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CHARACTERIZING FOAMS FLOW OBTAINED BY CONTINUOUS FOAMING OPERATION

Anamaria MARDARU[1], Gholamreza DJELVEH[2], Gabriela ISOPENCU[3], Cosmin JINESCU[4], Alina Monica MAREŞ[5], Gabriela GHIMICIU[6]

Lucrarea îşi propune caracterizarea reologică a spumelor alimentare obținute prin procesul continuu de spumare în regim laminar. Datele experimentale privind caracterizarea reologică s-au obținut utilizând două medii de simulare newtoniene.

Propietățile reologice sunt determinate atât în condiții de deformare puternică, (condiții de curgere-staționare), cât şi în condiții de deformare oscilatorie de mică amplitudine, oferind posibilitatea determinării proprietăților viscoelastice ale produsului.

The aim of this paper is the rheological characterization of foams obtained by the continuous foaming operation in laminar flow conditions. Experimental data on the rheological characterization of foams were obtained using two Newtonian media.

The rheological properties are obtained both under conditions of high deformation (under steady state conditions, and under conditions of small dynamic oscillatory under small oscillatory shear test, making it possible to determine the viscous-elastic properties of the product.

Keywords: rheology, proteins, polysaccharides, shear rate, foams

1. Introduction

Researches in food industry, regarding the aerated products called foams, are based on the intention to obtain the new products with low calorie content, fine texture and specific organoleptic qualities.

Many products in food industry correspond to aerated foods (e.g. dairy products, ice cream, mousses, fruit desserts, foams based on meat) and they are

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[1] PhD student, Chemical Engineering Dept., University POLITEHNICA of Bucharest, Romania, e-mail: mardaru_ana@yahoo.com

[2] Professor, ENSCCF, LGCB, BP 10448, F-63000 Clermont-Ferrand, France

[3] Assist., PhD, Chemical Engineering Dept., University POLITEHNICA of Bucharest, Romania

[4] Assoc. Professor, Mechanical Engineering Dept., University POLITEHNICA of Bucharest, Romania

[5] Assist., PhD, Chemical Engineering Dept., University POLITEHNICA of Bucharest, Romania

[6] PhD student, Chemical Engineering Dept., University POLITEHNICA of Bucharest, Romania

presented in the form of foams for marketing reasons, due to their visual appearance and texture [1-2].

Foaming operation has been applied to develop new products adapted to consumer choice and needs, using air as a zero-cost ingredient [3]. As mentioned by Campbell and Mougeot (1999), foaming became a key processing operation in the food industry, but it is still not fully understood, because it results from a complex interplay between formulation and process conditions [4]. The gaseous phase is incorporated in the continuous phase (liquid) in the form of tiny bubbles with uniform distribution, which modified the product texture and appearance, because the bubbles confer softness, a special mouth feel and a more uniform distribution of flavor, enhancing the product homogeneity. Therefore, foam is a macroscopic dispersion of gas, whose existence and properties is controlled by colloidal forces, surface forces and interactions between the individual films separating gas bubbles [1-5].

The incorporated bubbles are usually stabilized by proteins and other food emulsifiers which, being surface active, adsorb onto the bubble surface and prevent coarsening. Interfacial rheological properties of the foams could be influenced by bubble coalescence and by modification of interparticle forces.

The properties of foams depend widely on their microstructure, especially the gas content (expressed by the overrun), as well as the bubble size distribution [2]. The microstructure is the result of the combined effects of operating conditions of foaming operations, type of impellers and of physicochemical properties of the continuous phase (the matrix) [6-8]. The stability of the bubbles in gas-liquid interface is provided by surface-active protein, localized in lamellae structures [9]. In the lamellae are formed two polar surface-active protein films in an ultra-thin layer of liquid, which repel each other (Fig. 1).

