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RHEOLOGICAL AND TEXTURAL PROPERTIES OF GOAT'S MILK AND MIXTURE OF GOAT'S AND COW'S MILK FRUIT YOGURT

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Abstract. Yogurt rheological and textural parameters are known to have an important impact on food quality and acceptability. The paper includes the determination of the viscoelastic and textural parameters of goat's milk and cow's milk yogurt in terms of physico-chemical indices and technological properties. Two series of yogurts were prepared: series I of goat's milk and cow's milk 50:50 (5 samples) and series II of 100% goat's milk (5 samples), adding the aronia, strawberries, raspberries, peaches using classical technology. Texture parameters with higher values were obtained for yogurt of first series due to the presence of casein fractions specific to cow's milk. Added fruits to yogurt have had a positive impact on texture indices, due to contained hydrocolloids that confer thickening, stabilizing, gelling and emulsifying properties to food products. Due to the organic acids contained in fruits, the pH of yogurt is lower, so the voluminosity of casein micelle increases at lower pH value due to increased hydration, possitivly influensed the viscosity parameters. Manufacture of yogurt from goat's milk and cow's milk induced stronger yogurt gel (series I), due to a higher content of α casein in cow's milk compared to goat's milk. The viscoelastic characteristics of yogurt samples, show that G′ is higher than G″ during the entire frequency range. The added fruits to yogurt influence the viscoelastic parameters more through some components present in their composition: The higher dry matter content in the yogurt samples with the addition of aronia, respectively indicates the higher values for the parameters G' and G'', namely for the yogurt of the second series.

Keywords: *yogurt, rheological parameters, textural parameters, casein fractions, heat treatment of yogurt, starter cultures of yogurt, dairy gels.*

Introduction

The improved rheological properties of food products positively reflect on the course of the technological process and on the product quality, [1].

Texture is an essential quality indicator in assessing the yogurt quality. For foodstuffs, according to ISO, texture represents all the rheological and structural attributes perceptible by mechanical, tactile and, where appropriate, visual receptors, [2].

Rheology is the science that studies the interdependence between mechanical stress, the response of bodies and their properties, yogurt gel formation and rheological properties (viscosity, elastic and viscous modulus, texture), [3]. Yogurt gel formation can be followed and studied without affecting the structure of the gel by dynamic rheology methods at low oscillations, [4].

Methods based on small deformations applied in an oscillating manner are frequently used to study the formation process and the gels properties, [4]. The dynamic response of viscoelastic fluids to oscillatory stimuli is characterized by two basic indices - the storage elastic modulus G' and the loss elastic modulus G''.

The components used in this case are: the components of the complex modulus of elasticity (elastic modulus, G' and the viscous modulus, G'') and the tangent of the loss angle (tg δ), defined as the ratio between the elastic component and the viscous component for a viscoelastic body. In the case of dairy gels, the elastic modulus G' characterizes the energy conserved by the deformation cycle and the gel firmness, which is determined by the protein-protein interactions, [5, 6]. High values of elastic modulus indicate high gel firmness, [4].

The G' and G'' curves shape depends on the material characteristics, but also on the values of the independent variables covered by the measuring device (frequency, time, temperature, effort).

To identify the gel formation time, the G' value evolution as a function of time is measured. Some authors consider the gelation point when the modulus of elasticity reaches 1 Pa [7], other authors - 0.1 Pa, [8, 9].

Based on the modeling curves experimentally obtained, the calculation of the gelation time is performed. If the acidification curve is also established, the gelling pH value can be assessed. The knowledge of dynamic properties such as G' and G'' allows the estimation of the other linear viscoelastic properties as well as the behavior of the fluid in other types of deformations such as stretching, [3].

The aim of paper is to investigate the viscosity of goat's milk and mixture of goat's and cow's milk yogurt with the addition of scald fruit.

The raw materials used, due to the different chemical composition, predict different results for the rheological properties of the end product. Classic goat milk yogurt has a less consistent coagulum compared with cow milk yogurt, [10].

The most common method for improving the texture of different yogurts is increasing milk total solids (TS) content, which can be achieved via evaporation or by the addition of skim milk powder, milk proteins or thickening agents, [11, 12] or hydrocolloids such as xanthan gum, carrageenan, guar gum and pectin, are hydrophilic polymers commonly used to confer thickening, stabilizing, gelling and emulsifying properties to food products, [13]. Such hydrocolloids could be content in fruits, that besides functional properties may positively influence the viscosity of yogurt.

