Rheological modification of fluid foods for patients with dysphagia

Waqas Muhammad Qazi[1] and Mats Stading[1,2]

[1] SP Technical Research Institute of Sweden, Soft Materials Science, Gothenburg, Sweden
2 Chalmers University of Technology, Göteborg, Sweden

ABSTRACT

Swallowing disorders, or dysphagia, is a growing problem especially as the population gets older. Fluid thickening is a well-established strategy for treating dysphagia, but the effects of thickening on the physiology of impaired swallowing are not fully understood and the relations to basic rheology are scarce. Commercial thickeners studied showed different behavior in both shear thinning, yield stress and first normal stress difference, and even larger differences in extensional viscosity.

INTRODUCTION

Swallowing disorders, or dysphagia, is a growing problem especially as the population gets older. Already over 50 years of age 22% suffer from swallowing disorders and in the age group above 70, 40 % suffer due to factors such as degenerative diseases and side effects of medication[1]. It is estimated that 99 million people, i.e. 8% of the world population suffers from dysphagia[2]. These persons must eat texture adjusted foods.

Healthy individuals apply highly unconscious, but very well coordinated strategies for the oral processing producing easy-to-swallow boluses. People who suffer from dysphagia have impaired swallowing mechanisms. One serious case is when the epiglottis does not fully function and food or beverage leaks into the larynx (aspiration), which is common in the elderly population. Dysphagia is a prevalent symptom in degenerative diseases such as stroke, dementia, Parkinson’s disease and Alzheimers’s disease. Swallowing disorders covers a broad range of problems, from coughing during meals to malnutrition, and 30-60% of the patients in homes for the elderly are estimated to be malnourished[3]. Foods that give a better controlled passage through the opening to the larynx, even with a malfunctional epiglottis, will make a significant contribution to an improved quality of life for people with dysphagia.

Fluid thickening is a well-established management strategy for dysphagia. Fluid foods are thickened with hydrocolloids which provide increases shear and extensional viscosity. However, the effects of thickening on the physiology of impaired swallowing are not fully understood and the relations to basic rheology are scarce[4]. Fluids are commonly thickened using commercial thickeners consisting of mixtures of hydrocolloids such as starches, guar and xanthan, to a perceived consistency or to a measure of shear viscosity at a specific shear rate, typically 50 s^{-1}. The guidelines vary according to country, but the American Dietetic Association guidelines [5] are often referred to. They give a perceived consistency and apparent viscosity at an apparent shear viscosity at 50 s^{-1} as

- Thin: < 0.05 Pas
- Nectar like: 0.05-0.35 Pas
- Honey like: 0.35-1.75 Pas
- Spoon thick: >1.75 Pas

In the present study shear and extensional rheology of various commercial thickeners for dysphagia management have been determined, with specific emphasis of demonstrating the effect of fluid elasticity on safe swallowing[6].

RESULTS AND DISCUSSION

Fluids with thickeners from the major suppliers in the dysphagia were characterized regarding shear rheology (viscosity, yield stress and first normal stress difference) using both a laboratory rheometer and an in-line ultrasonic tube viscometer[7]. The latter was used to assure similar flow conditions as the flow through the swallowing tract (pharynx and esophagus). Commercial thickener solutions were compared to model fluids (Newtonian, Boger and shear thinning) [6]. The extensional viscosity was determined using Hyperbolic Contraction Flow[6] at fixed Hencky strain. In order to compare at equal conditions the concentration of thickener was adjusted to give an apparent shear viscosity of 0.55 Pas at 50 s^{-1}.

The commercial thickeners showed different behavior in both shear thinning, yield stress and first normal stress difference, and even bigger differences in extensional viscosity. The fluids containing xanthan displayed in general higher elasticity as expressed by the extensional viscosity than fluids based on starch.

CONCLUSIONS

The main conclusion of the study is that rheology is needed in the area of clinical dysphagia management. It is not sufficient to specify an apparent shear viscosity at a single shear rate because the fluid foods and thickened drinks vary considerably in their extended rheological properties, which has an effect on such a complex flow as swallowing represents.

REFERENCES

1. Cook, I.J., Kahrilas, P.J. (1999) "A technical review on management of oropharyngeal dysphagia", *Gastro-enterology*, **116,** 455.

2. Steele, C.M. (2015) "The blind scientist and the elephant of swallowing: A review of instrumental perspectives on swallowing physiology", *J. Text. Stud.*, **46**,122.

3. Groher, M.E., Bukatman, M.S. (1986) "The prevalence of a swallowing disorder in two teaching hospitals", *Dysphagia*, **1**, 3-6.