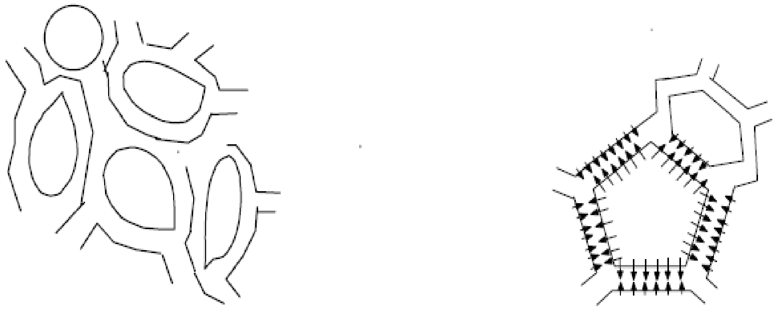

Fig. 1. Schematic representation of the foam structure with bubble lamellae formatted by the two surfactant protein films

⬭ - gas bubble, ⇉⇇ - polar groups of surface-active protein

In aerated products, the use of protein (derived from egg or milk), as a functional ingredient product, provides good stability. Research on foaming was mainly focused on the ingredients and the protein acts as foaming agents in food. However, foaming agents must provide both abundant and stable foams.

Among food proteins, whey proteins have been identified as ingredients of high nutritional and functional interests that exhibit high foaming and stabilizing properties. β-lacto globulin, the main protein of whey [1], is able to undergo denaturizing and form surface gels at the air–water interfaces, and also to stabilize food by heat-induced gelation. However, the ability of proteins to form and stabilize foams is still difficult to link quantitatively to surface properties [9].

Generally, proteins alone cannot provide stable foams without the addition of other stabilizing agents; the most common are polysaccharides. Polysaccharides are typically used in food industry for their texturing properties as thickening and gelling agents [1]. The properties of the proteins [10] have been mainly studied, without taking into account the interactions with other ingredients. However, polysaccharides often interact with proteins, and mixtures of polysaccharides usually present synergistic properties.

Mixtures of guar and xanthan exhibit high gelling properties, while guar and xanthan used separately as thickening agents do not usually present gelling properties when they are used in food. Contrary to guar and xanthan, pectin is a weaker thickening agent because of its lower molecular weight.

Contrary to guar, xanthan is a carboxylated biopolymer that is negatively charged in the usual range of food pH, and can, therefore, present electrostatic interactions with proteins. However, thermodynamic incompatibility between xanthan and milk proteins remains the rule [1].

The theoretical understanding of the stability of protein–polysaccharide mixtures in water has gained a considerable interest in food industry in the last decade, when a few ternary diagrams have been established and when the interactions between polysaccharides and proteins have been clearly described. These can be summarized as follows:

- miscibility and compatibility; this situation is all, but a general rule in food.
- thermodynamic incompatibility leading to the phase separation when proteins and polysaccharides repel each other; the segregation of the biopolymers takes place and two distinct immiscible phases can be formed, each of them being enriched with only one biopolymer species.
- complex coacervation when the biopolymers attract each other; phase separation may occur: in this case, one phase contains coacervates, whereas the other one is depleted of polymers.

For concentrated media, thermodynamic incompatibility prevails, but the phase separation does not usually occur, because the system is ‘‘*gelled*’’ by the high viscosity of the matrix, which leads to locally segregated microstructures. Consequently, the control of the kinetics of stabilization and phase separation allows obtaining a variety of microstructures and, therefore, interesting properties. This can be achieved by several formulation factors, such as pH, ionic strength and concentration. Protein–polysaccharide interactions widely depend on the intrinsic properties of polysaccharides (namely, electric charge, molecular weight, branching), and acts on the viscosity, elasticity and surface tension [11-12].

Therefore, it is important to highlight how the rheological behaviour (expressed by the elastic module, viscous module, tan delta, deformation, shear rate and shear stress) depends on the macroscopic parameters and the foam composition (gas, liquid surfactant).

Foams have an irreversible flow, being necessary to determine how the foam components influence the flow properties (flow type –uniformity of shear or shear in some places, the slip wall, etc.). The change of the surfactants has an impact not only on the surface tension, but also on gas-liquid interfacial properties.

The rheological studies of the interfacial fluid foam can determine how the dispersed phase resists against deformation or coalescence. Compositions of interfacial layer change the structure and rheology, determining duration of shelf life and the choice of foaming agent.

