Applied Rheology | DOI: 10.3933/APPLRHEOL-25-63876 | WWW.APPLIEDRHEOLOGY.ORG

Effects of Rheological Factors on Perceived Ease of Swallowing

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

[1]SP Food and Bioscience, Soft Materials Science, 402 29 Göteborg, Sweden
[2]Department of Materials and Manufacturing Technology,
Chalmers University of Technology, 412 76 Göteborg, Sweden
[3]Diagnostic Centre of Imaging and Functional Medicine, Skåne University Hospital,
Lund University, 205 02 Malmö, Sweden

* Corresponding author: mats.stading@sp.se

Received: 22.6.2015, Final version: 31.8.2015

Abstract:
This study is a contribution to the understanding of how rheological properties of a fluid influences swallowing, especially people suffering from swallowing disorders (dysphagia). Our hypothesis was that fluid elasticity contributes to safe and pleasant swallowing. In the present study three food grade model fluids with specific rheological properties were developed and used: a Newtonian fluid with constant shear viscosity, an elastic Boger fluid with constant shear viscosity and a shear-thinning fluid which was elastic and had rate dependent shear viscosity. By comparing the swallowing of these model fluids the specific rheological effects could be distinguished. Sensory analysis of the perceived ease of swallowing was performed by a panel of healthy individuals, and by a group of dysphagic patients. The swallowing of the latter group was also characterized by videoflouroscopy and the transit times in the mouth and pharynx were determined. The hypothesis was confirmed by dysphagic patients who perceived swallowing easier for the elastic model fluids. A sensory panel of healthy individuals could not distinguish differences in swallowing, likely because their swallowing functions well and is an involuntary process. Quantitative videofluoroscopic measurements of swallowing transit times for the dysphagic patients suggested that fluid elasticity contributed to easy and safe swallowing, but the effect was not statistically significant due to the large spread of type of swallowing disorder.

Key words:
Rheology, dysphagia, elastic properties, model fluids, sensory analysis, videoflouroscopy

1 INTRODUCTION

The complete chewing and swallowing process is an intricate combination of voluntary and involuntary actions and it involves complex flow geometry as well as a mixture of shear and extensional flow. For healthy individuals it is an integral part of our food processing and a source of pleasure through the experience of textures tastes and flavours. We can influence the process as long as the food is in the mouth, but as soon as the bolus hits the pharyngeal arches we automatically swallow. It is a process we seldom notice unless the swallowing is unpleasant or if it goes wrong. On the other hand, for people suffering from swallowing disorders it is a daily struggle during every meal. Already over 50 years of age 22 % suffer from swallowing disorders and in the age group above 70 years 40 % suffer due to factors such as degenerative diseases, side effects of medication or trauma [1]. As we live longer this is a growing problem, and dysphagia may cause serious states such as pneumonia by the bolus entering the airways and malnutrition due to the difficulties in eating overall [2]. The persons suffering from dysphagia must eat texture adjusted foods, and the oral processing is considerably affected.

By designing the rheological properties of the food, swallow ability can be affected. The National Dysphagia diet describes four levels of liquid consistency defined at 25 °C and a shear rate of 50 s-1 including thin (0.001 to 0.05 Pas), nectar (0.05 – 0.35 Pas), honey (0.35 – 1.75 Pas), and spoon-thick (> 1.75 Pas). Various food thickeners are used to achieve this objective [3]. Low viscosity fluids show more difficulties for swallowing [4] than high viscosity fluids: a viscous bolus is more likely to delay the oral and pharyngeal bolus passage thereby allowing more time for the epiglottis to close [5]. Numerical studies of non-Newtonian and Newtonian fluids has shown that non-Newtonian fluids are

properties of the model fluids for the current group of patients. Pharyngeal retention is an indication of weak muscles in the pharynx. Residues from swallowed food could stay in the pharynx due to weaker muscles which may cause misdirected swallowing. The physiological health status of the individual patients was in this case the dominant factor in determining the safety of swallowing than the fluids properties of the liquids itself.

