

Rheological investigations of food gels under high pressure

Kulisiewicz, L.^{*}, Baars, A., Delgado A.

Lehrstuhl für Strömungsmechanik, Technische Fakultät, Friedrich-Alexander Universität Erlangen-Nürnberg, Cauerstr. 4, 91058 Erlangen, Germany

leszek.kulisiewicz@lstm.uni-erlangen.de

^{*} *Corresponding author*

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Introduction

Application of high hydrostatic pressure up to 1 GPa offers a variety of advantages and potentials in the modern technology of food processing. It enables inactivation of microorganisms or enzymes while the amount of aromas and vitamins is not substantially decreased [Sasagawa and Yamazaki, 2002]. However, physical properties of the biomatter change significantly due to increase of pressure [Kulisiewicz et al. 2006]. The knowledge of physical properties of treated substance is essential for understanding, design and control of the processing technology. Specifically rheological data are from elevated interest as they provide information on flow behaviour and molecular structure of the investigated substance. Numerous food systems, for which high pressure technology might potentially bring significant advantages [Suzuki, 2002], feature viscoelastic behaviour (e.g., jams, fruit jellies, pastes, creams, yoghurt). A prevalent component of those foodstuffs is gelatin. This animal origin protein is used as a gelling agent, stabiliser, thickener and texturizer [Guo, 2003]. Gelatin plays an important role in production of foods with reduced fat content to simulate the mouth feel of fat without extensive calories.

The present contribution reports on rheological investigations of household gelatine gels under high pressure. Since the proper measurement technique is missing, for the purpose of this study an in-situ rheometer was developed for non-destructive investigations of viscoelastic substances under pressure up to 300 MPa.

Materials and Methods

Experimental setup. The measurement system developed within the present study uses transmission of small amplitude torsional shear waves for determination of storage and loss moduli G' and G'' . The test is non destructive, allowing investigations of shear sensitive samples, e.g., critical gels. The sample fills the gap between two parallel plates of 23 mm diameter, each plate connected to a piezoelectric element, one working as the sensor, one as the actor. High pressure vessel containing the developed rheometer can stand pressures up to 300 MPa. Temperature of the sample can be regulated by a glycol bath surrounding the pressure vessel. A thermocouple placed inside the sample chamber provides one-point measurement of the sample temperature.

Sample preparation and experimental procedure. Gelatin solution is used as a model system for preliminary tests. The sample is prepared according to the method given in [Djabourov et al., 1988] as a 0,1 w/w household gelatin aqueous solution. The solution is poured into the measurement chamber of the rheometer at 40°C. Next, the rheometer is placed inside the pressure cell and the pressure is increased up to 100 MPa. After pressure increase the sample is held at 40°C for 30 minutes in order to equilibrate the temperature inhomogeneities developed due to polytropic compression. Afterwards, the temperature of the thermal bath is set to 20°C. Due to large thermal inertia of the pressure chamber, it takes around 25 minutes

until the quench temperature of 20°C is reached inside the chamber. The measurement is being carried out for 300 minutes. After that period the temperature is increased again up to 40°C. The chamber is held at that temperature for several hours followed by a pressure increase up to 200 MPa. After the equilibration time, temperature is decreased again to 20°C and the measurement is started

Results and Discussion

The first results on the development of the storage modulus G' over time under high pressure are depicted in Fig. 1. The measurement at atmospheric conditions and comparative measurement at dynamic stress rheometer (Rheometric Scientific SR-5000) used for means of calibration are shown as well. The time is referred to the total measurement time t_{end} and the storage modulus to the value at $t = t_{end}$. The first measurements carried out at 100 and 200 MPa reveal that gelatin has kept its jellifying properties under high pressure.

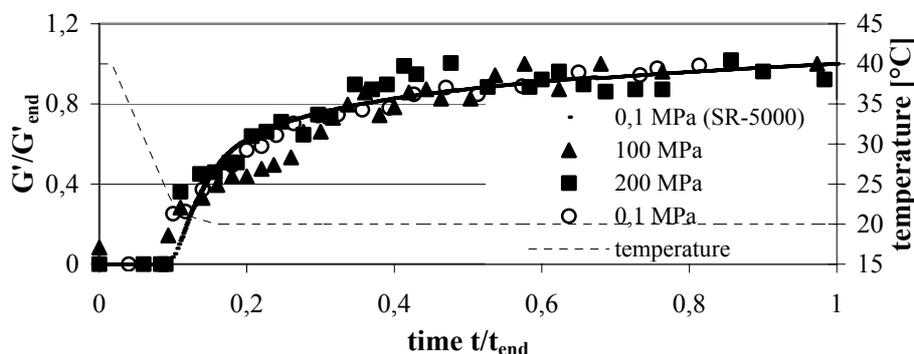


Fig. 1: Development of the storage modulus G' over time during gelation of gelatine

The storage modulus at the end of experiment at ambient pressure equals 3,8 kPa, at 100 MPa reaches 8 kPa and 15 kPa at 200 MPa. Apparently, the storage modulus of gelatine gels is increasing with pressure. However, as it can be seen from the relative representation in Fig. 1, the course of gelation curves is similar for all investigated pressure values, which suggests similar nature of the gelation process. It is hypothesised that the reason for higher values of storage modulus is the higher number of triple helix junction zones along each gelatin molecular strand. The triple helix junction zones connecting three molecular strands are stabilised by hydrogen bonds. The stable length of a junction zone depends on the strength of hydrogen bonds [Guo, 2003], being shorter when hydrogen bonds exhibit higher stability. This is the case under elevated pressure [Heremans and Smeller, 1998], which should lead to a decrease of triple helix junction zone length. Since the storage modulus of gelatin gel is increasing, it is concluded that the reason is the higher number of junction zones per molecular strand. However, the corroboration of the presented here hypothesis requires further investigations.

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