On Some Rheological Properties relevant to Food Oral Processing

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Marco RAMAIOLI

UMR 782, Food and Microbiological Engineering
INRA, France
marco.ramaioli@inra.fr

www.linkedin.com/in/marco-ramaioli/

@MarcoRamaioli

Context

Personalised Food
(Sensory, Dietary choices, Allergies, Age-adapted, Nutrition, …)
Taste and Convenience
(ready to eat, out of home)

Healthy Food
(Fresh, Low Processed, Organic, Free-From, …)

Public

Public Health

- Impact of diet on Non-Communicable Diseases
- Education
- Legislation

« Reprendre le pouvoir sur nos assiettes » : les députés s'attaquent à la malbouffe

Global Challenges
(UN and #INRA2025):
-growing world population,
-increased consumption per capita,
-higher urbanisation.

Food Systems

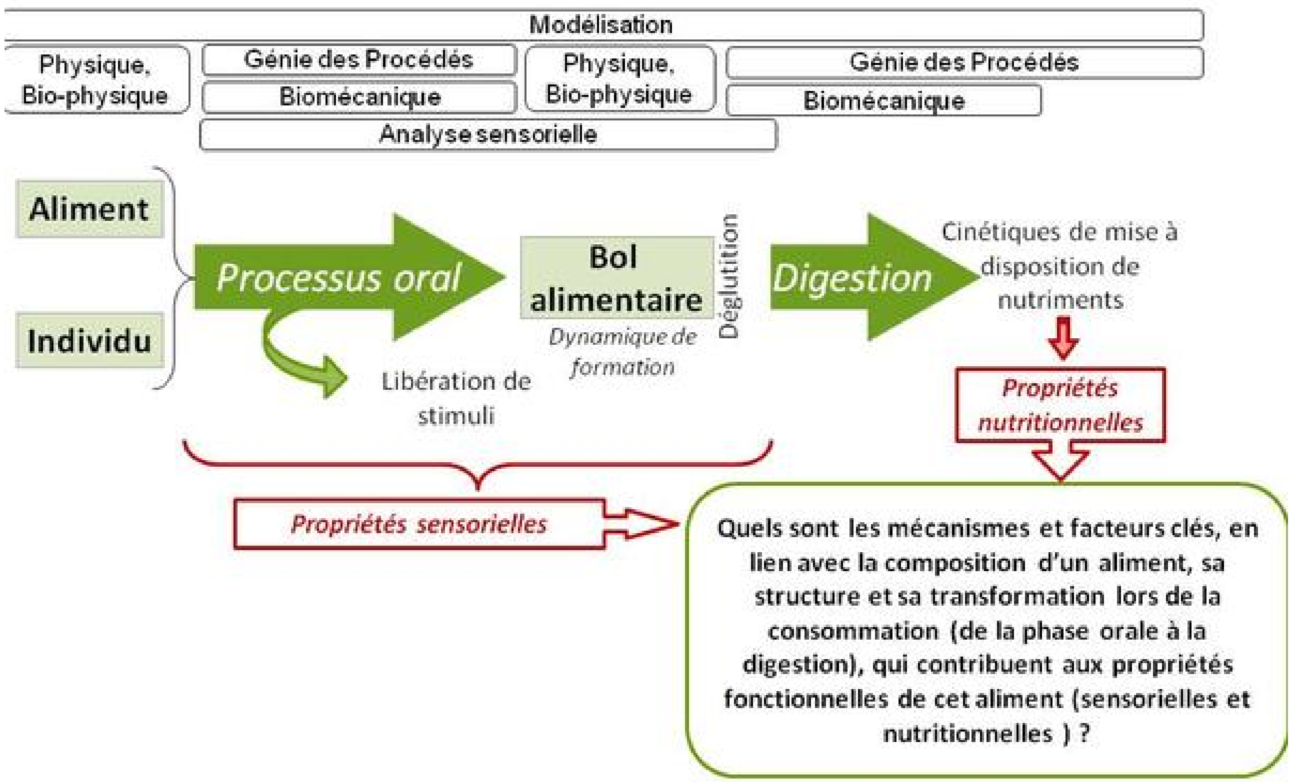
Food Industry
« En 2017, les 17 647 entreprises du secteur ont réalisé un chiffre d'affaires de 180 milliards d'euros et employaient 429 079 personnes »
(ANIA)

marco.ramaioli@inra.fr

To set the scene… let's discuss

- What is Food Oral Processing?
- Why is "food mechanics" relevant to Food Oral Processing and Swallowing?
- What properties are relevant?

Food Oral Processing @ INRA's UMR GMPA

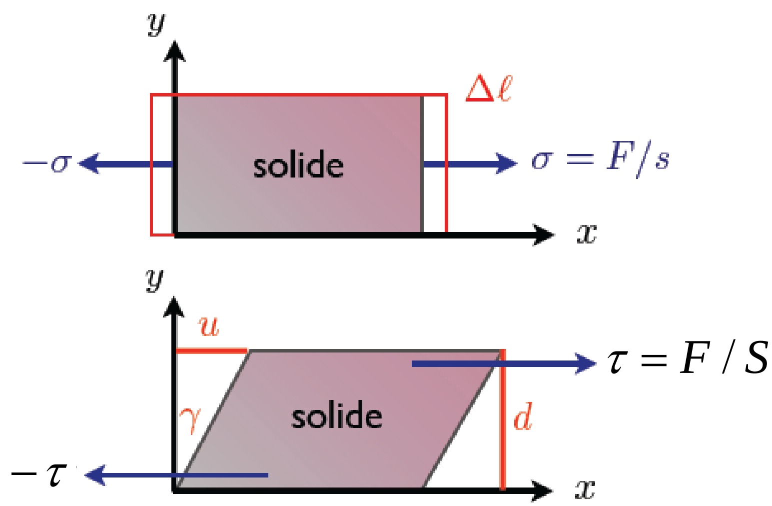


https://www6.versailles-grignon.inra.fr/gmpa/Equipes-de-Recherches/ADP

In this lecture

1. Few words on Food Mechanics
2. An example linking food rheology to perception
3. An example linking food rheology to swallowing

Simple Mechanics - Solids – Linear Elasticity



$$\sigma = E\frac{\Delta\ell}{\ell_0}$$

Young modulus

$$\tau = Gu / d$$

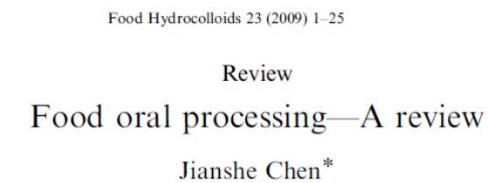
Shear modulus

Shear strain $\gamma = \frac{u}{d}$

Hooke's law $\tau = G\gamma$

N.Vandewalle, Université de Liège, BE

The complex Food Oral Processing of solid food…


Food Hydrocolloids 23 (2009) 1–25

Review

Food oral processing—A review

Jianshe Chen*

TPA

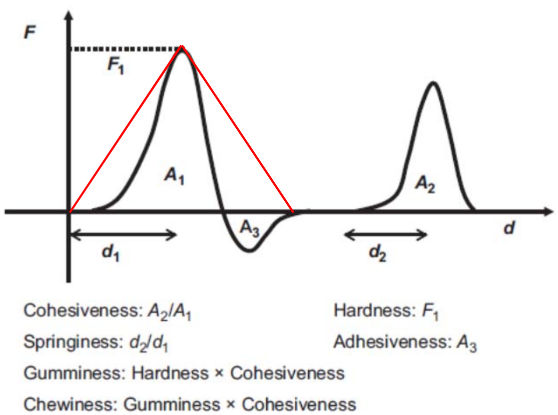


Fig. 1. A typical force–displacement curve obtained from a double-compression test using the texture profile analysis approach. One single test is capable to characterize a number of textural parameters.