The goat milk fat globules are 1/5 of the size of the cows' milk, they have a better dispersion and make a more homogeneous mixture. It consists of several different components, including glycoproteins, non-polar lipids, phospholipids and sphingolipids, all contributing to the nutritional and technological aspects of fat globulin membrane components, [14, 15, 16, 17]. The goat's milk fat is more easily digestible, and can be considered an important source used in various metabolic processes, and even for combating some metabolic diseases, [17, 18, 19].

Goat milk proteins are more easily digestible than cows' milk proteins. Goat milk has lower casein content and a lower coagulation capacity. This difference in coagulation power is attributed to low levels of α_{s1}-casein in goat milk compared to cow's milk, being a key reason for goat's milk to be considered as more easily digested than cow's milk. 96% of goat milk casein is hydrolyzed, compared with 76 - 90% casein from cow's milk. The result is attributed to the higher level of β-casein and a lower level of α_{s1}-casein in casein of goat milk, [17, 20].

Due to well-balanced chemical composition, curative properties, fine curd formation and high digestibility goat milk perfectly fit for dairy products manufacture, such as yogurt, that can highlight all its beneficial properties, [17].

Rheological properties of yoghurt are determined by their production conditions and composition. If there is any disturbance in the balancing of milk components, then it directly impacts on the rheological properties of prepared yoghurt, [21, 22, 23].

Materials and methods

Materials

- ✓ Goat milk was carried out at a local farm, according to Moldovan standard: 2015 Goat and sheep raw milk. Specifications. This standard establishes technical conditions for the raw goat milk quality collected for industrial processing.
- ✓ Raw cow milk, obtained from local farm was received according to Guvernamental Decision No. 158, on 07.03.2019 with regard to the approval of the Technical Regulation "Milk and dairy products" that included technical conditions for the quality of raw cow milk collected for industrial processing. The milk was pasteurized and standardized to a fat content of 2.5%
- ✓ Starter culture, containing *Lactobacillus delbrueckii ssp. Bulgaricus and Streptococcus salivarius ssp. thermophillus* ready for direct vat inoculation were used for yogurt preparation.
- ✓ Whole milk powder 26%, according to Guvernamental Decision No. 158, on 07.03.2019 with regard to the approval of the Technical Regulation "Milk and dairy products"
- ✓ Fruits: aronia, peach, raspberry, strawberry, of local production, preserved as a puree, according to requirements of Guvernamental Decision No. 221 of 16.03.2009 on the approval of the Rules on criteria microbiological for all use.
- ✓ Sugar, according to the requirements of Guvernamental Decision No. 774, technical regulations “Sugar. Production and marketing”.

Yogurt preparation.

The milk was pasteurized (85-90°C/30 min), cooled to 45 °C and inoculated with 1.5% starter culture consisting of Lactobacillus delbrueckii ssp. bulgaricus and Streptococcus salivarius spp. thermophilus. The 10% content of scald fruits of chokeberry, peach, raspberry, strawberry was added in the yogurt. The yogurt samples were packaged in 180 g containers and thermostated at 37°C for 6 hours, [24]. The end of the coagulation process was determined by the pH value and firmness of the coagulum. After the packed product was chilling, cooling and stored at 6±2°C.

Table 1

Notify the probe

Sample code	Sample description
	Series I
P1	Goat milk 50% + cow milk 50%, classic yogurt
P2	Goat milk 50% + cow milk 50% + aronia
P3	Goat milk 50 % + cow milk 50% + peach
P4	Goat milk 50% + cow milk 50% + raspberry
P5	Goat milk 50% + cow milk 50% + strawberry
Series II	
P6	Goat milk 100% , classic yogurt
P7	Goat milk 100% + aronia
P8	Goat milk 100% + peach
P9	Goat milk 100% + raspberry
P10	Goat milk 100% + straspberry

Methods

Texture evaluation. The sample was placed in a cylinder 60 mm high and 50 mm in diameter where a double compression was performed. The cylindrical part was inserted into the sample at a distance of 15 mm. The applied force is 7g. Test speed of 1 mm / s, withdrawal speed of 1 mm / s. Between the two compressions the sample was left to rest for 3 seconds, [25].