In oscillatory tests, materials are subjected to deformation (in controlled rate instruments) or stress (in controlled stress instruments), which harmonically varies with time. Sinusoidal, simple shear is typical. To illustrate this concept, one considers two rectangular plates oriented parallel to each other. The lower plate is fixed and the upper plate is let to move back and forth in a horizontal direction. Assume the sample being tested is located between the plates of a controlled rate device. Suppose the strain in the material between the plates is a function of time defined as: [13]

$$\gamma(t) = \gamma_0 \sin(\omega t) \tag{1}$$

where : γ_0- is the amplitude of the strain at time t_0, Pa; γ - the amplitude of the strain at time t, Pa; ω- angular frequency; rad/s; t-time, s

Using a sine wave for strain input results in a periodic shear rate found by taking the derivative of equation (1)

$$\frac{d\gamma}{dt} = \dot{\gamma} = \frac{d(\gamma_0 \sin(\omega t))}{dt} \tag{2}$$

which can be evaluated as:

$$\dot{\gamma} = \gamma_0 \omega \cos(\omega t) \tag{3}$$

With small strain amplitude (so the material will behave in a linear viscous-elastic manner), the following shear stress is produced by the strain input:

$$\sigma = \sigma_0 \sin(\omega t + \delta) \tag{4}$$

where: σ_0 - the amplitude of the shear stress at the initial time, Pa; σ - the amplitude of the shear stress at the time t, Pa; δ - the phase lag or phase shift (also called the mechanical loss angle).

The time period associated with the lag phase, equal to $\frac{\delta}{\omega}$, can be considered as the peak force per unit area received by the stationary plate.

Dividing both sides of equations (3) by γ_0

$$\frac{\sigma}{\gamma_0} = \left(\frac{\sigma_0}{\gamma_0}\right)\sin(\omega t + \delta) \tag{5}$$

The complete results of small amplitude oscillatory tests can be described by plots of the amplitude ratio and the phase shift as frequency dependent functions: $\frac{\sigma_0}{\gamma_0} = f(\delta)$. The shear stress output produced by a sinusoidal strain input may be written as:

$$\sigma = G^{'}\gamma + \left(\frac{G^{"}}{\omega}\right)\dot{\gamma} \tag{6}$$

where: G$^{'}$ - the shear storage modulus - and G$^{''}$- the shear loss modulus, are both functions of frequency and can be expressed in terms of the amplitude ratio and the phase shift:

$$G^{'} = \left(\frac{\sigma_0}{\gamma_0}\right)\cos(\delta) \tag{7}$$

$$G^{"} = \left(\frac{\sigma_0}{\gamma_0}\right)\sin(\delta) \tag{8}$$

Another popular material function used to describe viscous-elastic behaviour is the tangent of the phase shift or phase angle (called tan delta) which is also a function of frequency:

$$\tan(\delta) = \frac{G^{"}}{G'} \tag{9}$$

Viscous - elastic media present the particularity to behave either as elastic solid, or a fluid as a function of the intensity and the frequency of the mechanical stress applied to them. The fluid behaviour prevails for slow deformation and low shear rate, while elasticity dominates at high deformation and shear rate. This behaviour is often accounted by the dimensionless Deborah number:

$$De = \frac{\lambda_r}{t_k} = \frac{\text{relaxation time scale of fluid}}{\text{time scale of process}} \tag{10}$$

The value of De denotes a distinction between elastic, viscous and viscous-elastic fluids.

$$De = \begin{cases} \equiv 1, \text{ viscoelastic fluid} \\ \prec\prec 1, \text{viscous fluid} \\ \succ\succ 1, \text{elastic fluid} \end{cases} \tag{11}$$

Also can be used Weissenberg number (Wi) to define the elastic behaviour.

$$Wi = \frac{N_1}{2\eta\dot{\gamma}} \tag{12}$$

Viscous-elastic behaviour can be measured using Weissenberg number (Wi), which compares the intensity of viscous forces to the normal elastic forces. Wi is equal to “0” for non-elastic fluids and tends to infinity for purely elastic solids.

Elasticity number (El) is often used in place of Wi to measure the anisotropy generated by elasticity under strain:

$$El = \frac{Wi}{\mathrm{Re}} \tag{13}$$

Fig. 2 presents the profiles of the fluids subject at the different shear rate.