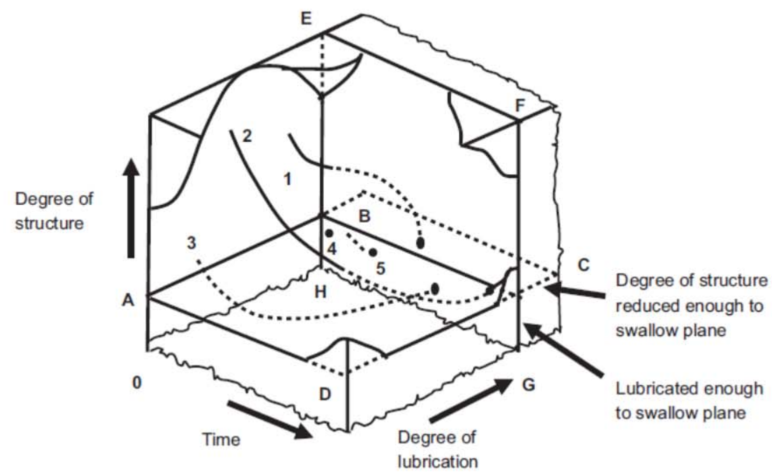


Fig. 3. The 'mouth process model': (1) tender juicy steak; (2) tough dry meat; (3) dry sponge cake; (4) oyster; (5) liquids. Before a food may be swallowed, its 'degree of structure' must have been reduced below the level of plane ABCD, and its 'degree of lubrication' must have crossed plane EFGH (adopted from Hutchings & Lillford, 1988).

The complex Food Oral Processing of solid food…

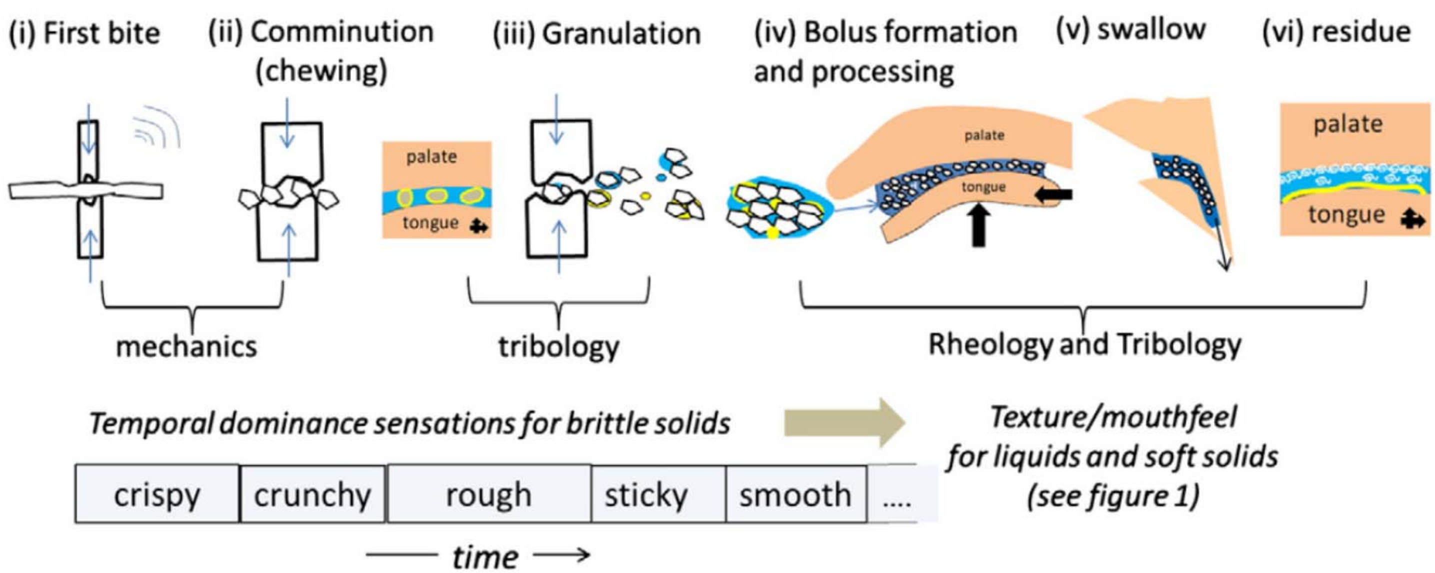
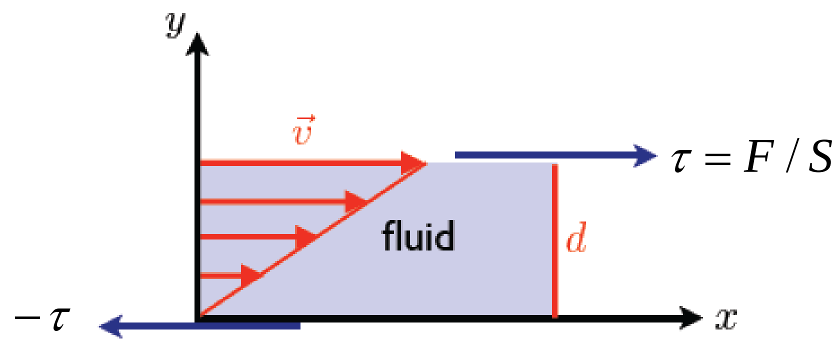


Fig. 3. Depiction of 6 key stages that we propose occur during oral processing of solid food. Also included is indication of where mechanics, rheology and tribology are important. Tribology arises in (iii) because of the interactions that occur between particles as well as at the oral surfaces, while in (iv, v, vi) it arises primarily from interactions occurring between oral surfaces. We also map on this a depiction of TDS curves for solid food that show how the dominant sensations vary over time. For oral processing of the bolus, as well as soft foods/fluids, the scheme presented in Fig. 1 is also relevant.

Stokes et al. 2013, Current Opinion in Colloid & Interface Science

Simple Mechanics - Newtonian Liquids



Shear rate $\dot{\gamma} = \frac{v}{d}$

Newtonian viscosity $\tau = \mu\dot{\gamma}$

e.g.

Air $\mu = 2\,10^{-5}\,\mathrm{Pa\,s}$

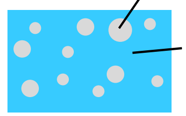
Water $\mu = 10^{-3}\,\mathrm{Pa\,s}$

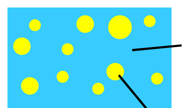
Silicon oils $\mu = 10^{-3} \rightarrow 10^{+3}\,\mathrm{Pa\,s}$

N.Vandewalle, Université de Liège, BE

Microstructured Products - Nomenclature

	Cont. Phase	Disp. Phase
• Suspensions	LIQ	SOL
• Emulsions	LIQ	LIQ
• Foams	LIQ	GAS



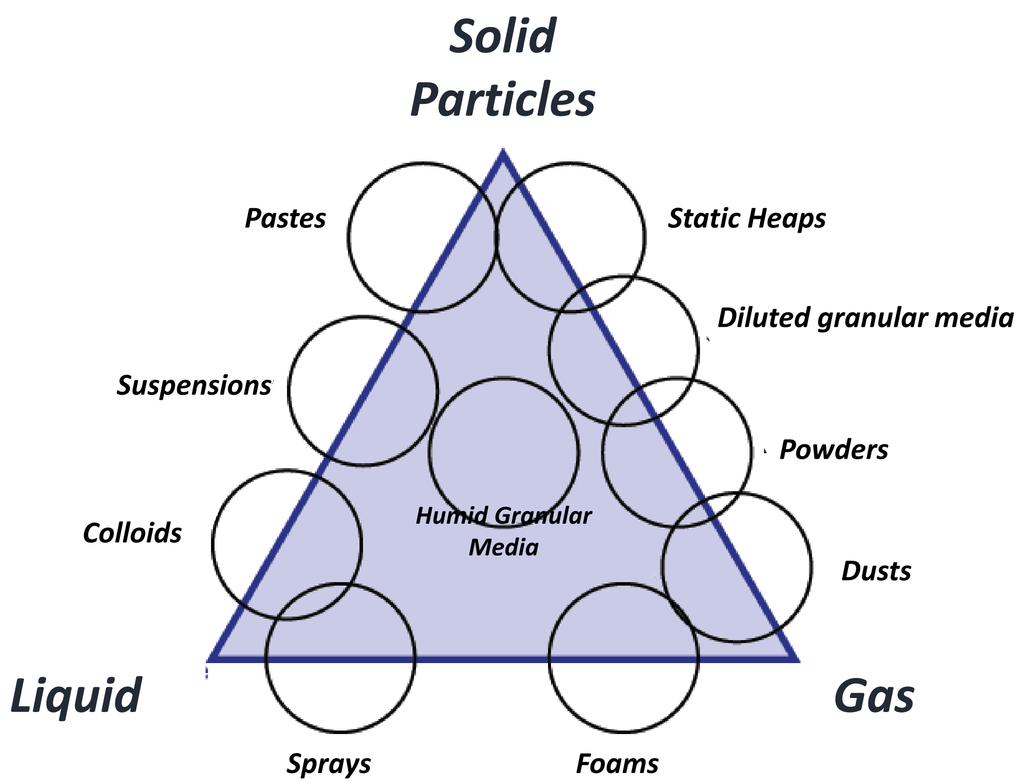


http://www.fashiontrends.pk

The volume fraction of the dispersed phase is:

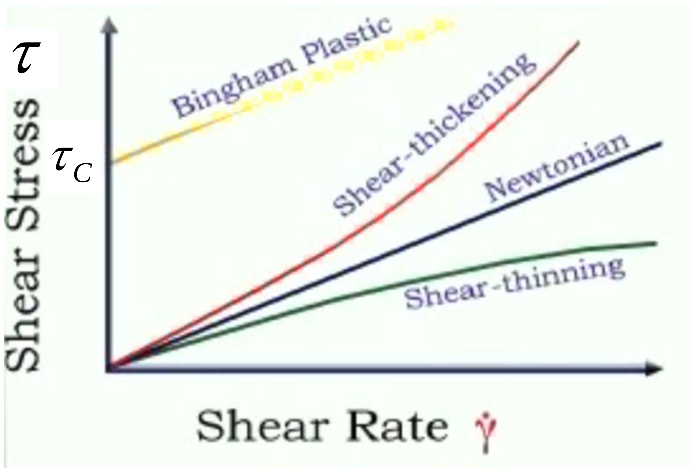
$$\Phi = \text{Vol. Dispersed Phase} / \text{Total Volume}$$

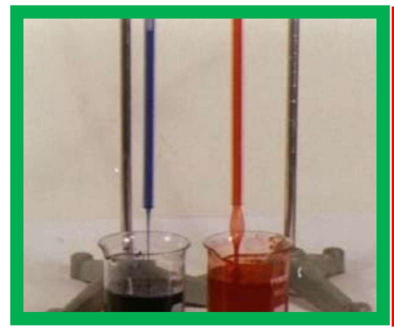
A ternary diagram



Modified from N.Vandewalle, Université de Liège

Non-Newtonian Fluid Mechanics





INNFM, U.Wales, K.Walters et al.

Steady State Shear Rheology

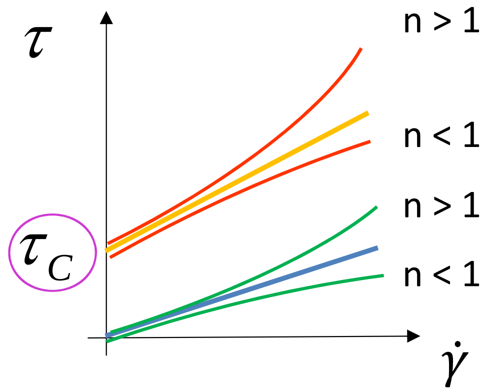
Constitutive laws:

- Newtonian $\tau = \mu\dot{\gamma}$
- Non Newtonian

$$\tau < \tau_c \Rightarrow \dot{\gamma} = 0$$

$$\tau > \tau_c \Rightarrow \tau = \tau_c + f(\dot{\gamma})$$

Yield-Stress

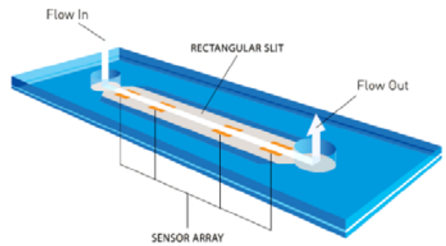


NB: this is a lin-lin diagram

$f(\dot{\gamma}) = \mu_P\dot{\gamma}$ Bingham

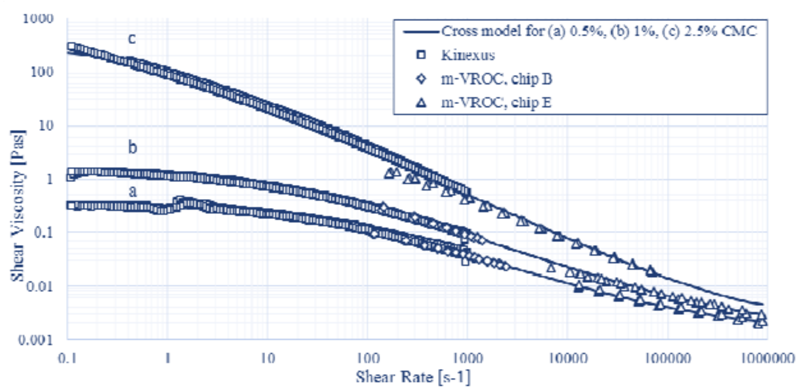
$f(\dot{\gamma}) = K\dot{\gamma}^n$ Herschel-Bulkley if $\tau_c \neq 0$; Power-Law if $\tau_c = 0$

High Shear Rheometry



http://www.rheosense.com/

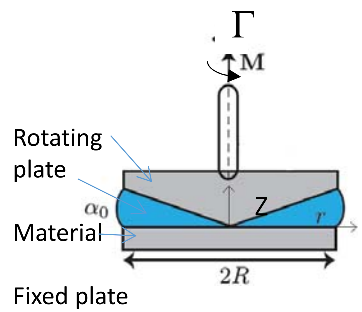
https://www.malvernpanalytical.com/en/products/product-range/kinexus-range



A.Tardelli et al. U.Surrey

marco.ramaioli@inra.fr

SAOS (Small Amplitude Oscillatory Shear)



Given an **imposed oscillatory stress:**

$$\tau = \tau_0 \sin \omega t = \frac{3M_0 \sin(\omega t)}{2\pi R^3}$$

The measured response can be described as:

$$\gamma = \gamma_0 \sin(\omega t + \phi) = \gamma_0 \cos(\phi)\sin(\omega t) + \gamma_0 \sin(\phi)\cdot\cos(\omega t)$$

$$= \frac{\tau_0}{G'}\sin(\omega t) + \frac{\tau_0}{G''}\cos(\omega t)$$

$$G' = \frac{\tau_0}{\gamma_0 \cos(\phi)} \qquad G'' = \frac{\tau_0}{\gamma_0 \sin(\phi)}$$

$\tan(\delta) = G''/G'$

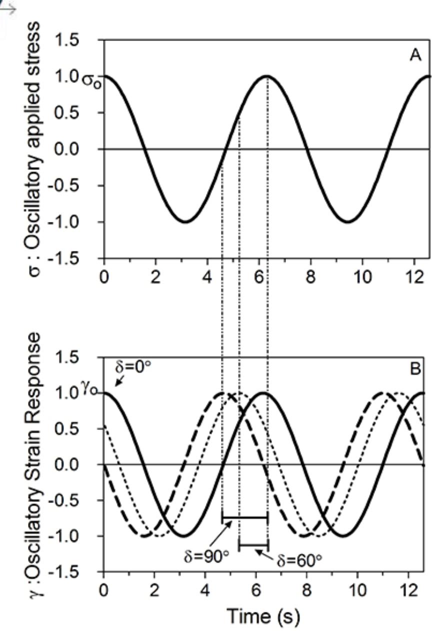


Figure 1 Oscillatory applied stress (σ) wave and the resulting strain wave (γ). Three phase angle differences are shown.

