

**ANALYSIS OF STRUCTURE-MECHANICAL PROPERTIES OF ACIDOPHILUS
BEVERAGE USING WHEY PROTEIN CONCENTRATE**

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Abstract

Rheological methods enable to determine the analytical dependences of dairy food quality and its structure-mechanical properties. The objective physical quantity can be used in technological process control and product assurance. The main rheological properties (shearing stress, effective viscosity factor, flow index, thixotropy coefficient) of acidophilus beverages with different rates of whey protein concentrate at different degree of temperature are analyzed. The process of structure alteration of acidophilus beverage under mechanical effect with increase (load) and decrease (unload) of deformation velocity gradient is studied. It is determined that the usage of whey protein concentrate in acidophilus beverages controls structure formation process, helps to produce the product with stable qualitative characteristics and high biological value.

Key words: acidophilus beverage, whey protein concentrate (WPC) produced on the basis of ultrafiltration method, structure-mechanical properties, structure formation, shearing stress, effective viscosity factor, flow index, thixotropy coefficient.

1. INTRODUCTION

Acid coagulation of casein is one of the main processes to determine the cultured milk product consistence and structure. Acid coagulation is based on the isoelectric caseation under the influence of lactic acid, generated on the fermentation microflora activity of the milk. The process of casein acid coagulation results in formation of coagulatory-condensation space structures. Mechanism of its formation:

- the alteration of milk pH rate interrupts stability of casein micelles;
- the unstable asymmetrical mosaic particles with hydrophilic and hydrophobic properties are formed;
- emerge the casein macromolecule aggregates that are the elements of shaping structure; structure strength is almost absolute zero;
- structural strength increases and it results in coagulatory-condensation structure of solid.

The gradual accumulation of lactic acid and no shaking cause the formation of compact and smooth structure. The acid coagulation structure contains both disintegrating-nonreciprocal and thixotropic-reciprocal bindings. The structure-mechanical properties (viscosity, strength, resilience, elasticity) depend on the correlation between these binding [6].

The speed of acid coagulation and structure-mechanical properties are determined by mass fraction of protein, fat, solid, amount of bacterial fermentation and its composition, heat processing practices and homogenization.

The analysis of structure-mechanical properties of the final product helps to evaluate the product quality and control structure production data [1, 2, 3, 4, 5, 7].

The article analyzes the structure formation of acidophilus beverages with usage of whey protein concentrate, produced by ultrafiltration method (WPC), for the purpose of final product consistence improvement and high biological value.

2. MATERIALS AND METHODS

2.1. Basic materials

Whole cow's milk, total solid ($11,8 \pm 0,5$) %, including mass fraction of fat ($3,4 \pm 0,5$) %, mass fraction of protein ($3 \pm 0,5$) %.

Skim cow's milk acidity no more than 20°T, density no less than 1030 kg/m³. Total solid ($8,8 \pm 0,5$) %, including mass fraction of fat 0,05 %, mass fraction of protein ($3,35 \pm 0,5$) %.

Cream with mass fraction of fat no less than 35 % and acidity no more than 20°T.

Whey protein concentrate (WPC-35), which is obtained from cheese whey with usage of ultrafiltration method, «Westland Cooperative Dairy Company Ltd» (New Zealand). Total solid (97 ± 2) %, including mass fraction of whey protein no more than 35 %.

Starter. Bacterial concentrated starter «Bibakton», which consists of four pure cultures of bacterium *Lactobacillus acidophilus* in accord with standard 9229-051-07532800-2004 (Russia).

2.2. Analytical methods

All analytical measurements were taken at least three times. The parameters are presented in substandard average.