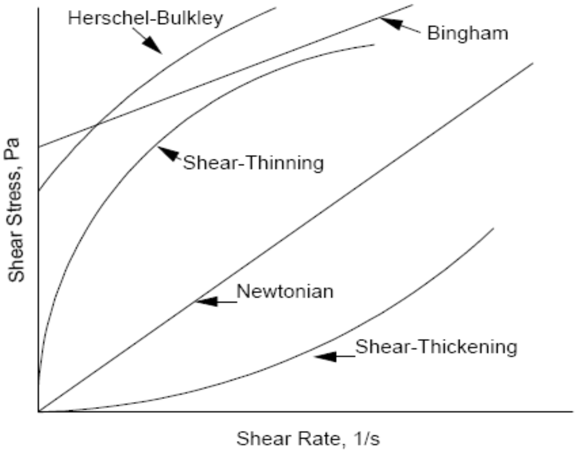

Fig. 2. Curves for typical time-independent fluids

The aim of this paper is to characterize from the rheological point of view the model media (synthetic solution) and the foams obtained by continuous foaming operation.

2. Materials and methods

Experimental data on the rheological characterization of foams and the influence of foam composition were obtained using Newtonian media, which are based on glucose syrup – characterized by the capacity of foaming. It is important to maintain the laminar flow conditions which defined the minimum viscosity value. Conversely, gas dispersion is known to become more difficult when the viscosity ratio decreases at values lower than 1, citated by Walstra, 2003, [11], which limits the use of highly viscous media [14].

The foaming agent consists of a whey protein isolate (Prolacta 90, Lactalis, France) which contained β-lactoglobulin (>90% w/w), as ingredient of high nutritional and functional interests and xanthan, which gives abundant and stable foams.

Xanthan gum has high solubility in water, high viscosity at low concentrations, high stability and solubility in acidic systems and excellent stability to freezing and thawing. This polysaccharide is commonly used in many food products because of its low cost, high solubility at low temperature, and high viscosity at low concentration.

The composition of the raw material is reported in Table 1.

Table 1

Composition of synthetic media used for foaming

Raw materials	**Dehydrated glucose**	**Water**	**Whey protein isolate, (WPI),**	**Xantan gum, (XG)**
Composition 1 (% w/w), (A)	64	36	2	-
Composition 2 (% w/w), (B)	64	36	2	0.1

The preparation of the synthetic media was performed using a high-speed mixer (UMC-5, Sympak-France, France) at room temperature under vacuum to avoid foam forming at the surfaces of the media. Dehydrated glucose syrup was added in the same vessel, at room temperature, using three successive additions of similar amount, each separated by 9 minutes of mixing under vacuum with the increasing of the rotation speed (from 500 to 1200 rpm). After glucose dissolution, whey protein isolate was added, and incorporated in the media by mixing for 10 minutes with a rotational speed of 900 rpm, and then the corresponding amount of xanthan was added. The obtained solution was kept overnight for aging, which is necessary for the total hydration of protein, for establishing the interaction between components and degassing.

Rheological properties were measured using a stress-controlled SR-5 rheometer (Rheometric Scientific, NJ, USA) equipped with a plate-plate system and a Peltier circulator for temperature control. Plate-plate system consists of two parallel discs, coaxial with the radius, R and h which is the distances between them; one of the discs is kept stationary, and the other is subjected to torque. Under the effect of this torque, the product is broken down into a circular, parallel layer with these discs.

Rheometer allowed measurements under conditions of high deformation (under steady state conditions) and obtain the viscosity of the fluid function of the shear rate. Also, the instrument allows the dynamic oscillatory measurements under small amplitude oscillatory shear test, making it possible to determine the viscous - elastic properties of the product. These give access, respectively, to the elastic shear modulus (G'), the viscous shear modulus (G"), the complex viscosity (η^*), and the tangent loss (tan δ) defined as the ratio G"/G' [1-6].

Rheological properties which can be measured in terms of high deformation are:

♦viscosity, η

♦shear stress, τ

♦first normal-stress difference, N_1

♦ Weissenberg number, Wi

The general conditions under which rheological measurements were made are: temperature T=25 ^{0}C, the gap between the plane L=0.5 mm, shear rate $\dot{\gamma}$ between 0.01-1000 s^{-1}. The particular condition used for the experiments are presented in Table 2.