http://lipidlibrary.aocs.org/Biochemistry/content.cfm?ItemNumber=40883

SAOS – Colloidal dispersions

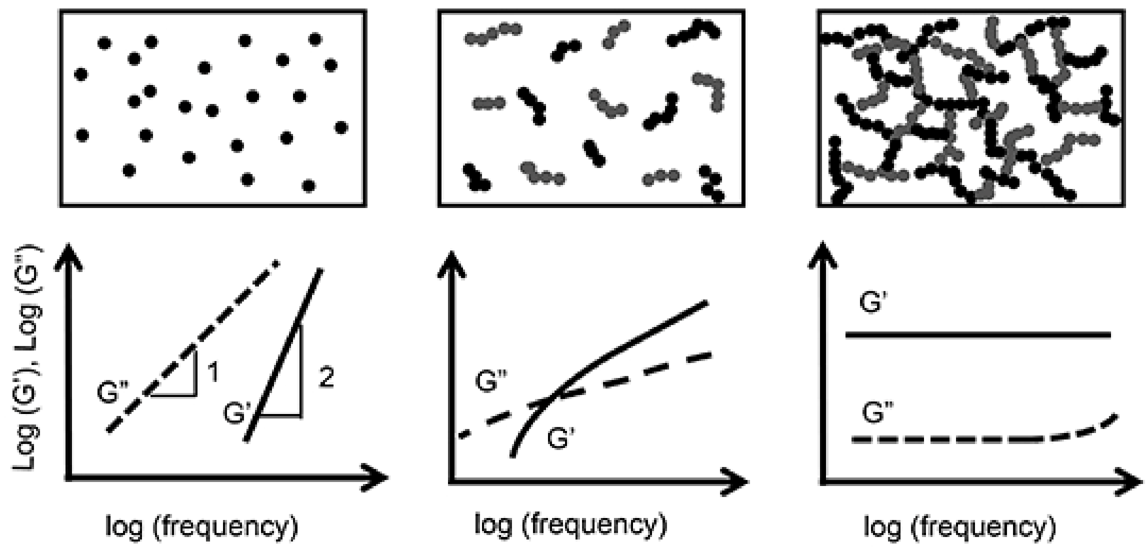


Figure 2 Microstructure of colloidal dispersions and the behaviour of *G'* and *G"* as functions of angular frequency for (A) a stable dispersion, (B) a weakly flocculated dispersion (C) a strongly flocculated dispersion or gel. Adapted from Khan *et al.* (1997).

http://lipidlibrary.aocs.org/Biochemistry/content.cfm?ItemNumber=40883

Characterising food extensional rheology

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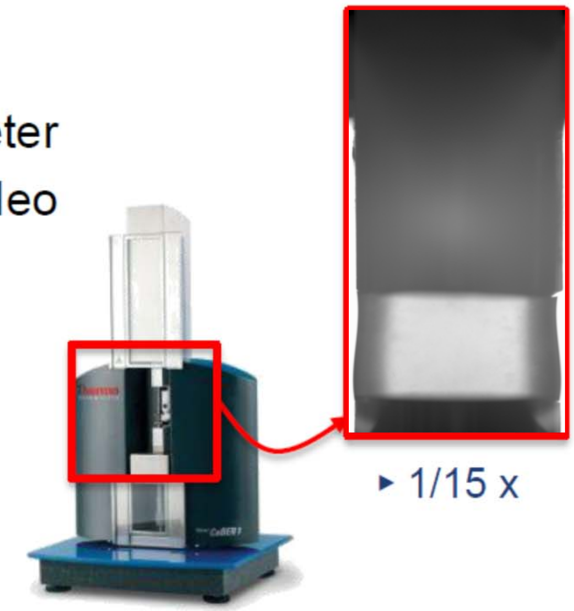
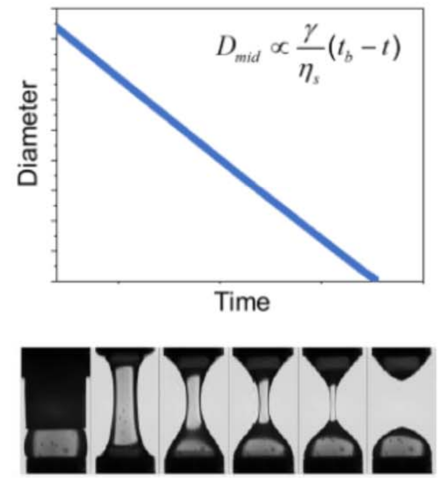
Capillary break-up
- Laser micrometer
- High-speed video

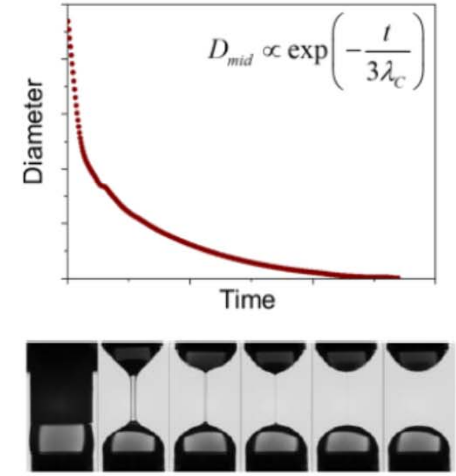


Haake CaBER 1

▸ 1/15 x



Viscous thinning



Elastic thinning

$$\dot{\varepsilon} = -\frac{2}{D_{mid}}\frac{dD_{mid}}{dt} \quad \text{and} \quad \eta_{ext} = \frac{2\sigma/D_{mid}}{\dot{\varepsilon}}$$

M.Marconati, PhD thesis, U.Surrey, 2019

2) How do these properties relate to perception?
Let's consider a "simple" case…

Food Hydrocolloids 61 (2016) 221–232

Contents lists available at ScienceDirect

Food Hydrocolloids

journal homepage: www.elsevier.com/locate/foodhyd

ELSEVIER

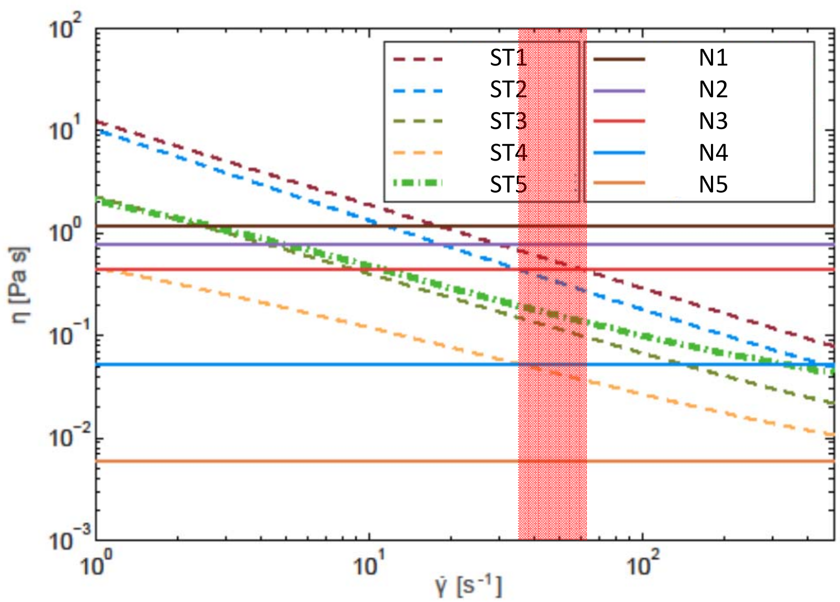
Predicting sensory perceptions of thickened solutions based on rheological analysis

Qi He [a, b], Joanne Hort [c], Bettina Wolf [a, *]

[a] Division of Food Sciences, The University of Nottingham, Sutton Bonington Campus, Leicestershire, LE12 5RD, UK
[b] Mondelēz International, Reading Scientific Service Limited, Pepper Lane, Reading, RG6 6LA, UK
[c] International Centre for Brewing Science and Sensory Science Centre, Sutton Bonington Campus, University of Nottingham, Loughborough, Leicestershire, LE12 5RD, UK

2) How do these properties relate to perception? Let's consider a "simple" case… soups

"The shear rate chosen for the measurement of viscosity to relate to the ***perception of thickness*** was determined by asking subjects to compare the thickness of cream soups to glucose syrups which were of **Shear Thinning (ST) and Newtonian (N) flow behaviour**, respectively.
He then postulated that the shear rate at which the viscosity curve of a soup and a syrup with similar perceived thickness crossed is pertinent to thickness perception and this shear rate is
50 1/s (Wood, 1968)"



Low viscosity liquids with a measured viscosity of 0.1 Pa s and below are orally evaluated at a constant shear stress of roughly 10 Pa while **higher viscosity** liquid foods are assessed at a constant shear rate of approximately 10 1/s (Shama & Sherman, 1973).