2.3. Acidophilic beverage producing

All samples of acidophilic beverages were produced of normalized cow's milk with mass fraction of fat 2.5. The samples differed from each other by various quantity of WPC of milk. Beforehand the total solid concentration was 18 %, including mass fraction of protein no more than 6,5 %. In order to get the experimental samples of acidophilus beverages, different amounts of WPC were added to normalized milk: 20 % (composition 1), 30 % (composition 2), 40 % (composition 3). Reference point was normalized milk without WPC. The composition were blended carefully at temperature 65°C, pressure ($15 \pm 2,5$) MPa, and were pasteurized at temperature (85 ± 2)°C in 15 minutes. Pasteurized compositions were cooled down till ($37 + 2$)°C and fermented with pure acidophilus bacterium *Lactobacillus acidophilus*. During (3,5 - 4) hours the compositions were fermented at temperature ($37 + 2$)°C till obtaining milk clotting with acidity (90 ± 5)°T. In the end of fermentation the experimental samples were cooled down till (6 ± 2)°C and blended to homogeneous consistence.

2.4. Measuring of rheological properties of acidophilus beverages

The influence of whey protein concentrate on the rheological properties of acidophilus beverages was revealed with the help of rotational viscometer Rheotest II. The measuring instrument consists of mechanical block, measurement control system, control and recording instruments, thermostat. Rotational viscometer measures the angular rotational velocity of inner cylinder ($\omega = 2\pi N$, rad·s) from 0,29 up to 25,4 s⁻¹. The measurement of rotational moment was taken in accord with indicating or recording instrument scale at relative value, rotational velocity was measured according to the mechanical block scale. The measurements of shearing stress and effective viscosity factor of deformation velocity gradient

alteration from 1,5 up to 1312 s⁻¹ were taken with the help of cylinder S1. Viscometer driver has 24 different rotational velocities. Measurement error is no more than ± 5 %.

Shearing stress:

$$\theta = \alpha \cdot z, \quad (2.1)$$

θ – shearing stress, Pa;

α – measurement from measuring instrument;

z – cylinder constant, Pa/scale unit.

Effective viscosity factor:

$$\eta_{\text{eff}} = \frac{\theta}{\dot{\gamma}}, \quad (2.2)$$

η_{eff} - effective viscosity factor, Pa·s;

$\dot{\gamma}$ - velocity gradient, s⁻¹.

Rheological data were computed, using application software and Microsoft Excel.

3. RHEOLOGICAL PROPERTIES OF ACIDOPHILUS BEVERAGES

Before measuring the acidophilus beverage samples (at quantity 25 ml) were put in measuring cell and during 20 minutes were thermostated at given temperature. In order to keep the same temperature of yoghurt, the outer fixed cylinder was constantly thermostated. Thermostating temperature of acidophilus beverages was kept within 0,1°C. New sample was used at different temperature. Rheological properties of acidophilus beverages were studied at temperature (37±2)°C (after fermentation), 6°C (storage product temperature), 20°C и (37±2)°C after cooling [8].

The data are presented on the shearing stress-deformation velocity gradient and the effective viscosity factor-deformation velocity gradient diagrams at different rates of temperature and of experimental samples (fig. 1 and 2).

The process of structure alteration of acidophilus beverage under mechanical effect with increase (load) and decrease (unload) of deformation velocity gradient is presented on fig. 3

4. RESULTS AND DISCUSSION

Experiment results revealed (fig. 1 and 2), after fermentation the product had the less rate of viscosity. After cooling till 6°C the sample's viscosity increased and flow index decreased. It confirms that the properties of experimental samples approximate to non-Newtonian behavior.

The further heating of acidophilus beverage was characterized by viscosity decreasing, but at temperature 37°C the viscosity of the sample just after fermentation was higher

The addition of WPC to acidophilus beverage samples (fig. 2) brought to viscosity increasing both at low (6 °C) and high (37°C) temperatures. Acidophilus beverage had weak thixotropic recovery of structure as the result of deformation in viscometer annulus (in flow). This fact confirms that load and unload curves of experimental samples form hysteresis curve (fig. 3).