Table 2

Operating parameters for the measurement of the rheological properties under low amplitude oscillatory deformation

Test at constant frequency $\nu = 1$ Hz	Test at constant strain $\sigma = 2\%$
Temperature, T=25 ^{0}C	Temperature, T=25 ^{0}C
Gap between the plane 0.5 mm	Gap between the plane 0.5 mm
Strain 0.01-100%	Frequency 0.01-100 Hz

The surface tension, σ, was measured using a K12 tensiometer using the Wilhelmy's plate method at 25^{0}C for 1 h without dilution. Torque (C) measurements enable the determination of the process viscosity, which corresponds to the apparent viscosity of the gas–liquid dispersion during foaming. This was used in order to avoid confusion between the viscosity of the model media before foaming, η, and the viscosity of the food foam product.

The apparent viscosity was estimated using a Couette analogy based on a ''*virtual Couette geometry''* [8]. This methodology consists in the possibility to use the foaming device as a rheometer, with torque measurements on the shaft of the impeller at controlled rotation speed.

Thakur et al. (2004) [8] defined a virtual Couette geometry for the column foaming device, which consists in a stator with diameter (35 mm) and an impeller length by 19.5 cm. The virtual internal cylinder diameter was calculated in order to require similar power input as the four-flat-right-angle blade impellers at the same rotation speed. Thakur et al. (2004) [8] found that the average shear rate, $\dot{\gamma}$, during foaming could be deduced using:

$$\dot{\gamma} = K_S N \tag{14}$$

in which the dimensionless shear rate constant is $K_S = 51 \pm 1$

Equation (14) shows that the shear velocity can vary between 340 and 1360 s^{-1} when N varies from 400 to 1600 rpm.

The viscosity during foaming, considered a process parameter, could be deduced from a balance of forces to a virtual geometry of radius r_0:

$$\eta = \frac{C}{2\pi r_0^2 L_0 K_S N} \tag{15}$$

Foam stability is quantified by visual observations of the samples stored at room temperature.

3. Experimental results

Models (synthetic) media and foams obtained by continuous foaming process [15], were characterized experimentally by measuring the rheological properties using the rheometer previously described.

The experimental data were obtained at constant liquid flow rate, 30 ml/min and varying the gas flow rate between 10 and 50 ml/min. Stirring speed was varied between 400 and 1600 rpm.

Foaming was carried out under steady state conditions, laminar flow and a blow-by phenomenon was absent.

Following the rheological analysis performed, it was found that the models media have a Newtonian behaviour. Viscosity of the model media depend from the viscosity of the glucose syrup and the added amount of protein and polysaccharide (xanthan).

Table 3

Characterization of the model foods

Parameter measured / **Composition of media**	**η (Pa*s)**	**Wi**	**σ (mN/m)**
Glucose syrup	1	inelastic	70
Glucose syrup +WPI 2%	1,3	inelastic	49
Glucose syrup +WPI 2%+ XG 0,1%	2	0.2	49

Adding the polysaccharide increases the stability of the product with high sugar content. For example, xanthan which is an exo-polysaccharide with a high molecular weight (between 103-104 kDa), when it is present in the solution at concentrations of less than 0.3%, increases only the viscosity, but if the concentration is higher, it interacts with other components, leading to changes in mixture properties [1, 16].

By adding protein in the glucose syrup, the surface tension value is decreasing [1], but when the polysaccharide is added, the value of the surface tension remains unchanged (Table 3).

For the model media containing xanthan, the higher viscosity, viscoelastic behavior (presented in Table 3) can be attributed to its rigid structure and negative charge, which improves the ability of xanthan to form hydrogen bonds in a matrix with low ionic strength.

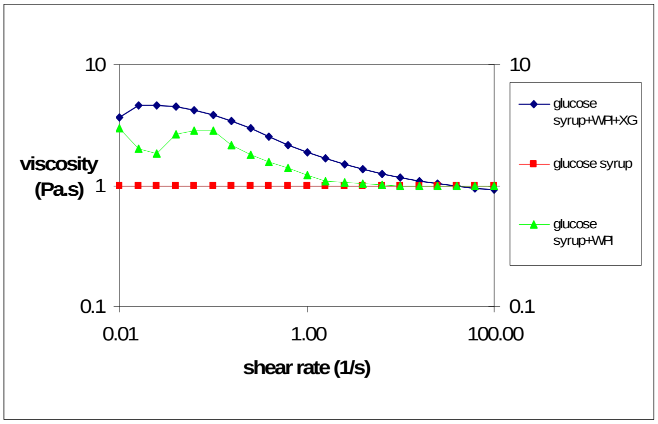

Fig. 3. Effect of addition of protein and polysaccharide on flow curves for a viscosity of 1 $Pa \cdot s$ of glucose syrup