He, Hort, Wolf, Food Hydrocolloids, 2016

2) How do these properties relate to perception?

INRA SCIENCE & IMPACT

Table 1
Attributes including their definitions and protocol as defined by the panel. A 10 point continuous line scale was used for all attributes.

	Attribute	Definition	Protocol
Mouthfeel	Initial thickness	The pressure needed to press the sample between the tongue and the palate.	Put a spoonful of sample onto the tongue, gently press the tongue against the palate 3 times.
	Thickness in mouth	The pressure taken to move the sample between the tongue and the palate.	Put a spoonful of sample onto the tongue, move the sample in the mouth, rub the tongue for 5 times.
	Stickiness on lips	The pressure to separate the sample from the lips.	Use lips to take a tip of sample (avoid touching from lips), and hold there for 5 s, then separate the lips for 3 times.
	Stickiness in mouth	The elasticity between the tongue and the palate.	Put a spoonful of sample onto the tongue, gently press the tongue against palate and hold there for 3 s and then separate for 5 times.
	Mouth coating	The amount of residues left in the oral cavity after swallowing.	Put a spoonful of sample into the mouth, move around the tongue and chew the sample for 5 times and swallow.
Flavour & taste	Overall flavour	The overall intensity of flavour perceived.	Put a spoonful of sample into the mouth, move around the tongue and chew the sample for 5 times and swallow.
	Overall sweetness	Overall intensity of sweetness of the samples.	Put a spoonful of sample into the mouth, move around the tongue and chew the sample for 5 times and swallow.

He, Hort, Wolf, Food Hydrocolloids, 2016

Rheological Design of Product Group 1 and 2

Group 1

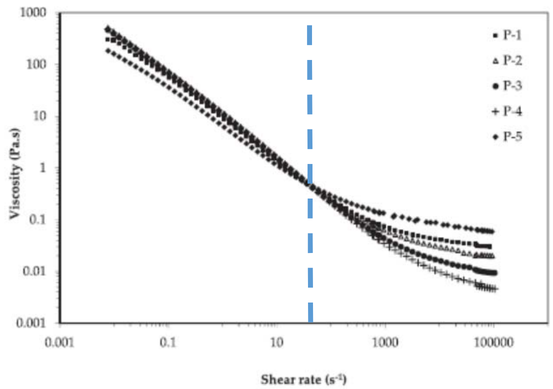


Fig. 1. Viscosity curves of low shear iso-viscous samples of Group 1.

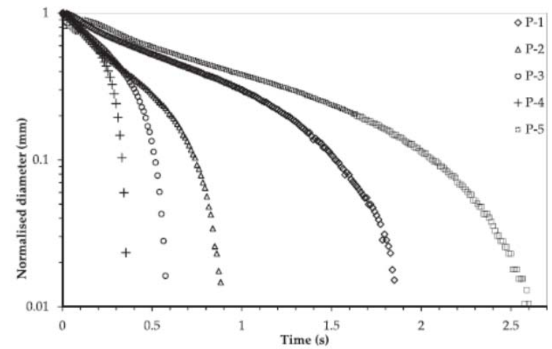


Fig. 3. Evolution of the normalised filament mid-point diameter for the low shear isoviscous Group 1 samples. Stretch time was 50 ms and measurement temperature 37 °C. Standard deviation is within 5% for all data.

Group 2

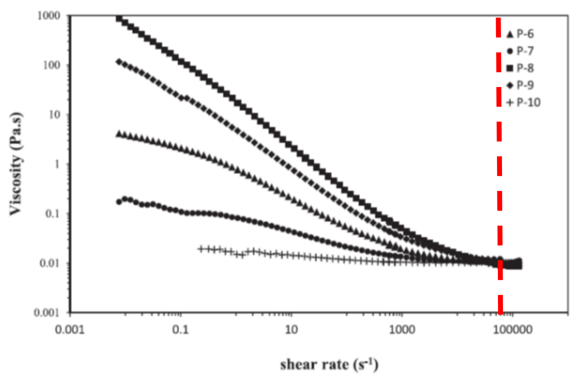


Fig. 2. Viscosity curves of high shear iso-viscous samples of Group 2.

He, Hort, Wolf, Food Hydrocolloids, 2016

Importance of Viscosity at both Low and High Shear

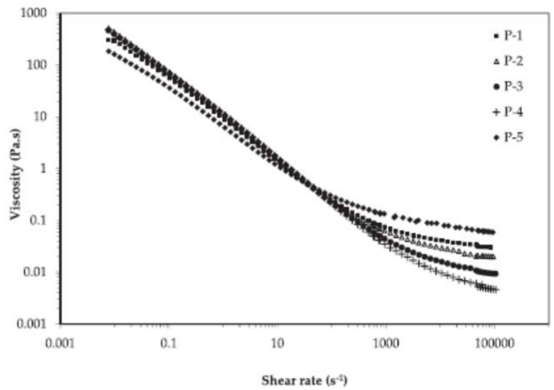


Fig. 1. Viscosity curves of low shear iso-viscous samples of Group 1.

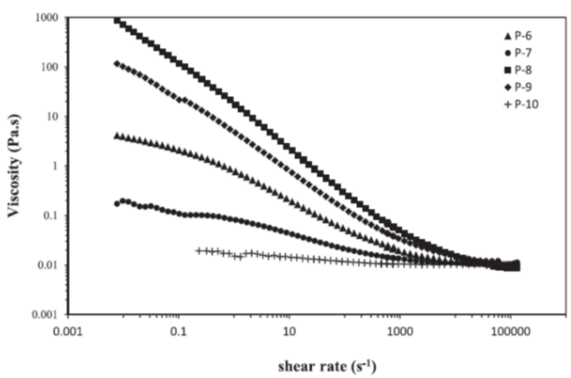
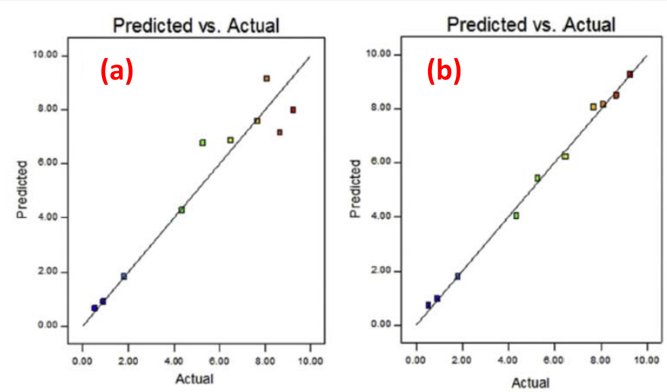


Fig. 2. Viscosity curves of high shear iso-viscous samples of Group 2.

"The ANOVA results show that for samples with either similar low shear or high shear viscosity, the perceived **mouthfeel perceptions** (e.g. initial thickness) were significantly different. **This is clear indication for the importance of considering both low and high shear viscosity when correlating shear viscosity with mouthfeel perceptions.**"

Table 6
Comparisons of prediction models for thickness perception with and without viscosity at high shear rate.

			R^2
Models without η_H	**(a)**	Initial thick = $0.44 + 17.95^*\eta_L$	0.920
		Thick in mouth = $0.23 + 17.55^*\eta_L$	0.910
Models with η_H	**(b)**	Initial thick = $-0.98 + 16.3^*\eta_L + 170^*\eta_H - 1839.4^*\eta^2_H$	0.996
		Thick in mouth = $-1.3 + 15.8^*\eta_L + 185^*\eta_H - 1993^*\eta^2_H$	0.995



He, Hort, Wolf, Food Hydrocolloids, 2016

Rheological Design of Product Group 1 and 2

"When building models to predict the sensory perceptions of **'Stickiness' and 'Mouth coating',** models that only included low shear viscosity and extensional viscosity predicted the perception better than models including all three factors or only low and high shear viscosity (see Equations in Table 7)."