4. Newman, R., Vilardell, N., Clavé, P. and Speyer, R. (2016) "Effect of bolus viscosity on the safety and efficacy of swallowing and the kinematics of the swallow response in patients with oropharyngeal dysphagia: White Paper by the European Society for Swallowing Disorders (ESSD)", *Dysphagia J.*, in press.

5. National Dysphagia Task Force (2002). National dysphagia diet: standardization for optimum care. Chicago, IL. American Dietetic Association.

6. Nyström, M., Muhammad, W, Bülow, M., Ekberg, O. and Stading, M. (2015) "Effects of rheological factors on perceived ease of swallowing", *Appl. Rheol.*, **25**, 63876.

7. Wiklund, J., Ricci, S., Haldenwang, Meacci, V., Stading, M. and Kotzé, R. (2014) "Flow-Viz – A fully integrated and commercial in-line fluid characterization system for industrial applications" In 9th ISUD Conference. *International Symposium on Ultrasonic Doppler Methods for Fluid Mechanics and Fluid Engineering.* Strasbourg, France, 137-139

Impact of silver nanoparticles on the mechanical properties of *Aquabacterium* biofilms

Yvonne Schmitt[1], Alexandra Grün[1], Natalie Jonas[2], Dimitri Demeshko[2], Werner Manz[1], and Silke Rathgeber[1,2]

[1] Institute for Natural Sciences, University of Koblenz-Landau, 56070 Koblenz, Germany
[2] Technology Institute for Functional Polymers and Surfaces (tifko) GmbH, 56566 Neuwied, Germany

Biofilms comprise bacteria embedded in a matrix consisting of polysaccharides, extracellular DNA, proteins and lipids.[1] Aquatic biofilms play an important role in sediment stabilization in riverine systems. The antimicrobial properties of silver nanoparticles (AgNP) led to a wide range of applications in consumer products.[2] As a consequence there is an increasing release of AgNP into aquatic environments.[2] AgNP are supposed to be a continuous source for silver ions (Ag^+) [3] which can bind to functional groups of the biofilm constituents, leading potentially to a decrease in the number of possible intermolecular interactions and, thus, reduced stability of the network. An impairment of the sediment stabilization due to enrichment of the AgNP in the biofilms might be detrimental to the whole ecosystem.

Hence we studied the mechanical properties of *A. citratiphilum* biofilms by means of rheology. The bacterium chosen is representative for a numerically dominant group of bacteria in different freshwater habitats. The biofilms were exposed to environmenally relevant concentrations of AgNP. In order to distinguish physical effects, resulting from the presence of the nanoparticles in the biofilms, from effects, due to the activity of the Ag^+-ions, we studied biofilms exposed to Ag^+-ions as reference. The impact of the AgNP and Ag^+-ions on the mechanical properties of the biofilms were in particular analyzed by means of creep and recovery tests at various stress levels.

Creep and recovery could be described by a modified Burgers model. The tests revealed that the relaxation of the biofilms in response to a stress step function is characterized by a fast and slow relaxation process and viscous flow. Ag^+-ions and AgNP lead to an increased viscosity of the biofilms. The presence of the AgNP causes a softening of the biofilms due to a destruction of the physical crosslinks responsible for the fast relaxation process. As a consequence the dissipative portion in the recovery curve increases. This is not observed for the biofilms loaded with Ag^+-ions. Neither AgNP nor Ag^+-ions affect the slow relaxation process.

The presence of the AgNP indeed perturbs the cohesion of the biofilms, but the detrimental effect is not due to the release of Ag^+-ions but is most likely due to the particulate character of the nanoparticles.

ACKNOWLEDGMENTS

This study was supported by the German Research Foundation (DFG; Research unit INTERNANO: FOR 1536, subprojects

BIOFILM MA3273/3-1 and MASK SCHA849/16).

REFERENCES

1. Flemming, H.-C., Wingender, J. (2010), "The biofilm matrix", *Nat. Rev. Microbiol.,* **8**, 623-633.

2. Chernousova, S., Epple, M. (2013), "Silver as Antibacterial Agent: Ion, Nanoparticle, and Metal", *Angew. Chem. Int. Ed,* **52**, 1636-1653.

3. Navarro, E., Piccapiera, F., Wagner, B., Marconi, F., Kaegi, R., Odzak, N., et al. (2008), "Toxicity of Silver Nanoparticles to *Chlamydomonas reinhardtii*", *Environ. Sci. Technol.,* **42**, 8959 – 8964.