EFFECT OF ADDITION OF CORN FLAKES ON RHEOLOGICAL BEHAVIOR OF SOME YOGURT

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Abstract: *Yogurt is one of the most consumed fermented milk product in the world due to its benefits for the human body. The purpose of this work is to study the effect of addition of some corn flakes on rheological behavior of different types of yogurts. For this study, the yogurt samples were obtained in the laboratory using the cultures starter DIPROX YBA 986. The effect of addition of corn flakes in yoghurt was investigated by a rotational viscometer, Brookfield viscometer (Brookfield Engineering Inc, Model RV – DV I Prime) with RV spindles. The Brookfield viscometer DV I Prime with disk spindles represents an easily and cheap method for rheological characterization of non-Newtonian fluids, in this case of yoghurt.*

Keywords: *yogurt, viscosity, viscometer, corn flakes*

1. Introduction

Yogurt is produced by a fermentation process during which a weak protein gel develops due to a decrease in the pH of the milk. The pH of the milk is decreased due to the conversion of lactose to acid lactic by the fermentation culture bacteria. In the liquid milk, casein micelles are presented as individual units. As the pH reaches pH 5.0, the casein micelles are partially broken down and become linked to each other under the form of aggregated and chains forming part of a three-dimensional protein matrix in which the liquid phase of the milk is immobilized. This gel structure contributes substantially due to the overall texture and organoleptic properties of yoghurt and gives rise to shear and time dependent viscosity [1].

The most frequent defects related to yogurt texture that may lead to consumer rejection are apparent viscosity variations and the occurrence of syneresis [2].

Yogurt rheological characterization is required for product and process development and to ensure consumer acceptability [3]. This characterization can be made using either instrumental or sensory measurements.

The firmness of yogurt and the viscosity of just-stirred gel are greatly influenced by the amount of heat treatment the yogurt mix receives. Heating unfolds the globular whey proteins and exposes sulphydryl groups, which react with other sulphydryl groups and disulfides and induce linkages and protein-casein aggregates [4-5].

The gel strength of yogurt is related to the cumulative effects of the chemical interactions. The binding of δ-lacto globulin to the casein micelle seems to be responsible for the increase of gel strength [6, 7, and 8].

Cereals constitute the staple food of the human race. In many countries, they are mainstay of life and form the single largest component in their daily diet. Ready-to-eat (RTE) cereals are processed grain formulation suitable for human consumption without requiring further processing or cooking. Corn flakes are possible the most common form of breakfast cereals [9].
In the final step, the cereal is treated to restore vitamins lost through cooking and is often coated with sweet flavourings to make it more attractive [10].
Toasting is an important processing step for the manufacture of breakfast cereals that dictates the attributes of RTE corn flakes that are usually characterised by their unique crispness and maintaining the integrity while consuming with milk. These attributes are critical for the acceptance of the product by the consumers [11].

2. Materials and methods

2.1. Materials
UHT milk, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* pure starter culture DI PROX 986 provided by Enzymes & Derivates, Piatra Neamț, România, corn flakes from the market; orbital shaker; thermostat; Brookfield viscometer Model RV- DV II Pro, with disk spindle, RV3, RV4, RV5, RV6 type.

2.2. Sample preparation
The yogurt samples were made using UHT milk, having the physical and chemical parameters in Tabel 1.

Tabel 1.
Milk properties

	10,5%
Fat, g/100g	3
Protein, g/100 g	3
Sugar, g/100g	4.5
Ash, %	0.72
Acidity, ^{0}T	18

300 mL milk was inoculated using 0.015 g starter culture. After inoculation with starter culture, the sample were homogenised with an orbital shaker for 15 min at 100 rpm. After shaking the sample were thermostated at 42^{0}C for 6 hours. The corn flakes were added in the next concentration to the yogurt sample: 0, 1.5 g (S1), 2 g (S2), 2.5 g (S3), 3 g (S4).

2.3. Determination of rheological properties

Viscosity measurements were carried out on the yogurt samples at ambient temperature (25^{0}C), with a Brookfield viscometer (Brookfield Engineering Inc, Model RV- DV II Pro+) at 2,5; 5; 10; 20; 50; and 100 rpm with RV spindle (RV3, RV4, RV5, RV6 type). The spindle nos was used in accordance with the sample nature to get all readings within the scale [12].
The samples in 300 mL of beaker with a 8,56 cm diameter (according to the Brookfield requests) were kept in a thermostatically controlled water bath for about 10 min before measurements in order to attain desirable temperature of 25^{0}C.
First measurements were taken 2 min after the spindle was immersed in each sample, so as to allow thermal equilibrium in the sample, and to eliminate the effect of immediate time dependence.
All data were then taken after 40 s in each sample. Each measurement was duplicated on the sample.
The obtained empirical data were converted using the Mitschka relationships to shear rate and shear stress. The shear rate versus shear stress data were interpreted using the power law expression

$$\sigma = k \cdot \gamma^n \qquad (1)$$

where:
σ – shear stress (N/m^2),
γ is the shear rate (s^{-1}),
n is the flow behaviour index, *k* is the consistency index (Ns^n/m^2).

The values for the flow behaviour index n, were obtained from plots of log shear stress versus log rotational speed; the slope of the line (if the

dependence is sufficiently close to a linear one) is simply equal to the flow index of the fluid, *n*.
The shear stress is calculated using the next equation:

$$\tau_i = k_\tau \cdot \alpha_i \cdot C \qquad (2)$$

where:

τ_i – shear stress (dyne/cm^2)

k_τ = 0.119, this constant is for the spindle nos 2

α_i – torque dial, %

C – 7,187 dyne/cm for RV viscometer

The shear rate is calculated using the next equation:

$$\gamma_i = k_\gamma(n) \cdot N_i \qquad (3)$$

where:

γ_i – shear rate, s^{-1}

$k_\gamma(n)$ – constant, depends by the value of n

N_i – rotational speed, rpm.