"Stickiness and mouth coating were better correlated to extensional viscosity than low shear viscosity, although a model including both parameters predicted stickiness and mouth coating best."

Table 7
Prediction models for Stickiness and Mouth coating and model descriptors.

	R^2
Stickiness on lips $= 1.42 + 9.26^{*}\eta_L + 0.04^{*}\eta_E$	0.965
Stickiness in mouth $= 0.54 + 10.1^{*}\eta_L + 0.05^{*}\eta_E$	0.963
Mouth coating $= 0.34 + 10.82^{*}\eta_L + 0.05^{*}\eta_E$	0.981

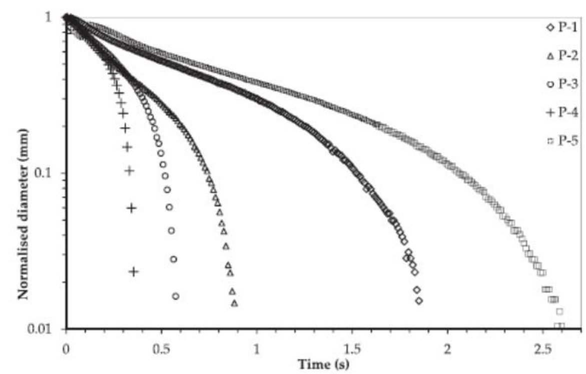


Fig. 3. Evolution of the normalised filament mid-point diameter for the low shear isoviscous Group 1 samples. Stretch time was 50 ms and measurement temperature 37 °C. Standard deviation is within 5% for all data.

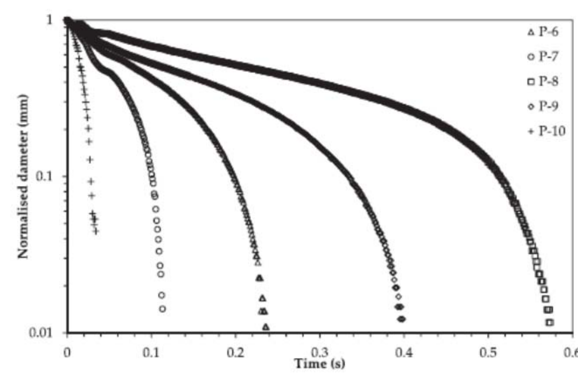


Fig. 4. Evolution of the normalised filament mid-point diameter for the high shear isoviscous Group 2 samples. Stretch time was 50 ms and measurement temperature 37 °C. Standard deviation is within 5% for all data.

He, Hort, Wolf, Food Hydrocolloids, 2016

Surface properties should also be considered

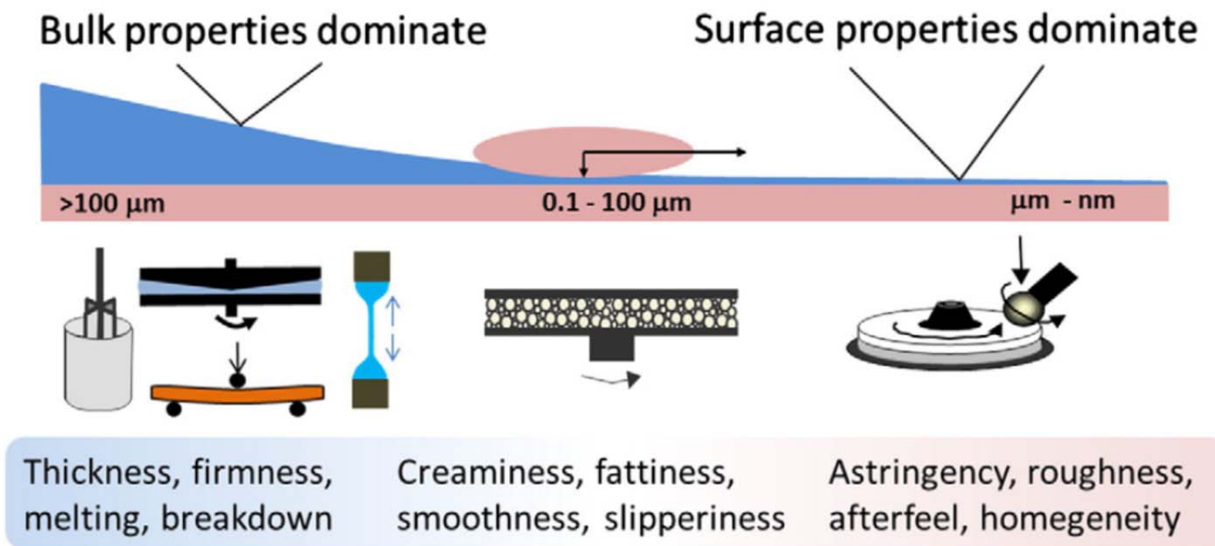


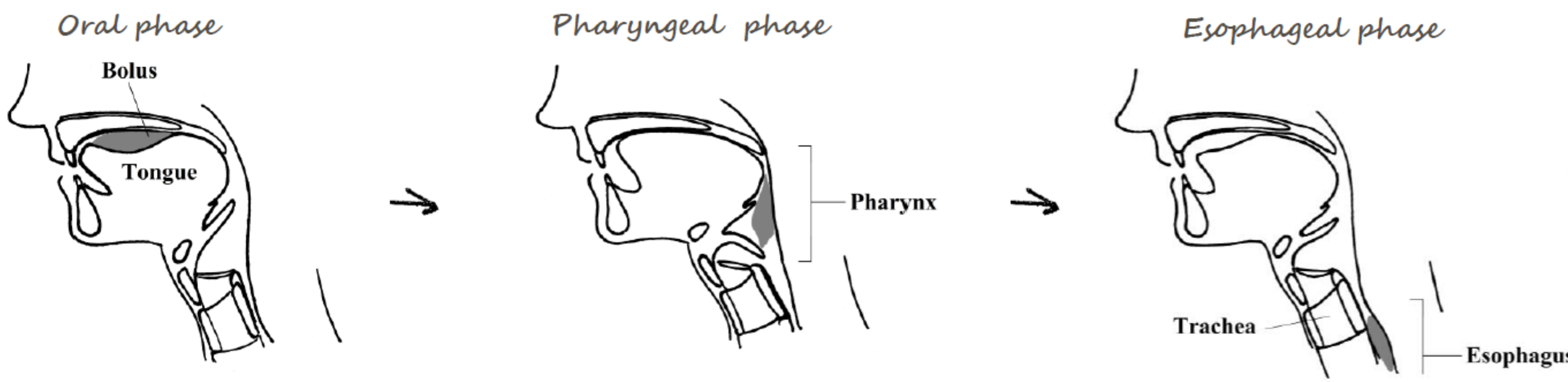
Fig. 1. Depiction of the transition in film thickness of fluid-like (and soft) foods or beverages between oral surfaces as they are consumed, indicating it goes from a rheology-dominant deformation process to where tribology (surface properties) dominates. Also shown is an indicator of the types of techniques that could be used to study the multiscale deformations, and where typical textural mouthfeel attributes may lie.