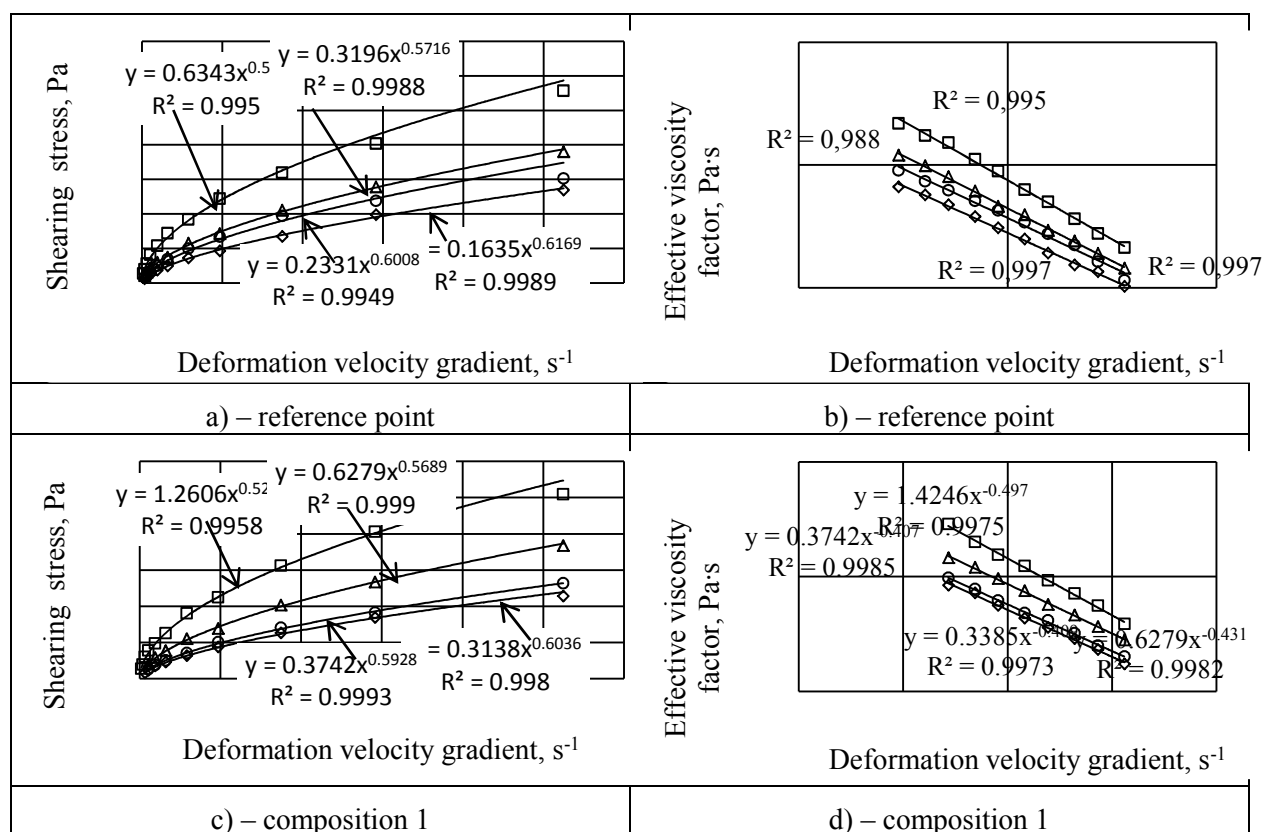
The prolonged mechanical influence broke the structure, because flow curve of broken structure has linear character and flow index comes to 1. But mechanical influence with duration of 10 minutes does not break the structure completely.

Picture 3 shows, reference point possesses more hysteresis curve (thixotropy coefficient 1,914), than composition (thixotropy coefficient 1,8). It means that addition of concentrate together with mechanical influence improves the final product stability (transportation, agitating, measuring etc.).

