Effect of shear vs. extensional flow during swallowing

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

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

ABSTRACT

When we eat the swallowing is mainly an involuntary process. However, for an increasing number of the population the actual swallowing causes problems. The effect of elasticity on swallowing was thus evaluated. Edible model fluid foods were developed and the rheological properties were evaluated. The study indicated positive effects of fluid elasticity on the ease of swallowing for patients suffering from dysphagia.

INTRODUCTION

Swallowing is a highly unconscious process. We prepare a bolus by chewing and mixing with saliva and as soon as we initiate swallowing, it is an involuntary process[1]. However, for an increasing proportion of the population the actual swallowing causes problems. Swallowing disorders, or dysphagia, affects 40% of the ones older than 70 due to dementia, trauma or medication side effects, and as a consequence 30-60% of the patients in homes for the elderly are estimated to be malnourished[2]. The swallowing disorders may also cause the food to enter into the airways which causes anything ranging from coughing to pneumonia. It is therefore important to formulate foods and nutritional supplements which have suitable rheological effects for safe swallowing.

Previous studies have indicated an effect of fluid elasticity on swallowing[3]. In the present study the effect of elasticity in fluid foods was evaluated by well-define edible model fluids with the aim of determining if fluid elasticity effects the ease of swallowing.

MATERIAL AND METHODS

Edible model fluid foods were developed having specific rheological characteristics[4]:

- Newtonian fluids
  (constant shear viscosity),
- Boger fluids
  (elastic, constant shear viscosity)
- Shear thinning fluids
  (elastic, shear rate dependent).

The model fluids were based on maltodextrin and xanthan[5] with the addition of iodine (Omnipaque®, GE Healthcare) to make them opaque to x-rays to enable videoflouroscopic analysis during clinical trials.

The rheological properties were evaluated using shear rheometry (ARES G2, TA Instruments) and Hyperbolic Contraction Flow[6, 7]. Sensory evaluation by 12 patients suffering from dysphagia together with quantitative videoflouroscopy was performed at the Department of Imaging and Function, Skåne University Hospital, Sweden. The patients were asked to grade the samples through a five digit

line-scale, labelled "5=very easy to swallow" and "1=very difficult to swallow".

RESULTS

Fig. 1 presents the steady shear properties of the model fluids without contrast media (Fig. 1a) and diluted with iodinated contrast medium (Fig. 1b). The model fluids were designed by setting the concentration of the high molecular weight, elastic polymer (xanthan) dissolved in high viscosity maltodextrin, with or without contrast medium. A corresponding Newtonian model without xanthan was used as reference. Fig. 1a shows that the shear viscosity of the Newtonian fluid is constant, and the Boger fluids nearly constant, while the Shear-thinning fluid is distinctly shear-thinning.

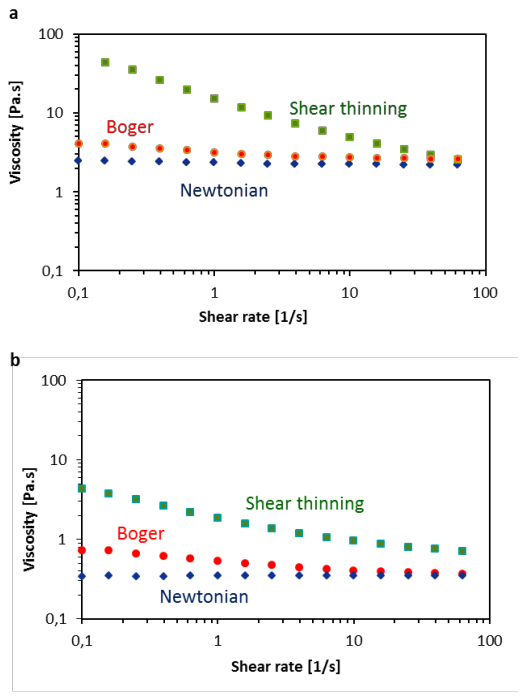

Figure 1. Shear viscosity of the three model fluids a) before dilution, b) after dilution with the contrast medium Omnipaque®.

Boger fluids based on polyacrylamide instead of xanthan have an even more constant shear viscosity, but with the limitation of having the Boger fluid edible, this is as constant as it gets. Fig. 1b further shows that iodine (the contrast media) did not affect the main rheological features of the model fluids except lowering the shear-viscosity.

The extensional viscosity of the model fluids was characterized by the Hyperbolic Contraction Flow method[6, 7] (Fig. 2). An increasing elasticity was observed with increasing amount of xanthan, and both the Boger and Shear thinning fluids were extension thickening. The Trouton ratio was in the range 15-20.

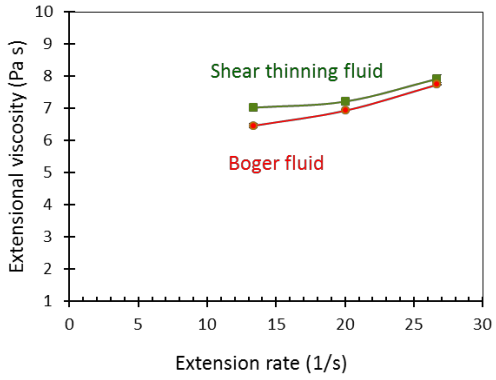

Figure 2. Extensional viscosity of the Boger and Shear thinning fluids.

The results of the sensory evaluation by the dysphagic patients are shown in Fig 3. They showed that elastic fluids were perceived comparatively easier to swallow. The Shear thinning fluid was the easiest to swallow with a total score by the 12 patients of 37 followed by the Boger fluid with score of 36. Conclusively, the Newtonian fluid was slightly more difficult to swallow. Due to the wide range of dysphagia symptoms among the 12 patients, the differences between the model fluids were not statistically significant. The clinical trials

further indicated that elastic properties may have a positive effect on the swallowing physiology especially in the initial stages of the swallow[4].

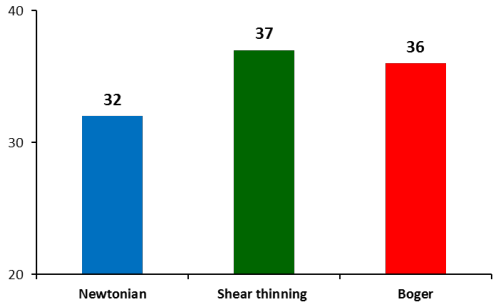

Figure 3. Total score of the perceived ease of swallowing as evaluated by the dysphagic patients (1=very difficult to swallow, and 5=very easy).

CONCLUSIONS

The study indicated positive effects of high extensional properties on the ease of swallowing for patients suffering from dysphagia.

ACKNOWLEDGMENTS

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