EFFECT OF ADDITION OF STARCH AND AGAR-AGAR ON RHEOLOGICAL BEHAVIOUR OF YOGURT

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Received 12 February 2011, accepted 5 March 2012

Abstract: *The purpose of this work is to study the effect of addition of starch and agar-agar on the rheological behaviour of different types of yogurts. The most common technique used for rheological liquids is Viscometers, measuring shear strength, described by the coefficient of viscosity. For this study, the yogurt samples were obtained in the laboratory using the cultures starter DIPROX YBA 986. The effect of addition of starch and agar-agar 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 easy and cheap method for rheological characterization of non-Newtonian fluids, in this case of yoghurt. The cluster analysis was performed using Unsrambler X version 10.1 (CAMO Process As, Oslo, Norway, 2005), all the rheological and physicochemical parameters were weighetd and normalized for performing the cluster analysis. In the case of yogurt samples obtained in the laboratory, the addition of starch and agar-agar increases the viscosity, proportional to the doses added. The results of cluster analysis shows that the samples with agar added are in the same group, while the sample with 12.04 g starch is much appropiate to the samples with agar-agar then with the sample with 10.61 g starch.*

Keywords: *yogurt, viscosity, viscometer, starch, agar-agar*

1. Introduction

For processed food the composition and the addition of ingredients to obtain a certain food quality and product performance requires profound rheological understanding of individual ingredients, their relation to food processing, and their final perception [1].

Yogurts are dairy products obtained by fermentation with lactic acid bacteria during which a weak protein gel develops due to a decrease in the pH of the milk. Following the fermentation of lactose lactic acid is formed causing the coagulation of milk proteins (casein) to form a gel-like structure, in which fat globules and the aqueous phase are embedded [2]. 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 [3].

The gel strength of yogurt is related to the cumulative effects of the chemical interactions [4].

For yoghurt production a variety of gums is being used with more functional roles:

- they give the product the rheological and organoleptic characteristics desired in acidic pH conditions;

- prevent the process of syneresis;

- they participate in gel formation in the case of gelificate yoghurt;

-they are designed to promote formation of a structural network by interacting with compounds of structural constituents of milk and fermentation products.

Agar is extracted from red algae. Agar is unique among gums in the sense that gelling occurs at temperatures much lower than the temperature at which agarose gels melt. Agar is compatible with many polysaccharides and proteins, in the sense that when their dispersions are mixed flocculation or other degradations do not occur.

Starch is a complex food hydrocolloid (polymer of α-D-glucose and partially crystalline polymer). Starch granules absorb water resulting in swelling up to several times their original size and lose their crystallinity. The complete process is known as gelatinization. Gelatinization of starch involves changes in amylase and amylopectin [5]. It has been reported that amylase undergoes aggregation at a much more rapid rate than amylopectin does[6].

Starch gelatinisation involves the following steps:

- reversible hydration and swelling of the granules;

- loss of birefringence in pasting temperature;

- increasing the transparency of the paste;

- the rapid increase in viscosity and achievement of maximum viscosity;

- leaching of linear molecules of amylose fully hydrated and circulated through the grain;

- the cooling takes place with formation of gelatinised starch retrogradation pasta, and then a gel.

An elevated starch concentration enhanced the strength of the custard gels considerably [7].

The most frequent defects related to yogurt texture that may lead to consumer rejection are apparent viscosity variations and the occurrence of syneresis [8].

Yogurt rheological characterization is required for product and process acceptability [9]. 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 [10, 11].

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 [12, 13, 14].

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 Neamţ, România; commercial starch, agar-agar provided by Enzymes & Derivates, Piatra Neamţ, România; orbital shaker;

thermostat; Brookfield viscometer Model RV- DV II Pro, with disk spindle, RV3, RV4, RV5, R V6 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

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

Tabel 2.
pH of yogurt samples

Sample	pH
S1	4.0
S2	4.5
A1	4.2
A2	4.0
A3	4.5

300 mL milk was inoculated using 0.015 g starter culture. After inoculation with starter culture, the samples were homogenised with an orbital shaker for 15 min at 100 rpm. After shaking the samples were thermostated at 42^{0}C for 6 hours. Starch and agar-agar were added in the next concentration to the yogurt sample: 10.61 g starch (S1), 12.04 g starch (S2), 0.27 g agar (A1), 0.3 g agar (A2) and 0.33 g agar (A3). The pH of the yogurt samples are in table 2.

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 0.5, 1, 2, 2.5, 4, 5 and 10 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 [15].