Stokes et al. 2013, Current Opinion in Colloid & Interface Science

In this lecture

1. Few words on Food Mechanics
2. An example linking food rheology to perception
3. An example linking food rheology to swallowing

Swallowing disorders affect the quality of life of millions of people



Relevant problems

- Swallowing disorders (dysphagia) affect 590 million people worldwide (Cichero *et al.*, 2017)
- 2 out of 5 adult Americans struggle taking tablets (Fields *et al.*, 2015)

Design of easy-to-swallow products to

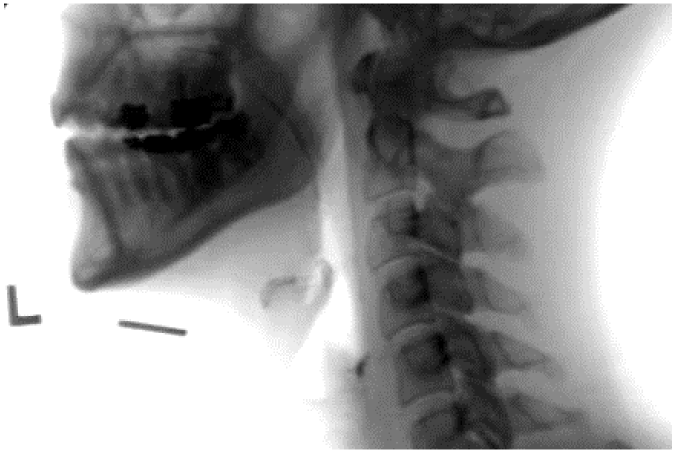
- Support hydration and nutrition for dysphagia sufferers
- Improve compliance to an oral drug therapy
- Enhance the eating experience

The complexity of human Swallowing

MRI

Biomedizinische NMR Forschungs GmbH, 2011

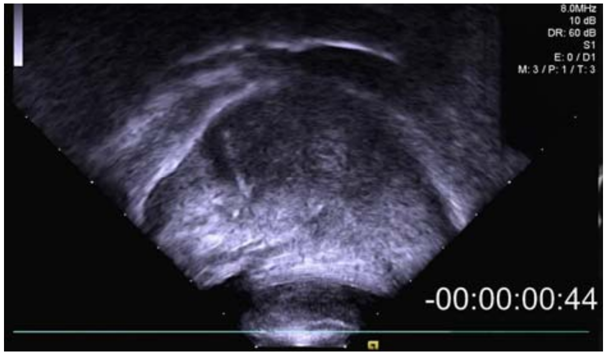
Video Fluoroscopy



Is sharing a portion of the airways and the digestive tract a “smart” anatomical design?

Observing the oral phase of swallowing using US imaging

In-vivo ultrasound observations



η = 0.85 Pa.s, V = 10 mL, P = 20 – 30 kPa

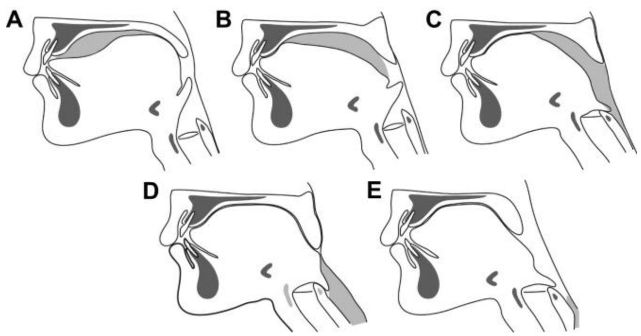
Playback at 20% real speed

Clinical trial with reference 03/12, approved by the Comm. Cant. d'Éthique de la Recherche Sur l'Être Humain, Vaud, CH

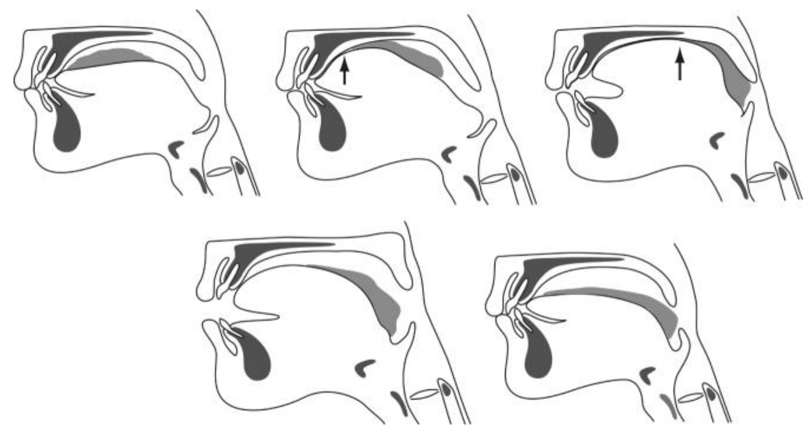
Mowlavi *et al.,* 2016, Journal of Biomechanics

Bolus movement

"The movement of the food in the oral cavity and to the oropharynx differs depending on the type of food (eating solid food versus drinking liquid)."



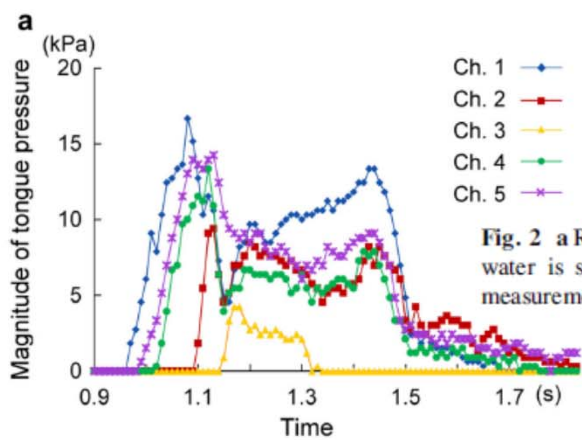
Normal swallowing of a liquid bolus: Drawings based on a videofluorographic recording. (A) The bolus is held between the anterior surface of the tongue and hard palate, in a "swallow ready" position (end of oral preparatory stage). The tongue presses against the palate both in front of and behind the bolus to prevent spillage. (B) The bolus is propelled from the oral cavity to the pharynx through the fauces (Oral propulsive stage). The anterior tongue pushes the bolus against the hard palate just behind the upper incisors while posterior tongue drops away from the palate. (C-D) Pharyngeal stage. (C) The soft palate elevates, closing off the nasopharynx. The area of tongue-palate contact spreads posteriorly, squeezing the bolus into the pharynx. The larynx is displaced upward and forward as the epiglottis tilts backward. (D) The upper esophageal sphincter opens. The tongue base retracts to contact the pharyngeal wall, which contracts around the bolus, starting superiorly and then progressing downward toward the esophagus. (E) The soft palate descends and the larynx and pharynx reopen. The upper esophageal sphincter returns to its usual closed state after the bolus passes.



Stage II transport: Drawings based on a videofluorographic recording. The tongue squeezes the bolus backward along the palate, through the fauces, and into the pharynx when the upper and lower teeth are closest together and during early jaw opening phase (first three frames). The bolus head reaches the valleculae while food processing continues (last two frames).

Matsuo K., Palmer JB., Phys Med Rehabil Clin N Am. 2008, 19(4):691-707

Tongue pressure measurements *in vivo*



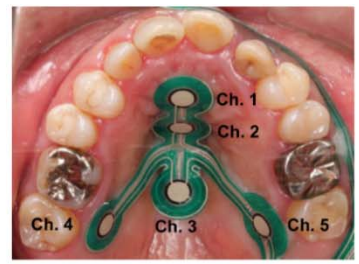
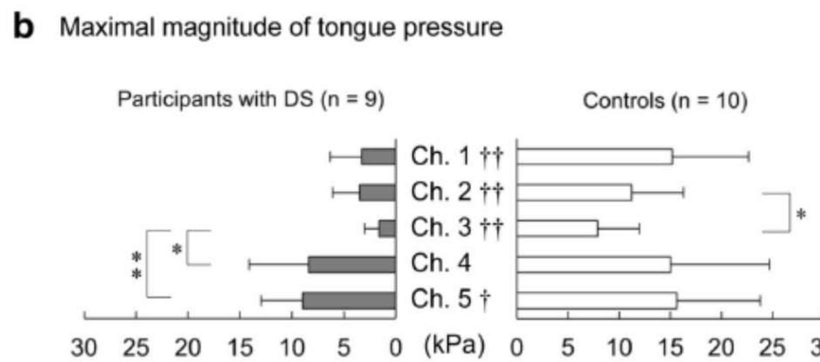


Fig. 1 Palatal view of the maxilla after attaching the sensor sheet in a participant with Down syndrome

Fig. 2 **a** Representative output signals of tongue pressure while 5 mL water is swallowed by a healthy participant. **b** Typical output of measurement of tongue pressure in Ch. 1



Dysphagia (2014) 29:509–518
DOI 10.1007/s00455-014-9538-5

ORIGINAL ARTICLE

Tongue Pressure During Swallowing in Adults with Down Syndrome and Its Relationship with Palatal Morphology

Megumi Hashimoto · Kazuko Igari · Soshi Hanawa · Ayumi Ito · Atsushi Takahashi · Naoko Ishida · Shigeto Koyama · Takahiro Ono · Keiichi Sasaki

Clinical studies demonstrated the positive effect of thickening thin liquids, however…

INRA SCIENCE & IMPACT

AP&T Alimentary Pharmacology and Therapeutics

Original Article | Free Access

The effects of a xanthan gum-based thickener on the swallowing function of patients with dysphagia

L. Rofes, V. Arreola, R. Mukherjee, J. Swanson, P. Clavé

First published: 13 March 2014 | https://doi.org/10.1111/apt.12696 | Cited by: 43

OD: "Increasing bolus viscosity with Resource ThickenUp Clear: (i) improved safety of swallow demonstrated by a reduction in the prevalence of cough and voice changes in the clinical study and penetrations and aspirations during video fluoroscopy. Prevalence of aspirations was 12.7% with thin liquid, 7.7% with nectar-like ($P < 0.01$) and 3.4% with spoon-thick ($P < 0.01$) viscosities."

