Edible Boger fluid and its rheology at human physiological conditions

Waqas Qazi[1], Magda Nyström[1], Olle Ekberg[2] and Mats Stading[1, 3]

[1] SP Food and Bioscience, Gothenburg, Sweden
[2] Skåne University Hospital, Malmö, Sweden
[3] Chalmers University of Technology, Gothenburg, Sweden

ABSRACT

Studies have shown that patients suffering from dysphagia have a slower oropharyngeal transit times than the healthy individuals. Therefore, elastic properties of liquids foods are hypothesized to be imperative for safe swallowing in those suffering from dysphagia. This makes the consideration of body temperature necessary while studying elastic fluids. Our result indicated that the elastic and viscous properties of the liquids products are considerably reduced when studied under the actual physiologic temperature conditions on the oral cavity and pharynx.

INTRODUCTION

Dysphagia refers to the difficulty in swallowing. Texture modification is a solution and leads to a common diet to manage dysphagia. Liquid foods are more likely to cause the aspiration than solid foods due to the faster oral and pharyngeal transit times[3]. Fluids with elastic properties have been identified to promote safe swallowing for those suffering from dysphagia. The current literature is based on relating shear thinning fluids to safe swallowing[4]. Salinas et al. 2014[5] have shown that the bolus deforms elangationally in the pharyngeal phase of swallowing. Therefore it is necessary to also consider the elastic properties of the food bolus while designing liquid foods for people with dysphagia.

Boger fluids when compared to Newtonian fluids provide a promising solution to study elastic properties of the liquids in relation to safe swallowing. Boger fluids are liquids with high elasticity and constant viscosity. A Food grade Boger fluid is difficult to construct due the limited availability of highly elastic food grade polymers. Xanthan gum is a well know and perhaps the only available high molecular food grade polymer with elastic properties[1].

While studying patients with dysphagia, the consideration of body heating is necessary. The patients have an overall slower oral and pharyngeal transit time for the food compare to normal individuals as observed previously[3]. Therefore it is essential to consider the elastic properties of the Boger liquid at body temperature. In this study we investigated the behavior of a Boger liquid both at room and body temperature and compared it with its Newtonian counterpart.

MATERIAL AND METHODS

Maltodextrin was supplied by AVEBE Food (Veendam, Holland). Its dextrose equivalent ranged between 14-17. Xanthan gum (Grindsted X) was supplied by Danisco® Denmark.

Preparation and mixing of maltodextrin and gum solutions

Maltodextrin was slowly added to deionized water (65% w/w). Slow stirring was continued for two days until complete dissolution of the maltodextrin. A stock solution (2%) of xanthan gum was prepared separately. The two polymer solutions were mixed in appropriate amount for an hour to achieve the final concentration of 200 ppm xanthan gum in the Boger fluid consisting of 64.35 %w/w maltodextrin.

Rheological measurements

All the rheological measurements were performed with the help of ARES G2 rotational rheometer (TA Instruments, Delaware, USA). The geometry used in this study was cone plate with 40 mm diameter and 0.0398 rad. The sample was placed carefully on the plate with a pipette. It is important not to over or under load the plate with the sample for correct measurement. Paraffin oil was poured onto the edges of the sample to avoid evaporation of the water. The shear rheological measurements were performed between 1 and 1000/s starting from the lowest shear rate. The measurements were performed in triplicate. The values given in the Figures are average values with the standard deviation. Standard deviation <0.01 are not included in the Figures. Measurements were performed at both 20 and 37°C respectively. Initially the linear viscoelastic region of the sample was determined at 1 Hz while the strain was varied from between 0.1 to 100 %. A strain 1 % strain was within the linear region and chosen for further measurements.

The mechanical spectrum was determined between 1 to 100 Hz. The moduli were plotted against the frequency on double logarithmic scale.

RESULTS AND DISCUSSION

Influence of temperature on viscosity and elasticity of the model fluids in shear rheology:

People suffering from dysphagia (dysphagics) have a slower response to the food they swallow. Therefore it is necessary to consider the viscoelastic properties of the food they swallow under the human physiological conditions than the serving temperature (~20°C).

