurt produced from heat treated milk with 8.44% TS and 9.65% TS is inconsiderable.

According to the investigation of Becker and Puhan, 1989, increase of protein content in milk by addition of skim milk powder, leads to increased viscosity of stirred yogurt, which agrees with the results gained in this investigations. According to the results of Denin-Djurdjević,2001, increasing of dry matter content resulted in increase of viscosity of stirred yogurt.

**The influence of storage period of acid casein gel before stirring on the average viscosity of stirred yogurt**

The influence of dry matter content, applied heat treatment and storage period of acid casein gel before stirring on the average viscosity of stirred yogurt is shown in Table 5. and Fig. 7.

Tab. 5. - The influence of applied heat treatment and storage period od acid casein gel before stirring on the average viscosity of stirred yogurt

| Dry matter (%) | Applied heat treatment | Storage period (days) 1 | 7 (Average viscosity (mPas)) | 14 |
|---|---|---|---|---|
| 8.44% | 85ºC/20’ | 38.74 | 35.68 | 31.44 |
| | 90ºC/10’ | 44.55 | 38.58 | 36.13 |
| 9.65% | 85ºC/20’ | 42.69 | 46.32 | 43.29 |
| | 90ºC/10’ | 46.28 | 57.18 | 54.02 |
| 10.84% | 85ºC/20’ | 70.52 | 60.33 | 54.90 |
| | 90ºC/10’ | 68.60 | 76.57 | 75.73 |

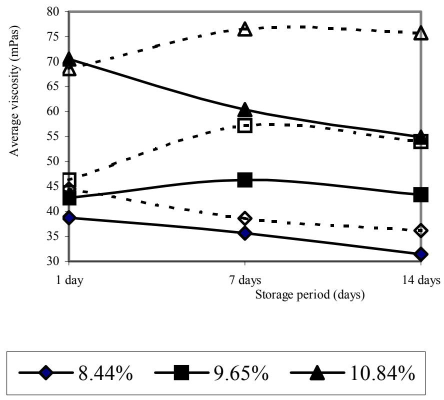


Fig. 7. - The influence of applied heat treatment (heat treatment at 85ºC/20' - full symbol, full line; and 90ºC/10' - empty symbol, dashed line) and storage period before stirring on average viscosity of stirred yogurt

Prolongation of storage period of acid casein gel before stirring of yogurt samples produced from milk with 8.44% TS had negative effect on the average viscosity, regardless of the applied heat treatment. The average viscosity of samples produced from milk with 9.65% TS increased after 7 days of storage and then slightly decreased after 14 days of storage. Samples of stirred yogurt with 8.44% TS and 9.65% TS produced from milk heat treated at 90ºC/10 min had a higher average viscosity than samples produced from milk heat treated at 85ºC/20 min. The sudden decrease of the average viscosity of stirred yogurt produced from milk with 10.84% TS heat treated at 85ºC/20 min is observed with prolongation of storage period of acid casein gel before stirring. However, this sample produced by stirring of acid casein gel after 1 day of storage had by 1.92 mPas higher average viscosity than sample produced from milk heat treated at 90ºC/10 min. The average viscosity of samples produced from milk heat treated at 90ºC/10 min increased after 7 days of storage and remained almost constant during 14 days.

Gained results agree with those of Denin-Djurdjević, 2001.

## Conclusion

According to the aforementioned results, it could be concluded:

Viscosity of stirred yogurt is smaller than viscosity of set-style yogurt. It can be explained by drop of continuous protein network. Aggregates that are formed during stirring of gel maintain some properties of gel, but the number of bonds as the well as the number of aggregates that directly influence viscosity is exchanged.

An increase of dry matter content leads to the increase of viscosity of stirred yogurt. The smallest viscosity had yogurt produced from reconstituted skim milk with 8.44% DM, while yogurt produced from reconstituted skim milk with 10.84% DM had the highest viscosity.

Applied heat treatment influences viscosity of stirred yogurt gained by stirring of acid casein gel after 7 and 14 days of storage. Samples of stirred yogurt produced form milk heat treated at 90ºC/10’ had higher viscosity than samples produced from milk heat treated at 85ºC/20’.