4 CONCLUSIONS

Sensory evaluation by dysphagic patients showed that introducing an elastic component over all made the fluid easier to swallow. Healthy individuals could however not distinguish differences in swallowing between the different model fluids, likely because they have normal, involuntary swallowing and instead pick up differences in mouth feel. Quantitative videoflouroscopy measurements of swallowing transit times for the dysphagic patients suggested that fluid elasticity contributed to easy and safe swallowing, but the difference was not statistically significant due to the large spread of type of swallowing disorders among the patients. To our knowledge the oral and pharyngeal transit times for rheological model fluids were measured for the first time for individuals suffering from dysphagia. A Boger fluid compared to its non-elastic Newtonian counterpart has never been tried on dysphagia patients. The extensional properties of the Boger fluid with concentration of 200 ppm xanthan showed relatively small elastic behaviour, especially for small extension rates, explaining the doubtful results of the sensory analysis and clinical trials. With higher xanthan content, however, shear-thinning is introduced, making it hard to separate the shear-thinning contra elasticity influence on swallowing. Thus, a more elastic, yet edible alternative to xanthan would be desirable in order to attain Boger fluids with even higher extensional viscosity. However, this is difficult to achieve with food grade components.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided from the Materials Science Area of Advance, Chalmers University of Technology and we are also very grateful to Mikael Sundin at Chemistry, Materials and Surfaces, SP Technical Research Institute of Sweden for providing us with the opportunity to perform CaBER measurements and providing us with surface tension measurements.

REFERENCES

[1] Cook IJ, Kahrilas KP: A technical review on management of oropharyngeal dysphagia, Gastroenterol. 116 (1999): 455–478.
[2] Khan A, Carmona R, Traube M: Dysphagia in the elderly, Clinics in Geriatric Medicine 30 (2014) 43–174.
[3] Zargaraan A, Rastmanesh R, Fadavia G, Zayeric F, Mohammadifara MA: Rheological aspects of dysphagia-oriented food products: a mini review, Food Sci. Human Wellness 2 (2013) 173–178.
[4] Nishinari K, Takemasa M, Sua L, Michiwakic Y, Mizunumad H, Ogoshie H: Effect of shear thinning on aspiration – Toward making solutions for judging the risk of aspiration, Food Hydrocolloid. 25 (2011) 1737–1743.
[5] Ishihara S, Nakauma M, Funami T, Odake S, Nishinari K: Viscoelastic and fragmentation characters of model bolus from polysaccharide gels after instrumental mastication, Food Hydrocolloid. 25 (2011) 1210–1218.
[6] Meng Y, Rao MA, Datta AK: Computer simulation of the pharyngeal bolus transport of Newtonian and non-Newtonian fluids, Food Bioprod. Proc. 83 (2005) 297–305.
[7] Stading M, Johansson D, Wendin K: Rheological properties of food for patients with swallowing disorders, Ann. Trans. Nordic Rheol. Soc. 16 (2008) 137–139.
[8] Gallegos C, Quinchia L, Ascanio G, Salinas-Vázquez M, Brito-de la Fuente E: Rheology and dysphagia: An overview, Ann. Trans. Nordic Rheol. Soc. 20 (2012) 3–10.
[9] Buettner A, Beer A, Hannig C, Settles M: Observation of the swallowing process by application of videofluoroscopy and real-time Magnetic Resonance Imaging - Consequences for retronasal aroma stimulation, Chem. Senses 26 (2001) 1211–1219.
[10] Chen J, Lolivret L: The determining role of bolus rheology in triggering a swallowing, Food Hydrocolloid. 25 (2011) 325–332.
[11] Petrie CJS: Elongations flows, Pitman (1979).
[12] Nakauma M, Ishihara S, Funami T, Nishinari K: Swallowing profiles of food polysaccharide solutions with different flow behaviors, Food Hydrocolloid. 25 (2011) 1165–1173.
[13] Entov VM, Hinch EJ: Effect of a spectrum of relaxation times on the capillary thinning of a filament of elastic liquid, J. Non-Newtonian Fluid Mech. 72 (1997) 31–53.
[14] Anna SL, McKinley GH: Elasto-capillary thinning and breakup of model elastic liquids, J. Rheol. 45 (2001) 115–138.
[15] Binding DM: An approximate analusis for contraction and converging flows, J. Non-Newtonian Fluid Mech. 27 (1988) 173–189.
[16] Wikström K, Bohlin L: Extensional flow studies of wheat flour dough. I. Experimental method for measurements in contraction flow geometry and application to flours varying in breadmaking performance, J. Cereal Sci. 29 (1999) 217–226.
[17] Stading M, Bohlin L: Contraction flow measurements of extensional properties, Ann. Trans. Nordic Rheol. Soc. 8/9 (2000) 181–185.
[18] Stading M, Bohlin L: Measurements of extensional flow properties of semi-solid foods in contraction flow, Proceedings of the 2nd International Symposium on Food