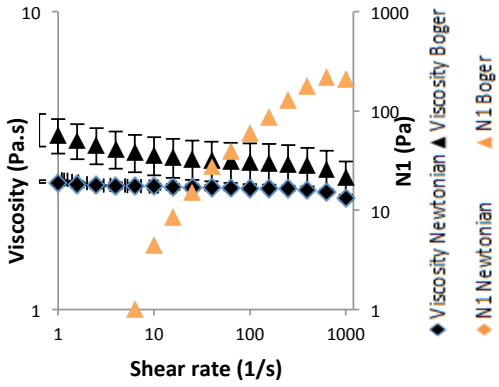

Figure 1. Shear viscosity and 1st normal stress difference (N_1) of the Boger fluid and its Newtonian counterpart at 20°C.

Figure 1 and 2 show the shear viscosity and 1st normal stress difference (N_1) for Boger and Newtonian liquid. This has a profound influence in the clinical trials. Our previous findings show the dysphagia

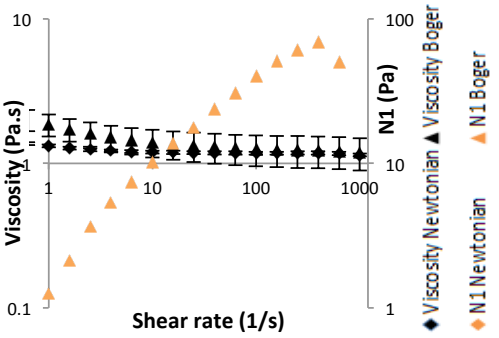

Figure 2. Shear viscosity and 1st normal stress difference of the Boger fluid and its Newtonian counterpart at 37°C.

patients have an overall lower oropharyngeal transit times than normal individuals. Here we observed a reduction of shear viscosity from 3.173.14 Pa.s) to 1.29-1.27 at the shear rate of 39 to 63/s

which is the shear rate range for human swallowing[3]. Similarly the proportional elasticity (N_1) of the Boger fluids was also decreased considerably (Figure 1 and 2) decreasing from 27.6-60.6 to 23.6-40.1 Pa at the shear rates 39 to 63/s. Figure 2: Shear viscosity and 1st normal stress difference of the Boger fluid and its Newtonian counterpart at 37°C.

Newtonian fluids, which lack the elasticity and therefore N_1 =0. (Not included in the Figures).

Influence of temperature on viscosity and elasticity of the model fluids in oscillatoryrheology:

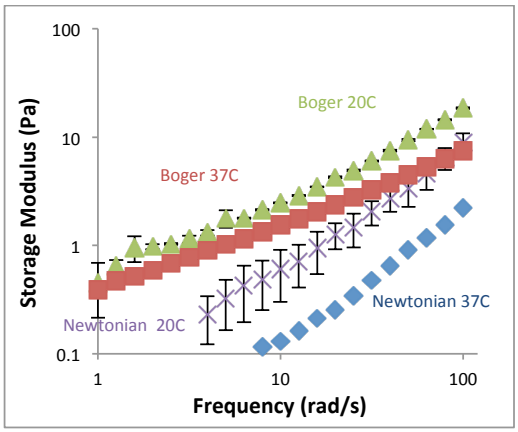

Figure 3. Storage modulus (G´) variation as a function of frequency in oscillatory measurements.

Viscoelasticity was monitored at temperatures 20 and 37°C to see if the storage modulus (G´) is influenced (Figure 3). G´ was as expected higher for the Boger and Newtonian fluids at 20°C than at 37°C. We observed a higher G´ for Boger liquid than its Newtonian counterpart at both temperatures. This is because Boger liquid was made with xanthan gum which contributes to the viscoelastic response as observed elsewhere[5]. This observation is valuable to consider for food products with soft gel like attributes designed for dysphagics. This study is a small part of a big project where human normal and abnormal swallow will be studied in great detail in an in vitro model and confirmed later on through clinical trials. The model is currently under construction at SP Food and bioscience.

CONCLUSION

The study shows an expected reduction in shear viscosity and elasticity for both the elastic Boger liquid and the Newtonian liquid with temperature. The same was observed in oscillatory measurements. It was noted that Newtonian liquid has great decreases in the storage modulus than the Boger liquid at higher temperature. The temperature dependence highlights the consideration of body temperature while designing liquid foods for those suffering from dysphagia.

ACKNOWLEDGMENTS

We are grateful to the Swedish Research Council Formas for the support of this work.

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