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 - the shear rate (s^{-1}),

n - 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.

2.4 Statistical analysis

The cluster analysis was performed using Unsrambler X version 10.1 (CAMO Process As, Oslo, Norway, 2005), all the rheological and physicochemical parameters were weighetd and normalized for performing the cluster analysis.

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.

Table 2.
Viscosity, flow index, consistency index and regression coefficient for yogurt samples

Sample	Viscosity * [cP]	n–flow index	K-consistency index [Ns^n/m^2]	R^2
S1	42231	0.63	27831	0.982
S2	106000	0.96	48317	0.96
A1	91900	0.86	46770	0.989
A2	97899	0.78	54213	0.985
A3	125000	0.81	69153	0.995

*Viscosity was measured at 0.5 1/s

In general, addition of starch increases the viscosity of yogurt in proportion to the dose added, as shown in figure 1. 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 the tendency of destabilization by separation of components is reduced.

The starch improved the rheological properties of the 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 [16, 17], and the amylopectin-casein system in particular [18], 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 the remaining water being bound by the second phase (e.g.starch) [19].

It seems that the addition of hydrocolloids (starch or agar-agar) lead to an increasing of consistency index (tab. 2), while the flow index increases in the case of additio of starch but in the case of agar agar it is not observed an increasing or decreasing of this parameter.

In figure 1 and figure2 is presented the evolution of viscosity with the two hidrocolloid with concentration of it and shear rate. The highest the concentration of hydrocolloid, the highest is the viscosity.

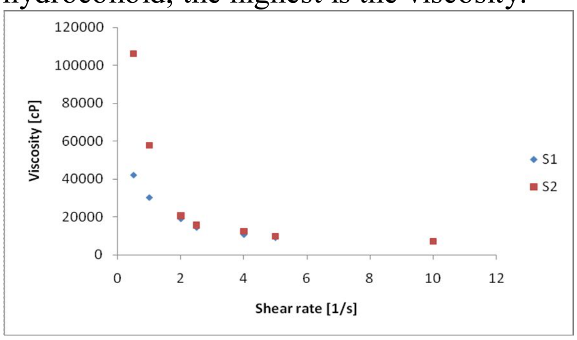

Figure 1. Viscosity profile of yogurt sample with starch (S1 – 10.61g starch, S2 – 12.04 g starch)

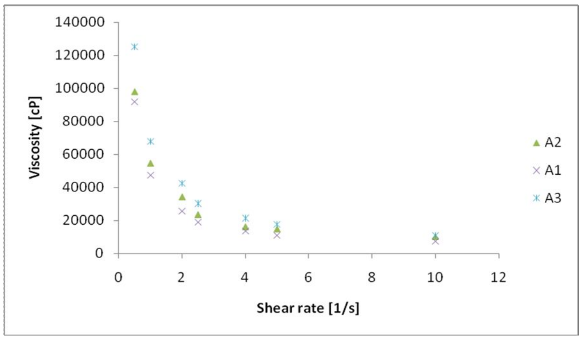

Figure 2. Viscosity profile of yogurt sample with agar-agar (A1 – 0.27 g agar, A2 – 0.3 g agar, A3 – 0.33 g agar)

The results of cluster analysis shows that the samples with agar added are in the same group, while the sample with 12.04 g starch is much appropiate to the samples with agar-agar then with the sample with 10.61 g starch.

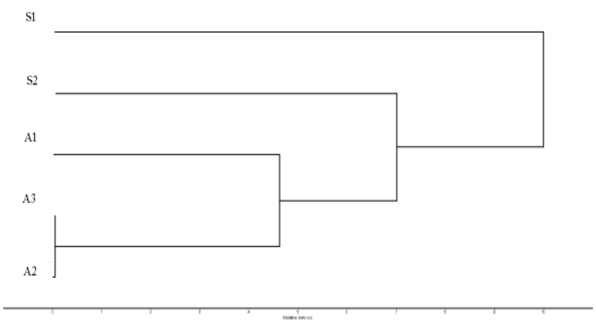

Figure 3. Diagram of yogurt samples clustered according to rheological and physicochemical properties

4. Conclusion

Due to large molecular sizes, to the specific configuration, the charge and possible formation of intra- and intermolecular links, gums are able to reduce water mobility. This reduction in water mobility increases the viscosity of gum solutions in water.

In the case of yogurt samples obtained in the laboratory, the addition of starch and agar-agar increases the viscosity, proportional to the doses added. Starch carries stable aqueous dispersions whose continuous phase 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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