Evaluation of the yogurt viscosity. The viscosity dynamics was investigated at consumption temperature of 4 °C. The plate where the sample will be placed is cooled to 4 °C, after which the drop of yogurt placed in the center is also cooled to the consumption temperature. Place the conical geometry over the sample and apply a friction force from 0.1 Hz to 10 Hz. The data is stored in an electronic program, after which it can be processed in Microsoft Office Excel, [26].

pH was determined using a pH meter TESTO 205.

Total dry matter content. Method for determining the content of dry substance in the MAC moisture analyzer consists of a sample with IR drying the aluminum support on the machine until a constant weight of the residue dried, [27].

Statistical analysis. Variance analysis of the results was carried out by least square method with application of Microsoft Office Excel program.

Results and discussions

The rheological properties of fermented dairy products are influenced by several technological factors: heat treatment temperature, cooling process and type of starter cultures used (temperature and duration of fermentation), [28].

The operating temperature should be close to 95˚C. Dannenberg and Kessler (1988) showed the close relationship between the rheological properties and the degree of β-lactoglobulin denaturation: between 60 and 90%, the firmness of the gel obtained increases considerably. Depending on the heating process and the heat intensity, a proportion of β-lactoglobulin and α- lactalbumin is bound to the casein. This determined the rheological properties of yoghurt, [29, 30].

On the other hand, the heat treatment of milk is used to destroy unwanted microorganism, which provides less competition for the starter culture. In this way helps to remove dissolved oxygen assisting starter growth because of yogurt starter cultures are sensitive to oxygen, [31].

Cooling also increases the gel firmness, [32]. Upon cooling, the hydrophobic bonds between casein are gradually replaced by non-covalent bonds such as hydrogen, dipole and electrostatic bonds, which are responsible for increasing the gels firmness, [33].

Table 2

pH value during fermentation of yogurt

Sample	Time, h			
	Initially	**2**	**4**	**6**
		Ist series		
P1	6,25±0.2	6,25±0.2	6,25±0.2	6,25±0.2
P2	6,24±0.1	6,24±0.1	6,24±0.1	6,24±0.1
P3	6,07±0.2	6,07±0.2	6,07±0.2	6,07±0.2
P4	5,83±0.2	5,83±0.2	5,83±0.2	5,83±0.2
P5	5,94±0.1	5,94±0.1	5,94±0.1	5,94±0.1
		II^d series		
P6	6,28±0.1	6,28±0.1	6,28±0.1	6,28±0.1
P7	6,1±0.1	6,1±0.1	6,1±0.1	6,1±0.1
P8	6,03±0.1	6,03±0.1	6,03±0.1	6,03±0.1
P9	5,55±0.1	5,55±0.1	5,55±0.1	5,55±0.1
P10	5,75±0.2	5,75±0.2	5,75±0.2	5,75±0.2

The microorganisms in the starter culture determine the subsequent viscosity of the finished product. The exopolymers produced by the bacteria are often the cause of a yogurt flowing structure or a hard lactic gel.

For an optimal fermentation process, it is recommended to observe the temperature regime indicated by the manufacturer, specific of the used starter cultures type, because prolonged fermentation at a low temperature leads to a decrease in the finished product viscosity.

At a temperature of ~ 45 °C, the viscosity becomes higher due to the increase in the amount of exopolysaccharides, [34].

The activity of the starter culture was analyzed according to the pH values obtained during the fermentation period, table 2.

The obtained pH values are specific to the microorganisms type in the starter culture used, according to their growth curve and support the full lactic gel formation.

The yogurt with the addition of raspberries and strawberries in both series showed lower pH values compared to the classic yogurt, due to the content of organic acids in those fruits, which, however, do not differ significantly towards the end of the fermentation process.

The dry matter plays an important role in forming the texture of the finished product. When total solids content is increased, the intensity of the attractive forces between the casein micelles decreases, increasing the waterholding capacity and decreasing gel shrinkage, porosity, and natural syneresis, [35, 36, 10].

The added fruits, due to the high fiber content and the hydrocolloid content, respectively, are meant to improve this parameter, although the scalding step, performed incorrectly, can increase the water content in the finished product, [38]. In table 3 an increase in the dry matter content is observed only for some samples of fruit yogurt shared with the classic yogurt, namely, 24.24% yogurt with aronia, 26.56% yogurt with raspberries. The dry matter content in the fruit samples is higher compared to the control sample.