5. CONCLUSION

The control of dairy product structure formation is the main condition of producing the final product with certain functional and structure-mechanical properties. Not only external appearance, both product yield and quality depend on these properties.

The rheological data prove that acidophilus beverage, produced of WPC made on basis of ultrafiltration method, possesses the same structure-mechanical and organoleptical properties as traditional acidophilus beverage. The results confirm that the application of WPC, made on basis of ultrafiltration method, in producing of acidophilus beverages control structure formation and produce the product with stable qualitative properties.



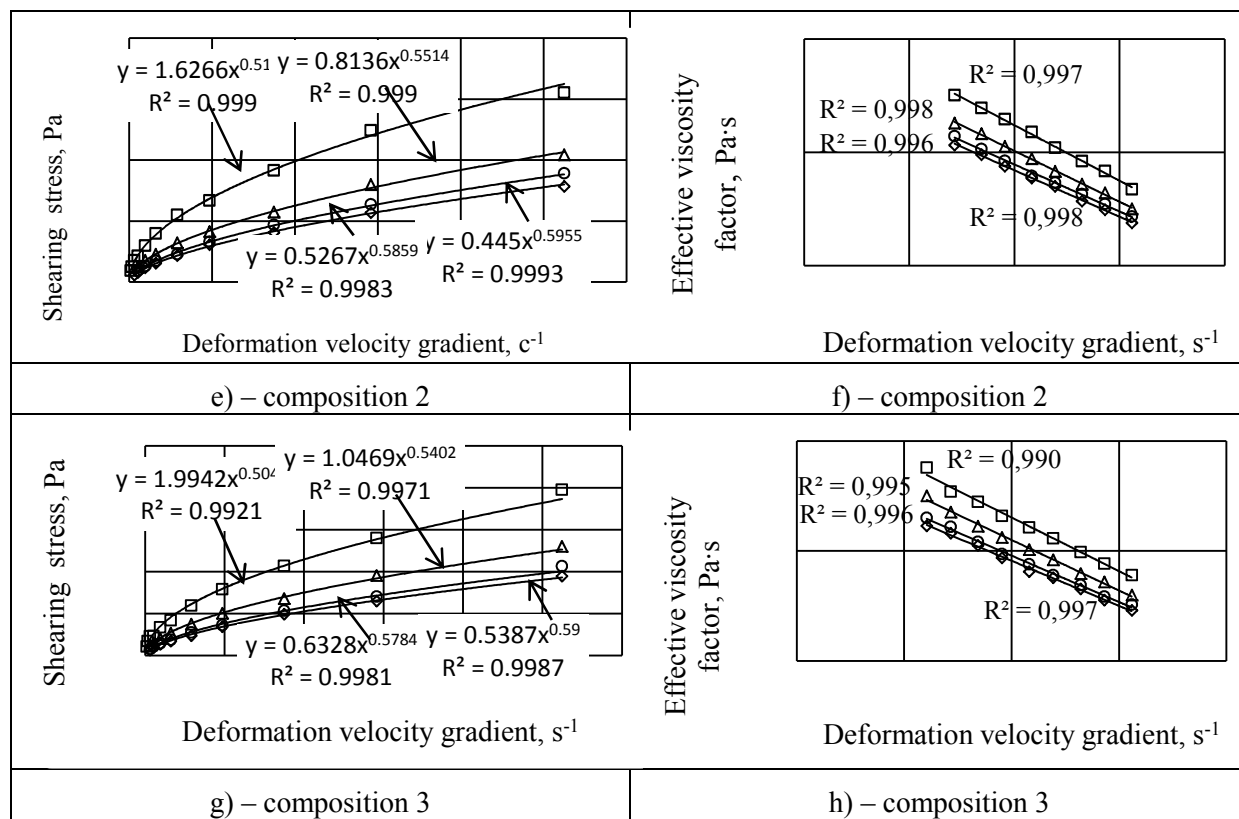
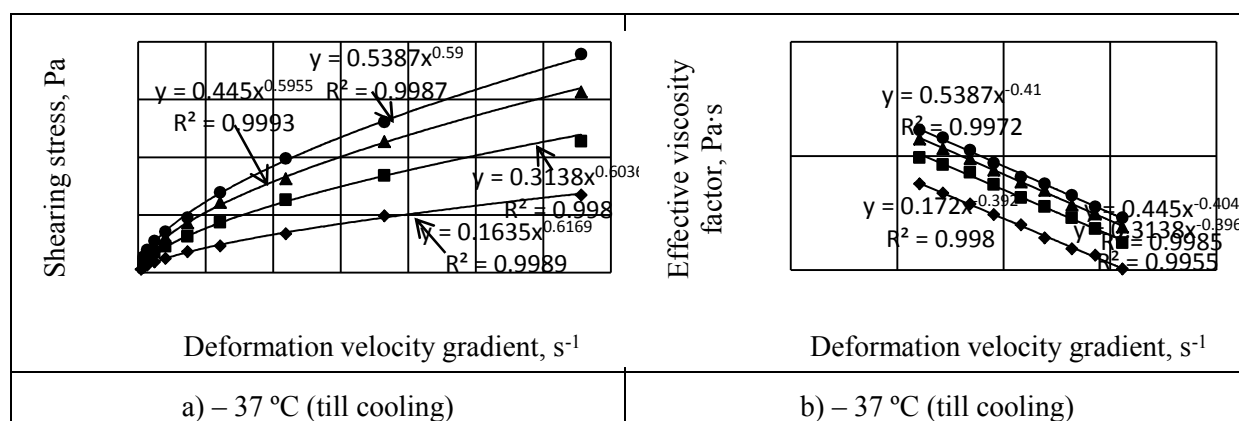