Storage period of acid casein gel before stirring had contrasting influence on average viscosity of stirred yogurt, which is specially related to the dry matter content. The average viscosity of stirred yogurt produced from milk with 8.44% DM decreased during storage period, regardless of the applied heat treatment. Samples produced from milk with 9.65% DM had the smallest average viscosity after 1 day of storage. The highest average viscosity had samples stirred after 7 days of storage, regardless of the applied heat treatment. Nevertheless, yogurt samples produced from milk with 10.84% DM had the highest average viscosity.

## REFERENCES

1. Afonso, I.M., Maia, J.M. (1999): Rheological monitoring of structure evolution and development in stirred yoghurt, J. Food Eng. 42, 183-190.
2. Association of official analytical chemists (AOAC) (1990): Official methods of analysis. 15th ed., Arlington, Virgiania, U.S.A.
3. Becker, T., Puhan, Z. (1989): Effect of different process to increase the milk solids non-fat content on the rheological properties of yoghurt. Milchwissenschaft, 44 (10), 626-629.
4. De Lorenzi, L., Pricl, S., Torriano, G. (1995): Rheological behaviour of low-fat and full-fat stirred yoghurt, Int. Dairy J. 5 (7), 661-671.
5. Denin-Djurdjević, J. (2001): Uticaj termičkog tretmana i demineralizovane surutke u prahu na reološke osobine kiselog kazeinskog gela. Magistarski rad. Poljoprivredni fakultet. Beograd.
6. Djordjević, J., Milčić, M., Maćej, O., Beatović, Z. (1988a): Proučavanje problematike suve materije jogurta. Mljekarstvo 38 (2), 31-36.
7. Djordjević, J., Milčić, M., Maćej, O., Beatović, Z. (1988b): Poboljšanje metode za određivanje suve materije jogurta. Mljekarstvo 38 (4), 99-103.
8. Guinee, T.P., Mullins, C.G., Reville, W.J., Cotter, M.P. (1995): Physical properties of stirred-curd unsweetened yoghurts stabilised with different dairy ingredients, Milchwissenschaft 50 (4), 196-200.
9. Hellinga. C., Somsen, D.J., Koenraads, J.P.J.M. (1986): Viscosity of stirred yoghurt: modern techniques useful in analysing and improving routine measurements, Neth. Dairy J. 40, 217-240.
10. Hess, S.J., Roberts, R.F., Ziegler, G.R. (1997): Rheological properties of nonfat yogurt stabilized using Lactobacillus delbruickii spp. bulgaricus producing exopolysaccharide or using commercial stabilizer systems, J. Dairy Sci. 80 (2), 252-263.
11. International Dairy Federation (IDF) (1981): Milk. Determination of fat content. Gerber butyrometers. IDF Standard 105.
12. International Dairy Federation (IDF) (1993): Milk. Determination of nitrogen content (Kjeldahl method) and calculation of crude protein content. IDF Standard 20B.
13. Kalab, M. (1979): Microstructure of dairy foods. 1. Milk products based on protein, J. Dairy Sci. 62 (8), 1352-1364.
14. Kalab, M., Emmons, D.B., Sargant, A.G. (1975): Milk gel structure. IV. Microstructure of yoghurts in relation to the presence of thickening agents, J. Dairy Res. 42 (3), 453-458
15. Labropoulos, A.E., Collins, W.F., Stone, W.K. (1984): Effects of Ultra-High temperature and Vat processes on heat-induced Rheological properties of yogurt, J. Dairy Sci., 67 (2), 405-409.
16. Laws, A.P., Marshall, V.M. (2001): The relevance of exopolysaccharides to the rheological properties in milk fermented with ropy strains of lactic acid bacteria. Int. Dairy J. 11, 709-721.
17. Maćej, O.D., Kosi, F.F., Mikuljanac, A.M., Jovanović, S.T. (1997): Uticaj tehnoloških operacija na kvalitet fermentisanih napitaka, Jugoslovenski mlekarski simpozijum "Kvalitet mleka i fermentisanih proizvoda", Zlatibor. Monografija. Ur. Obradović, D., Niketić, G., Carić, M., Mijačević, Z. i Sekulović, N. 62-70.
18. Marshall, V.M., Rawson, H.L. (1999): Effects of exopolysaccharide-producing strains of thermophilic lactic acid bacteria on the texture of stirred yoghurt, Int. J. of Food Science and Technology, 34, 137-143.
19. 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.