Table 3

Yogurt solids

Quality indicator	Sample				
	I[st] series				
	P1	**P2**	**P3**	**P4**	**P5**
Dry matter, %	18,63±0.2	24,24±0.02	22,98±0.02	26,56±0.1	18,78±0.01
	II[d] series				
	P6	**P7**	**P8**	**P9**	**P10**
	15,27±0.02	25,86±0.02	17,88±0.03	18,05±0.02	16,19±0.01

Texture represent a set of mechanical, geometric and surface properties of a food or food raw material, perceptible by tactile or mechanical receptors and, sometimes, visual and auditory. The mechanical properties are those related to the reaction of the product to the constraint, being divided into five primary characteristics: hardness, cohesiveness, viscosity, elasticity and adhesiveness and 3 secondary characteristics: fracturability, chewability and gumminess, [37].

The stickiness and adhesiveness of yogurt are usually most often determined by the used starter culture type and the addition of fruit, because the sugar content of the additives and the exopolysaccharides released by bacteria form a more or less viscous lactic gel. The content of these substances together with proteins, influences the dry matter of the product, [38].

Yogurt of series I, for texture parameters showed much higher values than yogurt of series II, which coincides with the total dry matter content, respectively the quality of the formed curd, due to the presence of casein fractions specific to cow's milk.

Fruits added to yogurt have had a positive impact on texture indices, possibly also due to the hydrocolloids contained that confer thickening, stabilizing, gelling and emulsifying properties to food products [12, 13], and polyphenols due to their binding with proteins, [12, 39].

Hardness/firmness and adhesiveness values of the yogurt samples containing scald fruits are shown in table 4.

Yogurt gels are a type of soft solid, and these network are relatively dynamic system that are prone to structural rearrangements, [31]. Gel formation can be monitored without affecting its structure, by dynamic rheology methods at small oscillations. For fluids that do not reach an equilibrium deformation, the degree of deformation changes continuously over time. The viscosity of gels, like yogurt, is non-Newtonian. Decreased viscosity with increasing shear rate is typical for acidic dairy gels, [21].

The fruits added to yogurt influence the viscoelastic parameters more through some components present in their composition, [40 - 42].

The higher dry matter content of the yogurt samples with the addition of aronia berry and peach indicates, respectively, higher values for parameters G' and G'', namely for yogurt series II (100% goat's milk).

Table 4

Evaluation of yogurt texture

Sample	Gumminess H*A2/A1	Firmness	Adhesiveness N*s	Stickiness
		I^st^ series		
P1	27.4±0.01	28±0.01	94.2±0.02	14.5±0.02
P2	27.9±0.03	28±0.01	94.1±0.02	14.6±0.01
P3	33.3±0.02	30±0.03	119.7±0.01	15.1±0.01
P4	42.1±0.01	35±0.01	174.7±0.02	18.1±0.03
P5	40.4±0.01	35±0.01	162.3±0.02	18.2±0.01
		II^d^ series		
P6	15.0±0.02	19±0.03	20.1±0.01	11.1±0.03
P7	13.4±0.01	18±0.01	11.2±0.03	8.6±0.01
P8	19.5±0.02	23±0.02	25.3±0.02	11.1±0.04
P9	21.1±0.03	24±0.02	36.2±0.01	11.6±0.01
P10	16.2±0.02	20±0.02	16.1±0.01	9.9±0.02

Due to the organic acids contained in, the pH of yogurt is lower, so the voluminosity of casein micelle increases at lower pH value due to increased hydration.

Analyzing the curves in figures 1 - 4, all yogurts exhibited viscoelastic characteristics, with G′ being higher than G″ during the entire frequency range, results obtaind also by Zhihua Panga et al., 2019. Module G' is responsible for the firmness of the gel formed by protein-protein interactions, [5].

Manufacture of yogurt from goat's milk and cow's milk induced stronger yogurt gel (series I), which is in agreement with the results from the curve in figure 1 - 4, due to a higher content of α casein in cow's milk compared to goat's milk, [43].