The addition of 2 % WPI increases the viscosity of the model media (syrup glucose+ WPI) up to $1.3\, Pa \cdot s$. The addition of 0.1% w/w xanthan approximately doubled the viscosity of the matrix; the flow curve was slightly shear-thinning, but exhibited a Newtonian plateau in the region of shear rate of foaming operation, with viscosity of 2 $Pa \cdot s$ and the rotation speed above 100 s^{-1} (Fig. 3).

An important rheological property is yield stress effort, which can be defined as the minimum effort required initiating shear flow. To investigate the yield stress of the model (synthetic) media a steady low shear was applied to these and the shear stress followed as a function of time [18-19].

In Fig. 4 is presented the evolution of the shear stress in time for the model (synthetic) media. A constant shear rate increases constant the effort during time.

When a constant low effort is applied, the initial deformation increases linearly, the sample is deformed due to elastic stretching of foam.

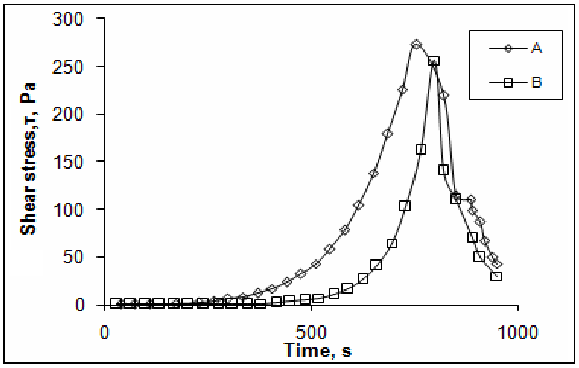

Fig. 4. Evolution of shear stress in time

At some point, the foam structure begins to tear under strain increasing and the system shows a deviation from linear behavior. The viscoelastic behaviour begins at this moment, because at the end of the strain application, the structure is completely broken, and it can be identified a maximum allowable shear stress which can be applied. Beyond this point the stress decays to a final equilibrium value as the rheometer plate begins to rotate [19].

Two yield stress values can be obtained by a shear stress vs. time measurement. The idea of static and dynamic effort flow can be explained by assuming two types of structures in a fluid. A structure is "insensitive" to speed shear flow and serves to define the dynamic equilibrium curve associated with the flow. A different structure is formed after a certain period of time, when the sample is at rest. The combination of the two structures leads to a flow resistance which causes flow static effort. The point where the stress vs. time departs linearity (i.e. the onset of viscoelestacity) represents the static yield stress, where there is still no macroscopic flow of the material, while the dynamic yield stress is the maximum value of shear stress achieved, at which point the broken structure flows in a ‘‘dynamic’’ state.

Rheological properties of foams are difficult to be measured since they are unstable, given the fluid caused by gravity drainage and Ostwald ripening, i.e. creation of larger bubbles from smaller ones [13, 19]. To find the linear viscoelastic region, frequency oscillatory deformation tests were carried out.

Oscillatory stress sweep performed on foams can determine the onset of nonlinear viscoelastic behaviour. A value of critical dynamic stress amplitude can be estimated as a quantity which confirms the results obtained from steady shear flow analysis of the yield stress.

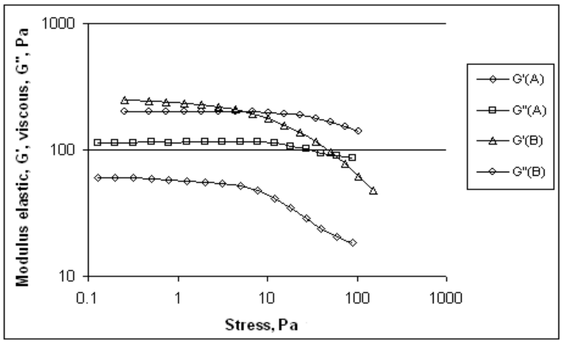

Fig. 5. Stress amplitude sweep for foams obtained in the conditions: G/L=30/30 ml/min, N=800 rpm

Foams obtained from the two simulation environments are tested for shear stress of small amplitude, so being able to determine the point where they diverge from the linear viscoelastic behavior. Fig. 5 shows the behavior of foams obtained by the continuous process of foaming when stirring rate is 800 rpm and flow ratio is the G / L = 30/30 ml / min. A largely constant elastic and viscous modulus was observed below a critical value of oscillatory stress.