20. O b r a d o v i ć, D. (2002): Značaj egzopolisaharida za fermentisane mlečne proizvode. Jugoslovenski mlekarski simpozijum "Savremeni trendovi u mlekarstvu" Vrnjačka Banja 2002. Zbornik Radova. Ur. Mijačević, Z., Niketić, G. 148-150.
21. P u d j a, P.D., O b r a d o v i ć, D.B. (1993): Uticaj termičkog i mehaničkog tretmana na prividnu viskoznost kiselog kazeinskog gela, Preh. Ind. Vol.4,(1-2), 10-14.
22. S h a h, N. P., S h i h a t a, A. (1998): Proteolytic breakdown of casein by whole cell, intracellular and cell wall extracts of probiotic and yogurt bacteria, J. Anim. Sci. Vol. 76 Suppl. 1/ J. Dairy Sci. Vol. 81, Suppl. 1 – abstracts. American Dairy Scoence Association, July 28-31. 1998, Denver, Colorado.
23. T a m i m e, A.Y., K a l a b, M., D a v i e s, G. (1984): Microstructure of set-style yoghurt manufactured from cow's milk fortified by various methods, Food Microstructure, Vol. 3, 83-92.
24. V a n M a r l e, M.E, V a n d e n E n d e, D., D e K r u i f, C.G., M e l l e m a, J. (1999): Steady-shear viscosity of stirred yogurts with varying ropiness, J. Rheology, 43 (6), 1643-1662.

Received July 19, 2002
Accepted October 21, 2002

# UTICAJ SADRŽAJA SUVE MATERIJE, PRIMENJENIH TERMIČKIH TRETMANA I PERIODA SKLADIŠTENJA NA VISKOZITET TEČNOG JOGURTA

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

## R e z i m e

U okviru ovih istraživanja korišćeno je rekonstituisano obrano mleko u prahu sa 8.44% SM, mleko sa 9.65% SM i 10.84% SM.

Za fermentaciju je korišćeno termički netretirano mleko i mleko termički tretirano na 85ºC/20 min i 90ºC/10min. Fermentacija je izvršena na temperaturi od 43ºC, sa dodatkom 2.5% tehničke jogurtne kulture (*Lb. delbrueckii subsp. bulgaricus* i *Str. thermophilus* u odnosu 1:1). Fermentacija je prekinuta pri pH 4.6. Uzorci su zatim brzo ohlađeni na 4ºC i skladišteni na toj temperaturi u toku 14 dana.

Kiseli kazeinski gel je pre merenja viskoziteta razbijan nakon 1, 7 i 14 dana skladištenja na 4ºC. Sva merenja su vršena pri brzini rotacije spindla od 30 obrt/min tokom 2 min, na temperaturi od 20ºC.

[1] Mr Jelena Denin Djurdjević., dr Ognjen Maćej, redovni profesor, dr Snežana Jovanović, docent, Poljoprivredni fakultet, 11081 Beograd-Zemun, Nemanjina 6, SR Jugoslavia

Na osnovu istraživanja može se zaključiti da na vrednost viskoziteta tečnog jogurta dobijenog nakon razbijanja kiselog kazeinskog gela utiču primenjeni termički tretman i sadržaj suve materije. Sa povećanjem suve materije povećava se i viskozitet tečnog jogurta. Najmanji viskozitet je imao jogurt proizveden od termički netretiranog mleka sa 8,44% SM, a najveći jogurt proizveden od mleka sa 10,84% SM.

Primenjeni termički tretmani mleka imali su značajan uticaj na viskozitet tečnog jogurta dobijenog razbijanjem kiselog kazeinskog gela nakon 7 i 14 dana skladištenja. Tečni jogurt dobijen od mleka termički tretiranog na 90ºC/10 min imao je veći viskozitet od uzoraka proizvedenih od mleka termički tretiranog na 85ºC/20 min.

Period skladištenja je uticao i na srednju vrednost viskoziteta tečnog jogurta. Kod tečnog jogurta sa 8,44% SM, srednja vrednost viskoziteta se smanjuje tokom perioda skladištenja bez obzira na primenjeni termički tretman mleka. Najveće srednje vrednosti viskoziteta imali su uzorci proizvedeni od mleka sa 10,84% SM.

Primljeno 19. jula 2002.
Odobreno 21. oktobra 2002.