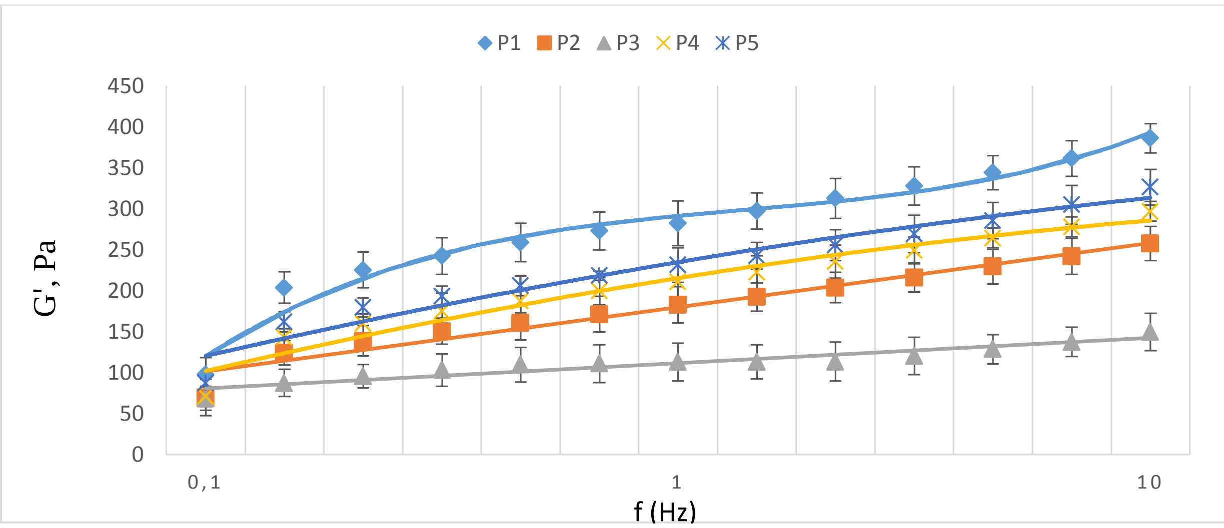
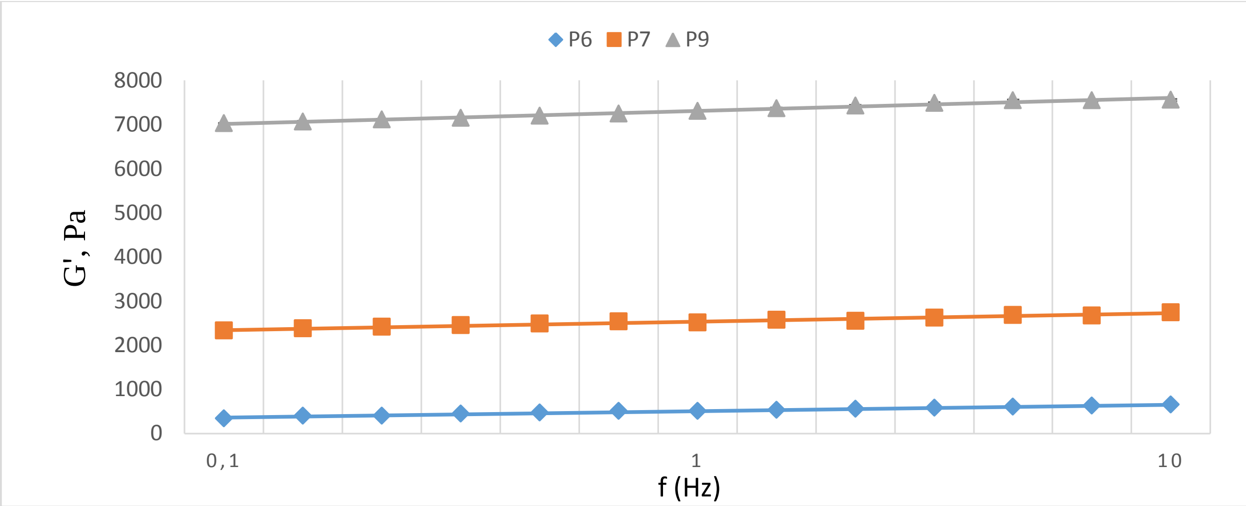
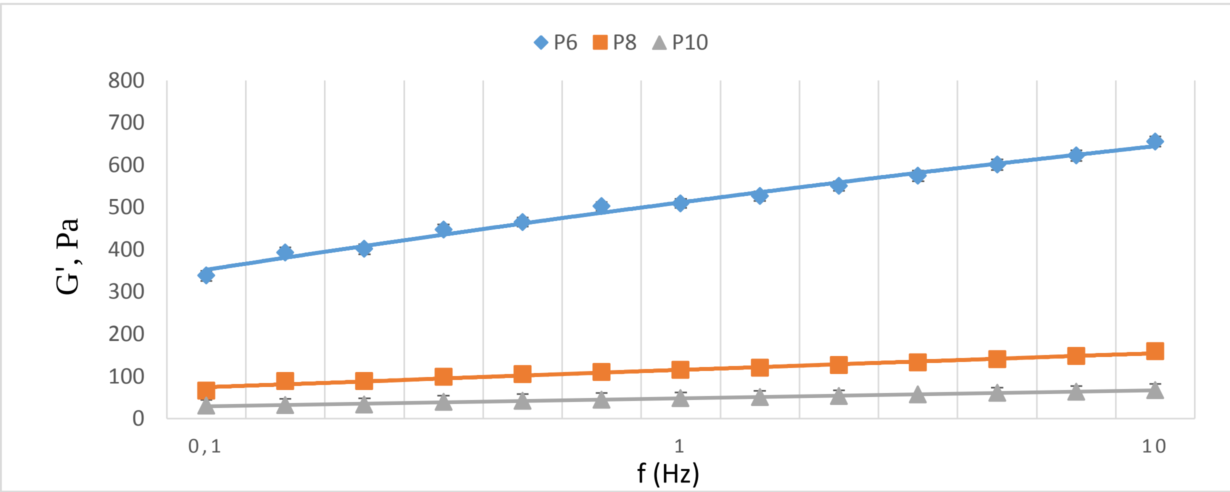