Rheology and Structure (2000) 117–120.
[19] Nyström M, Tamaddon-Jahromi HR, Stading M, Webster MF: Numerical simulations of Boger fluids through different contraction configurations for the development of a measuring system for extensional viscosity, Rheol. Acta 51 (2012) 713–727.
[20] Andersson H, Öhgren C, Johansson D, Kniola M, Stading M: Extensional flow, viscoelasticity and baking performance of gluten-free zein-starch dough supplemented with hydrocolloids, Food Hydrocolloids 25 (2011) 1587–1595.
[21] Staff DM, Shaker R: Videoendoscopic evaluation of supraesophageal dysphagia, Current Gastroenterol. Reports 3 (2001) 200–205.
[22] Ekberg O, Bulow M, Ekman S, Hall G, Stading M, Wendin K: Effect of barium sulfate contrast medium on rheology and sensory texture attributes in a model food, Acta Radiol. 50 (2009) 131–138.
[23] Dantas R, Kern MK, Massey BT, Dodds WJ, Kahrilas PJ, Brasseur JG, Cook IJ, Lang IM: Effect of swallowed bolus variables on oral and pharyngeal phases of swallowing, Am. J. Physiol. – Gastrointest. Liver Physiol. 258 (1990) G675–G681.
[24] Bülow M: Therapeutic aspects of oral and pharyngeal swallowing dysfunction – Videoradiographic and videomanometric analyses of adult healthy volunteers and dysphagic patients, Ph.D. thesis, Lund University (2003).
[25] Cassiani RA, Santos CM, Parreir LC, Dantas RO: The relationship between the oral and pharyngeal phases of swallowing, Clinics 66 (2011) 1385–1388.
[26] Lang IM: Brain stem control of the phases of swallowing, Dysphagia 24 (2009) 333–348.
[27] Koliandris AL, Rondeau E, Hewson L, Hort J, Taylor AJ, Cooper-White JJ, Wolf B: Food grade Boger fluids for sensory studies, Appl. Rheol. 21 (2011) 13777.
[28] McKinley GH, Tripathi A: How to extract the Newtonian viscosity from capillary breakup measurements in a filament rheometer, J. Rheol. 44 (2000) 653–670.
[29] Rugiu MG: Role of videofluoroscopy in evaluation of neurologic dysphagia, Acta Otorhinolaryngol Ital. 27 (2007) 306–316.
[30] Nyström M, Tamaddon-Jahromi RT, Stading M, Webster MF: Evaluation of an axisymmetric hyperbolic contraction measuring systems for extensional flow: simulations and experiments, J. Non-Newtonian Fluid Mech., in press.
[31] O'Leary M, Hanson B, Smith C: Viscosity and non-Newtonian features of thickened fluids used for dysphagia therapy, J. Food Sci. 75(2010) E330–E338.
[32] Chen FJ, Dirven S, Xu WL, Bronlund J, Li XN, Pullan A: Review of the swallowing system and process for a biologically mimicking swallowing robot, Mechatronics 22 (2012) 556–567.
[33] Salinas-Vázquez M, Vicente W, Brito-de la Fuente E, Gallegos C, Márquez J, Ascanio G: Early numerical studies on the peristaltic flow through the pharynx, J. Texture Stud. 45 (2014) 155–163.
[34] Lustre NDS, Freire TRB, Silverio CC: Medidas de tempo de trânsito oral em crianças com paralisia cerebral de diferentes níveis motores e sua relação com o grau de severidade para disfagia, Audiology – Communication Res. 18 (2013) 155–161.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org