Critical value of applied shear stress is where the values of G' and G'' decrease, marking the upper limit of linear viscoelastic properties of the foam. It is experimentally found that, for the foams studied, both the viscous and elastic modulus is constant for the range (0.1 to 10%), where the shear stress is lower than the critical value. At higher shear stress values than the critical one, foam rheological behavior is in the non-linear viscoelastic region and, in most cases, the foam structure will be destroyed.

Fig. 6 presents the mechanical spectrum of foams obtained from the two simulation media, when applying a 1 Hz frequency in the strain range 0.01-100%.

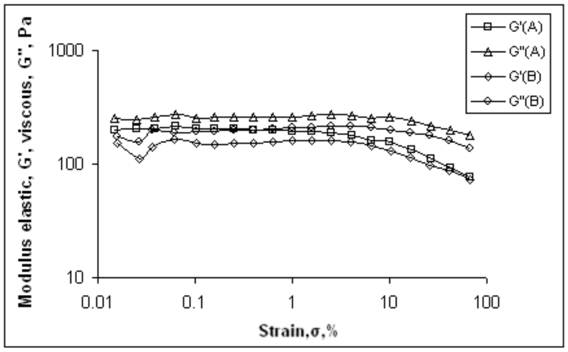

Fig. 6. Strain sweep experiment for foams obtained in the conditions: G/L=50/30 ml/min, N=1600 rpm

The high elastic modulus of foams obtained from the model media A can be explained by the presence of large bubbles of the foam, which affects the mechanical response of foams to small amplitude strains. Thus, at first foam behaves as a solid and with increasing shear, it behaves like a fluid. This solid-fluid transition behavior is influenced by foam micro-structure; foam tends to behave as a non-Newtonian fluid. This is particularly important, as the structure of fluid foams will influence the structure of solid foams obtained by heating or other solidification processes [16, 20].

The high value of G' shows that continuous phase viscosity is low, as gas dispersion and shear rate during foaming is proportional to stirring rate, with a direct effect on bubble size. Such a "solid like" behaviour, characteristic of a high value of the elastic modulus is thus a false indicator of a poor selection of formulation (e.g. a too-low viscosity of continuous phase) or of insufficient gas mixing conditions. A better foam quality is therefore obtained with xanthan gum.

Fig. 7 is shown the effect of applying a constant strain, 2% on the foams in the 0.1-10 Hz frequency range.

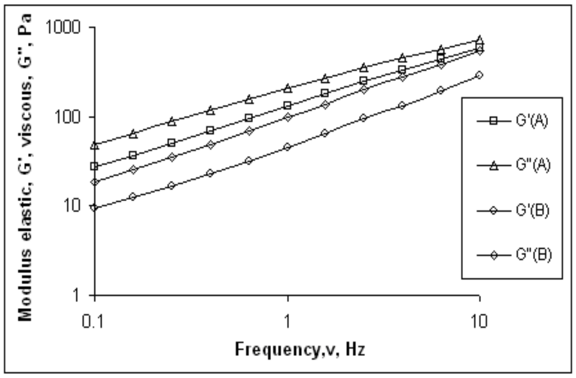

Fig. 7. Frequency sweep experiment for foam obtained in the conditions: G/L=50/30 ml/min, N=1600 rpm

A linear evolution of the viscous and elastic modules in the domain of 0.1 - 10 Hz can be noticed in Fig. 7. Values for elastic modulus and viscous foams obtained from the model media without xanthan are higher than those of foams which contain xanthan.

The viscoelasticity of the foams is determined predominantly by the presence of bubbles and perhaps their size, and less of xanthan concentration.