Figure 1. Viscoelastic parameters (G') from frequency of yogurts, series I.



(a)



(b)

Figure 2. Viscoelastic parameters (G') from frequency of yogurts, series II, (a, b).

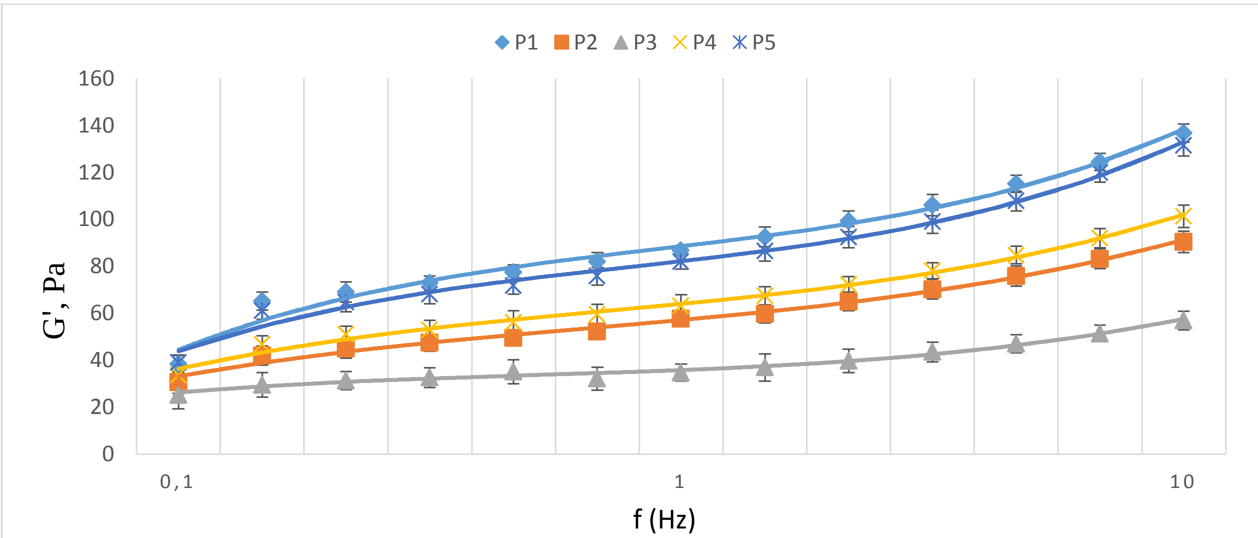


Figure 3. Viscoelastic parameters (G'') from frequency of yogurts, series I.

