Model Fluids for Safe Swallowing: A Rheological Perspective

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

[1] SIK – The Swedish Institute for Food and Biotechnology, Göteborg, Sweden

[2] Diagnostic Radiology, Skåne University Hospital, Malmö, Lund University, Sweden
[3] Chalmers University of Technology, Göteborg, Sweden

ABSTRACT

Dysphagia refers to the difficulty in swallowing. An innovative approach to manage dysphagia is designing the rheological properties of foods and drinks. Non-Newtonian fluids have been highlighted as helpful for safe swallowing and it has also been pointed out that the elastic properties of the food may help improve the swallowing process. However, literature lacks any consistent set of results which relates the food elasticity to swallowing. In the present project we created three food grade model fluids with Newtonian (constant shear viscosity), Boger (constant shear viscosity and elastic) and shear thinning (shear rate dependent and elastic) behavior to elucidate the individual effects of elasticity and shear thinning.

INTRODUCTION

A normal swallow consists of three phases; oral, pharyngeal, and esophageal. Swallowing begins in the oral cavity in order to transfer food from mouth to the stomach[1]. A normal eating process involves chewing and mastication. During these processes food experiences a number of structural transformations.

Dysphagia is a serious concern especially in the elderly population which often leads to malnutrition[2]. About 50% of the elderly (65 years or above) people in nursing homes suffer from swallowing disorders. The elderly population in US alone is expected to rise from 39 to 69 million by 2030. Swallowing disorders are more pronounced for low viscosity foods[3]. Commonly in diets the texture of a food product is adjusted which changes the rheological properties of the food and various food thickeners are used to achieve this objective[5]. Due to over-simplification and limited knowledge of rheology in relation to swallowing, the evidence of its success barely exists.

People suffering from swallowing disorders may have an entirely different oropharyngeal food processing. The key factor often ignored is the stage of swallowing and elasticity in the liquid swallowed product. Therefore a more comprehensive knowledge of the swallowing process in relation to the product´s elastic properties is required[5]. The current project was designed to study the effect of rheological properties of the model fluids affecting swallowing in individuals suffering from dysphagia. The model fluids were constructed with a view to observe how elasticity of the food material, in addition to shear viscosity, affects the swallowing process. Three different kinds of model fluids were produced. The fluids used varied in rheological behavior and especially in the degree of elasticity: A shear thinning liquid which is viscoelastic in nature with decreasing shear viscosity at the increasing shear rate; a Boger fluid which is also viscoelastic and has constant shear viscosity; and a Newtonian fluid with no elasticity and a fix viscosity.

RESULTS AND DISCUSSION

The model fluids were created with maltodextrin, xanthan gum and iodinated contrast media. Maltodextrin was used as the solvent to provide shear viscosity while xanthan gum was used as high molecular weight polymer to provide elasticity. Iodinated contrast media was used to achieve radio-opacity in the model fluids in order to facilitate the X-ray analysis during swallowing examination. The difference between fluids in this study is whether the high molecular weight polymer i.e. xanthan gum has been added or not and the concentration of xanthan gum. The Newtonian fluid here is composed of only maltodextrin in a high concentration dissolved in water. Newtonian fluid will act as a control to ultimately determine if elasticity in the sample facilitates swallowing of liquids.

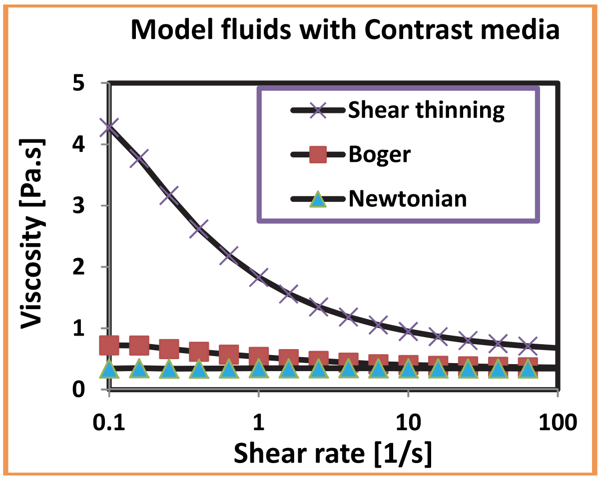

Figure 1. Shear rate dependence of the model fluids.

The Boger fluid was similar to the one reported by Koliandris[6] and had a very slight shear thinning at lower shear rates and constant viscosity at higher shear rate. From the figure 1 it is obvious that that shear thinning sample has a high viscosity at low shear rates which decreases upon increasing shear rate.

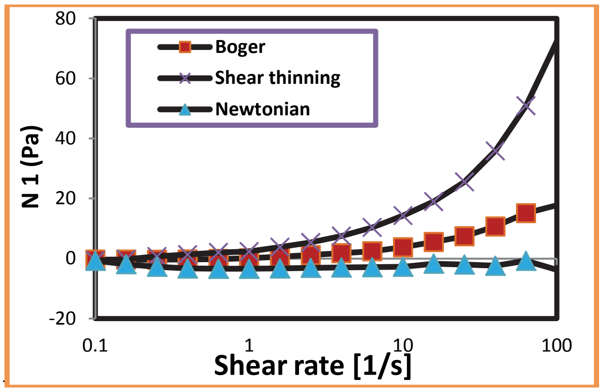

Figure 2. First Normal stress difference (N1) of the model fluids as a function of the shear rate (1/s).

Xanthan gum was used as the high molecular weight polymer providing elasticity. The effect can be observed by plotting the shear rate and the first normal stress difference (N_1) (Fig 2). N_1 increases with shear rate for elastic fluids as shown in Fig. 2. The normal stress for the Newtonian fluid was consequently not measurable. The shear thinning fluid also displayed a normal stress increase with shear rate which shows that the fluid is even more elastic than the Boger and Newtonian fluids.

In this study model fluids with desired rheological attributes were developed successfully that could be used in the radiological analysis.

CONCLUSIONS

Edible model fluids were successfully developed to elucidate the influence of fluid elasticity on swallowing.

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