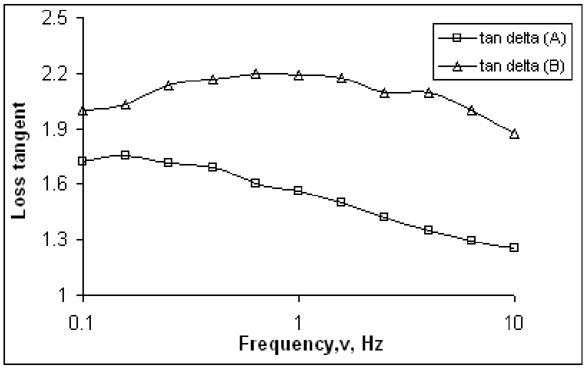

Fig. 8. Loss tangent in frequency sweep experiment for foams obtained in the conditions: G/L=50/30 ml/min, N=1600rpm

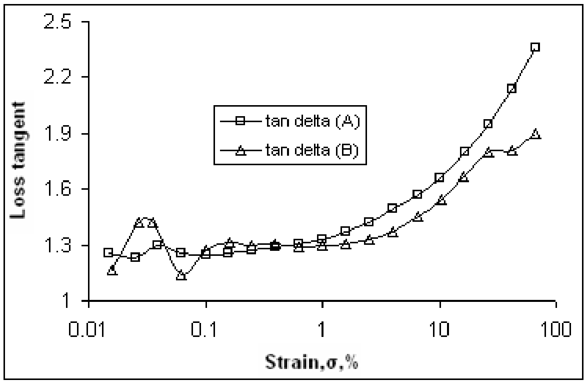

Fig. 9. Loss tangent in strain sweep experiment for foams obtained in conditions: G/L=50/30 ml/min, N=1600rpm

Rheological results obtained are also validated using the G"/G' ratio, denoted by tan δ, which measures the viscoelasticity at low deformation: when the tan δ tends to infinity, the fluid is purely viscous, and if it tends to 0, it is an elastic solid (Figs. 8 and 9). In this paper, tan δ is in the range 1-2.5 for all foams, indicating a slightly viscous behaviour.

Deborah number calculation with equation (9) shows that the two foam behaves like a viscous fluid (De=0.9), tending to a viscoelastic behavior De=1.

Foam drainage stability achieved is better for the environment B, containing xanthan, and higher viscosity helping reduce drainage.

4. Conclusions

The objective of this paper is to investigate the influence of composition and quantity of air enclosed in foams by shaking, and the characteristics of foams obtained by the continuous process of foaming.

In this work, rheometry, tensiometry and foaming experiments have been carried out to better understand the respective effects of protein and polysaccharide on the physicochemical properties of a Newtonian model food and its ability to form stable foams in a continuous foaming operation under laminar flow conditions.

The formulations used experimentally in continuous foaming show a Newtonian rheological behaviour, viscoelastic due to operating conditions presented above.

Rheological characteristics measured before and after foaming proved to be a valuable tool to measure, highlighting the foam microstructure stability over time. The results showed that the introduction of a gas in a food subject to aeration may have a different impact, depending on its initial composition.

The continuous foaming process is a complex operation that depends on the interdependence of operating conditions and on the composition of the continuous phase. To achieve the proper foaming process with purpose to obtain stable foam, material must always contain an efficient surfactant, with high elasticity, such as whey protein isolates, but some physical parameters and operating conditions can also play an opposite role. For example, high rotational speed improves the viscous forces responsible for the breaking of bubbles, but also increases the collision which strengthens bubbles coalescence. Similarly, high viscosity increases the viscous forces, but this can increase, sometimes at the expense of bubble deformation division.

Adding proteins and polysaccharides in a glucose syrup solution shows that the surface tension is not modified when the polysaccharide is added, that does not compete at the air-water interface.

Interfacial properties of mixtures of polysaccharides are related to the influence of the matrix protein and polysaccharide to achieve the foaming operation lies primarily in their influence on the continuous phase, especially the viscosity and elasticity matrix. Specific interactions between syrup of glucose, proteins and polysaccharides are highlighted. These include co-solubility without interactions (by guar), forming a viscoelastic network (Xanthan) and time-dependent behaviour (given by pectin), due to ternary interactions between polysaccharides, proteins and sugars.

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