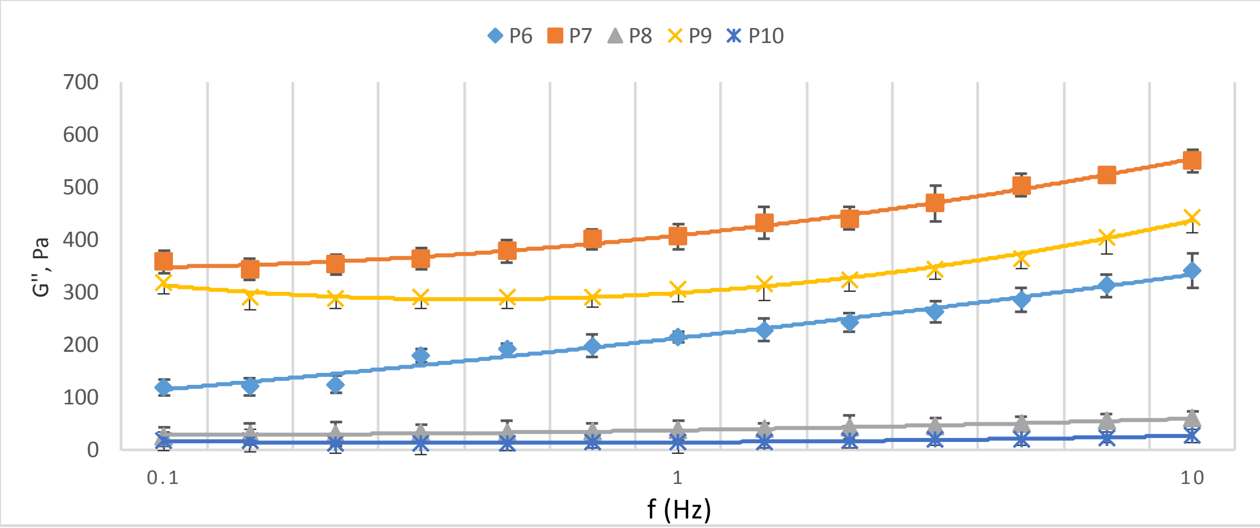


Figure 4. Viscoelastic parameters (G'') from frequency of yogurts, series II

In the case of dairy gels, the elastic modulus G' characterizes the energy conserved by the deformation cycle and the firmness of the gel, which is determined by the protein-protein interactions. The formation of the curves G' and G'' depends on the characteristics of the material, but also on the values of the independent variables, covered by the measuring device (frequency, time, temperature, effort), [44].

Conclusions

The fermented dairy products rheological properties are influenced by several technological factors: heat treatment temperature that should be close to 95˚C, cooling process that increases the firmness of the gel and type of starter cultures used (temperature and duration of fermentation).

The added fruits, due to the content in dietary fiber, improved the quality parameters, there is an increase in the dry matter content for fruit yogurt samples compared with classic yogurt, an increase in the dry matter content is observed for samples of yogurt with aronia berry and yogurt with raspberries for both series.

Yogurt of series I, for texture parameters, showed much higher values than yogurt of series II, due to the presence of casein fractions specific to cow's milk. Fruits added to yogurt have had a positive impact on texture indices, due to the content of dietary fiber and hydrocolloids contained that confer thickening, stabilizing, gelling and emulsifying properties to food products.

Analyzing viscoelastic parameters, all yogurts exhibited viscoelastic characteristics, with G′ being higher than G″ during the entire frequency range. Manufacture of yogurt from goat's milk and cow's milk induced stronger yogurt gel (series I) in comparation with goat milk yogurt, due to a higher content of α casein in cow's milk compared to goat's milk. The value of viscoelastic parameters was improved in goat's milk yogurt by adding scald fruits. The yogurt with aronia berry and yogurt with peach of series II indicates higher values for parameters G' and G''.

In the context of goat's milk valorization in yogurt with a well-formed lactic gel, it is recommended to use scalded aronia, raspberry and peach fruits, that besides increasing the biological value of the product have a visible positive effect on the rheological and textural properties of the end product.

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