Figure 1 – Shearing stress-deformation velocity gradient diagram(a, c, e, g) and effective viscosity factor-deformation velocity gradient diagram (b, d, f, h) at different rates of temperature: □ – 37 °C (till cooling); Δ – 6 °C; ○ – 20 °C; ◇ – 37 °C; of experimental samples: a, b – reference point; c, d – composition 1; e, f – composition 2; g, h – composition 3



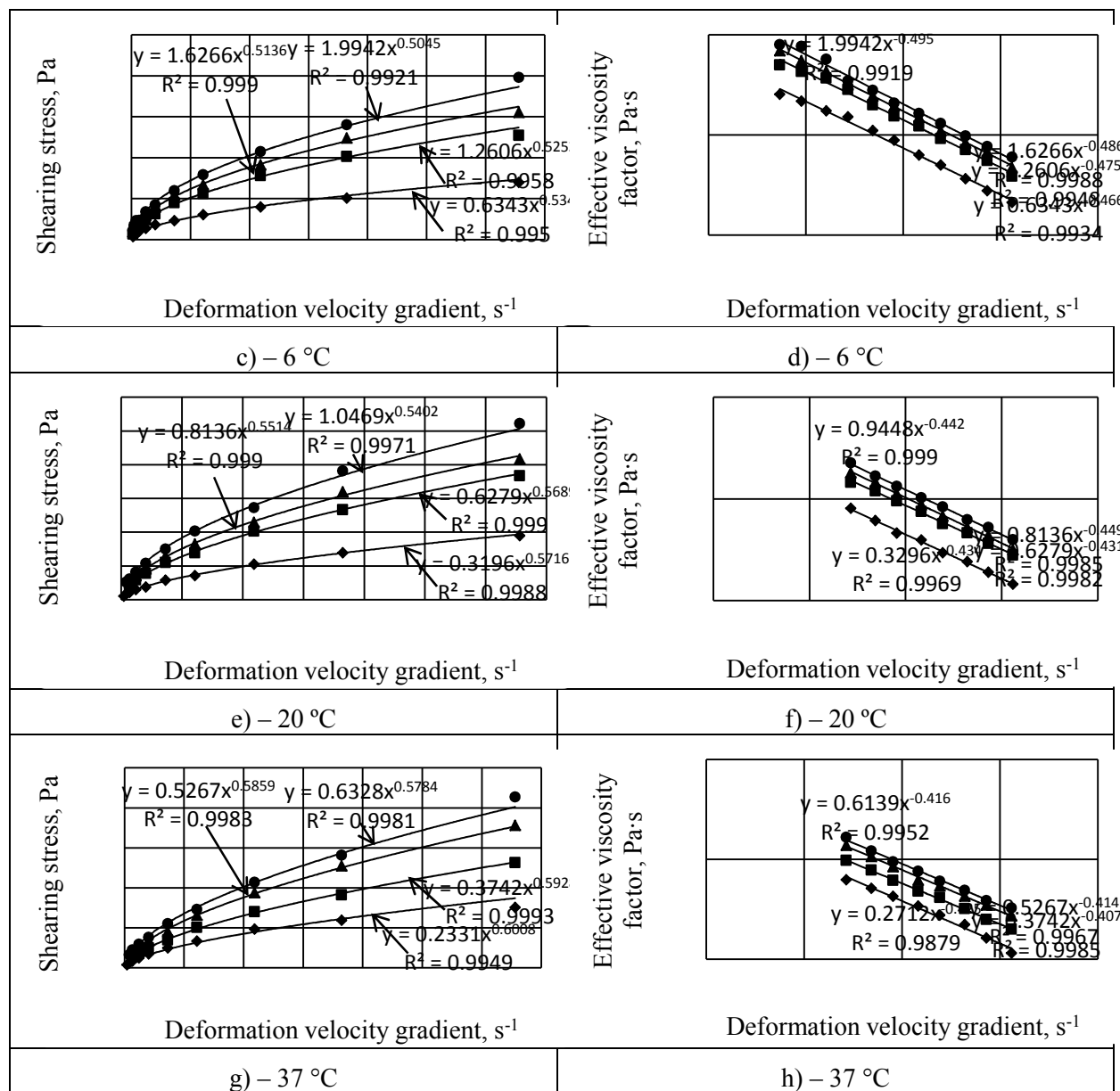
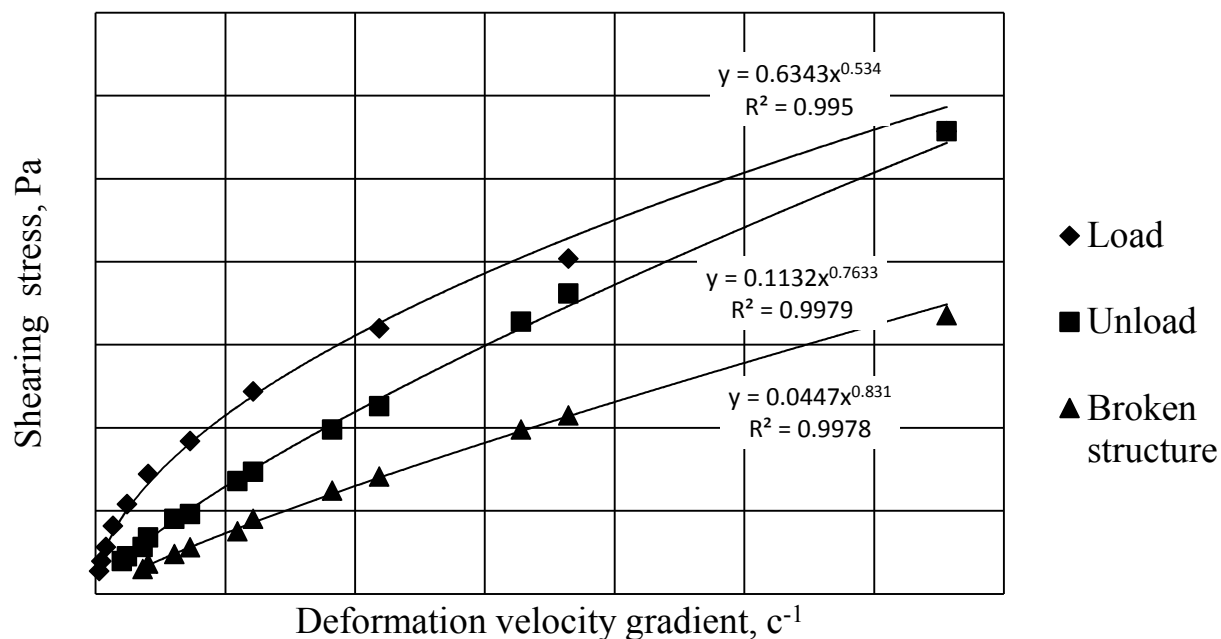
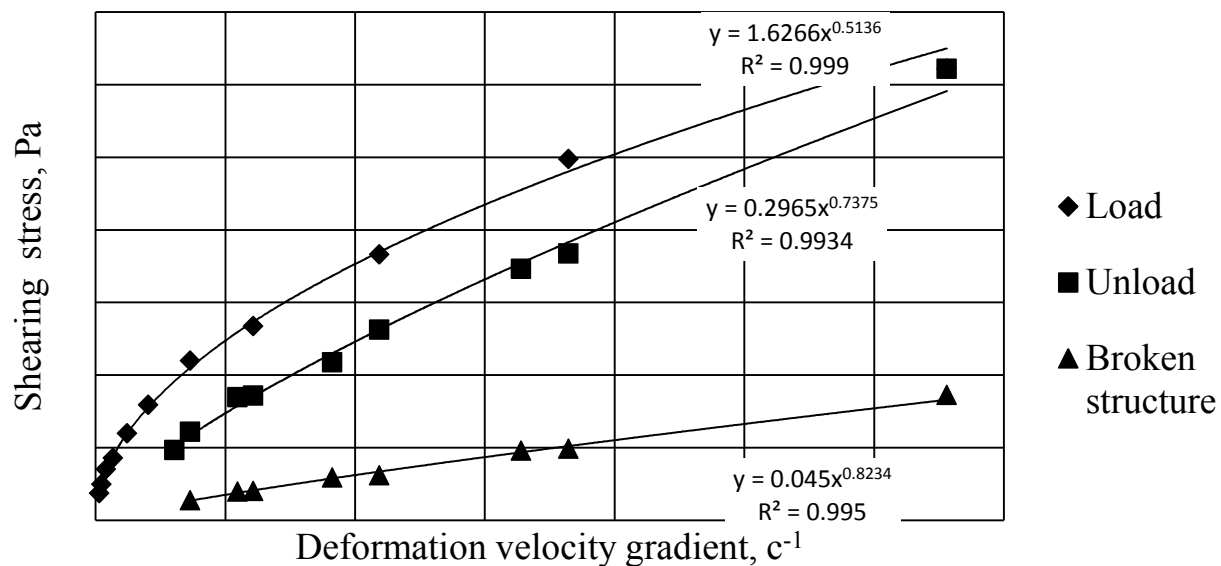


Figure 2 – Shearing stress-deformation velocity gradient diagram (a, c, e, g) and effective viscosity factor-deformation velocity gradient diagram (b, d, f, h) of experimental samples: ♦ – reference point ; ■ – composition 1; ▲ – composition 2; ● – composition 3; at different rates of temperature: a, b – 37 °C (till cooling); c, d – 6 °C; e, f – 20 °C; g, h – 37 °C



a) - reference point



b) - composition 2

Figure 3 – Shearing stress-deformation velocity gradient diagram of experimental samples at temperature 6°C

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