3. Results and discussion

The yogurt samples exhibited a non-Newtonian behaviour, the flow index (*n*) is under 1 for all the samples. The power law model is a suitable one for predicting the rheological parameters, the regression coefficient is near 1 (R^2>0.95) – see table 2.

In general, addition of corn flakes increases the viscosity of yogurt in proportion to the dose added. This is due to its high starch corn flakes. It achieved a stabilization of aqueous dispersions whose continuous phase is the water and the dispersed one is solid or liquid and tends to separate. Through addition of starch, the viscosity is increased and is yogurt reduces the tendency of destabilization by separation of components.

Table 2.
Power law parameters of yogurt samples

Sample	n – flow index	K – consistency index (Ns^n/m^2)	R^2
S1	0.903	4010	0.986
S2	0.843	6420	0.959
S3	0.567	24340	0.970
S4	0.357	32100	0.985

The starch improved the rheological properties of the corn flakes yogurt samples, due to the water-bind capacity, high molecular weight and due to the forming of the casein-starch system, the water-bind capacity. Various studies have reported the existence of phase separated networks in casein–polysaccharide mixtures [13, 14], and the amylopectin-casein system in particular [15], but not in the samples with low levels of amylopectin added.

Depending on the weight ratio of the two biopolymers in the mixture, as well as their relative affinities for water, a casein–starch system may either have the protein or the polysaccharide-rich domain forming the continuous phase, with the second component dispersed as the discontinuous phase. As a result, only a fraction of the total water content will be available to one biopolymer phase (e.g. casein), with theremaining water being bound by the second phase (e.g.starch) [16].

All viscosity samples increased with the increasing of corn flakes quantity, as shown in figure 1. The flow index decreased with the increasing of corn flakes doze, while the consistency index decreased with the increasing of the doze.

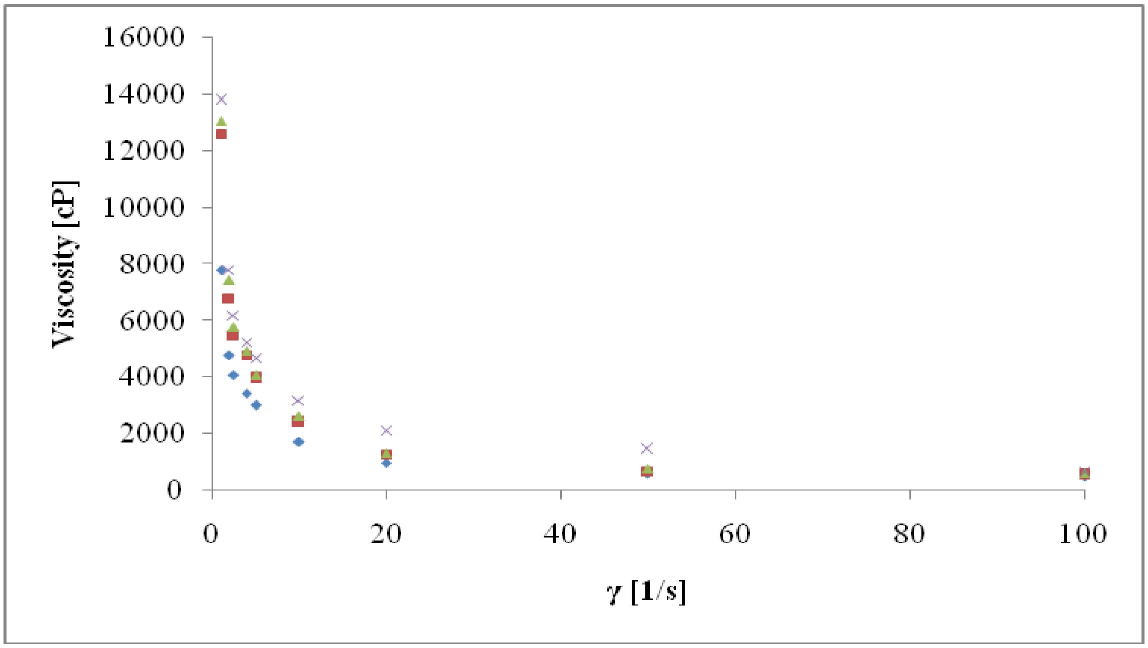

Figure 1. Viscosity profile of yogurt sample with corn flakes (cross - 1.5 g corn flakes, triangle - 2 g corn flakes, square - 2.5 g corn flakes, rhombus - 3 g corn flakes)

4. Conclusion

The yogurt is a complex viscous food material due to the complexity of its nature and composition. Rheological behavior of yogurt is influenced by sugars, fats and water.

The Brookfield viscometer DV I Prime with disk spindles represents an easily and cheap method for rheological characterization of non-Newtonian fluids, in this case of yogurt.

In the case of yogurt samples obtained in the laboratory, the addition of corn flakes increases the viscosity, proportional to the doses added. This is due to its high starch corn flakes, which carries stable aqueous dispersions whose continuous phase is and the dispersed one is solid or liquid and tends to separate. By means of starch addition, yogurt viscosity is increased and reduces the tendency to destabilize the separation of components.

5. References

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