Dysphagia (2016) 31:232–249
DOI 10.1007/s00455-016-9696-8

CrossMark

EDITORIAL

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)

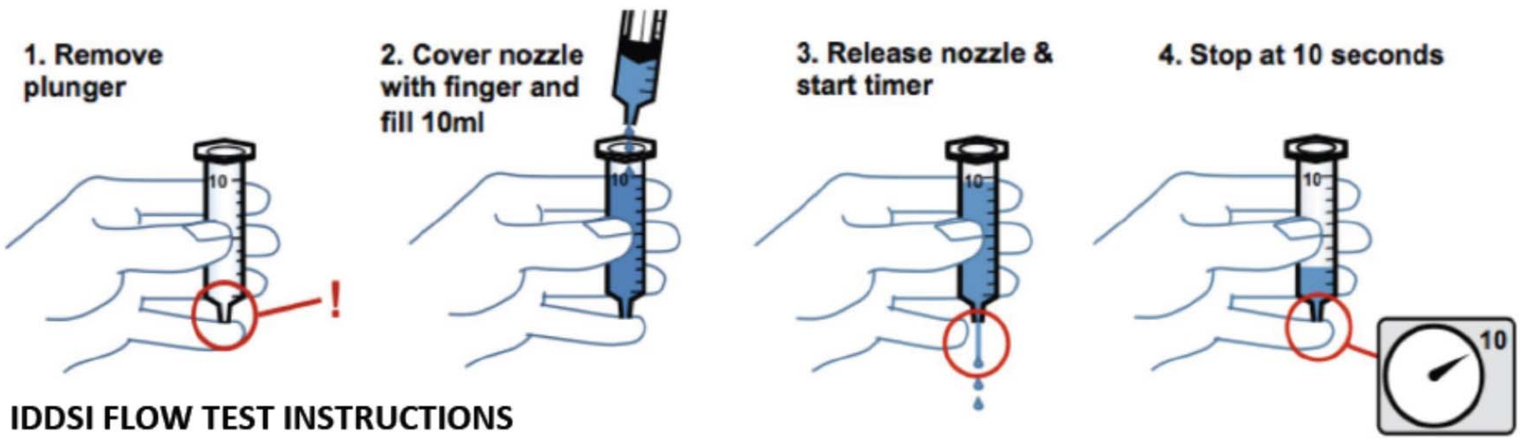
Roger Newman[1,5] · Natàlia Vilardell[2,5] · Pere Clavé[1,2,3,5] · Renée Speyer[1,4,5]

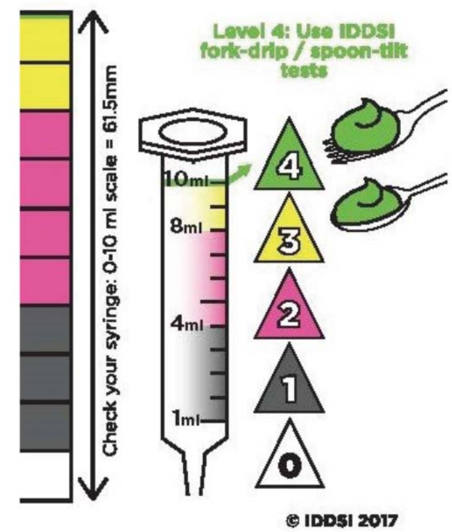
Main results suggest that increasing bolus viscosity:
(a) results in increased safety of swallowing,
(b) also results in increased amounts of oral and/or pharyngeal residue which may result in postswallow airway invasion,
(c) impacts the physiology with increased lingual pressure patterns, no major changes in impaired airway protection mechanisms, and controversial effects on oral and pharyngeal transit time, hyoid displacements, onset of UOS opening and bolus velocity— with several articles suggesting the therapeutic effect of thickeners is also due to intrinsic bolus properties,
(d) reduces palatability of thickened fluids and
(e) Correlates with increased risk of dehydration and decreased quality of life although the severity of dysphagia may be an confounding factor

A glass of water for people with severe swallowing disorders…

A simple but very approximate way to assess thickness...IDDSI

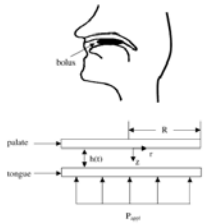
IDDSI
International Dysphagia Diet Standardisation Initiative
www.iddsi.org





https://iddsi.org

In vitro and *in silico* swallowing models



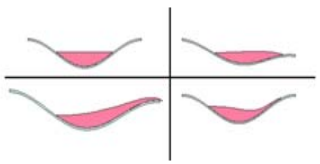
Nicosia and Robbins, 2001

Mowlavi et al., 2016

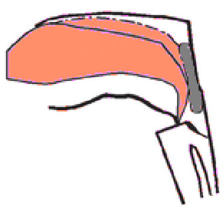
Dirven et al., 2017

Imposed stress (force)

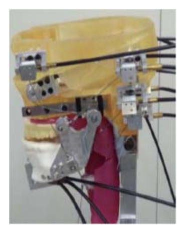
- Finite force
- Bolus rheology can strongly affect bolus flow



Nicosia, 2007



Sonomura et al., 2011



Noh et al., 2011

Imposed strain (displacements)

- Perfect trajectory control
- High force reserve

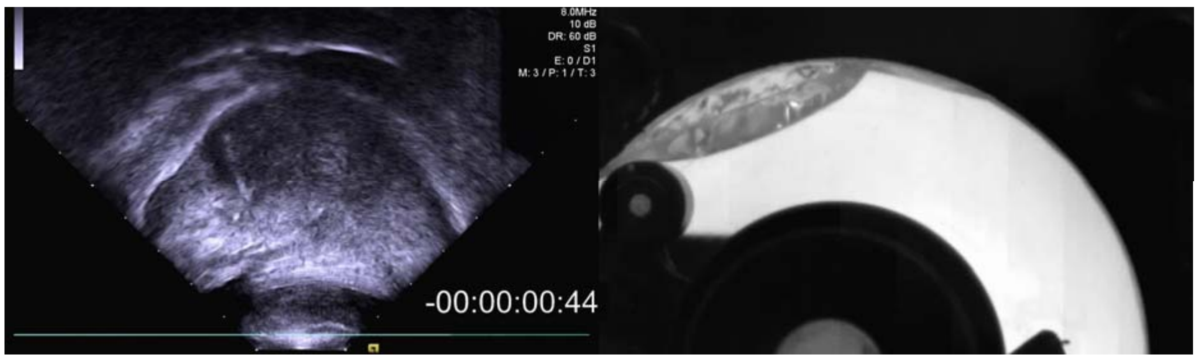
Marconati *et al.*, 2019, Trends in Food Sci. & Technology

marco.ramaioli@inra.fr

Qualitative comparison *in vivo* and *in vitro* oral bolus flow

In-vivo ultrasound observations

In-vitro experiments



η = 0.85 Pa.s, V = 10 mL, P = 20 – 30 kPa

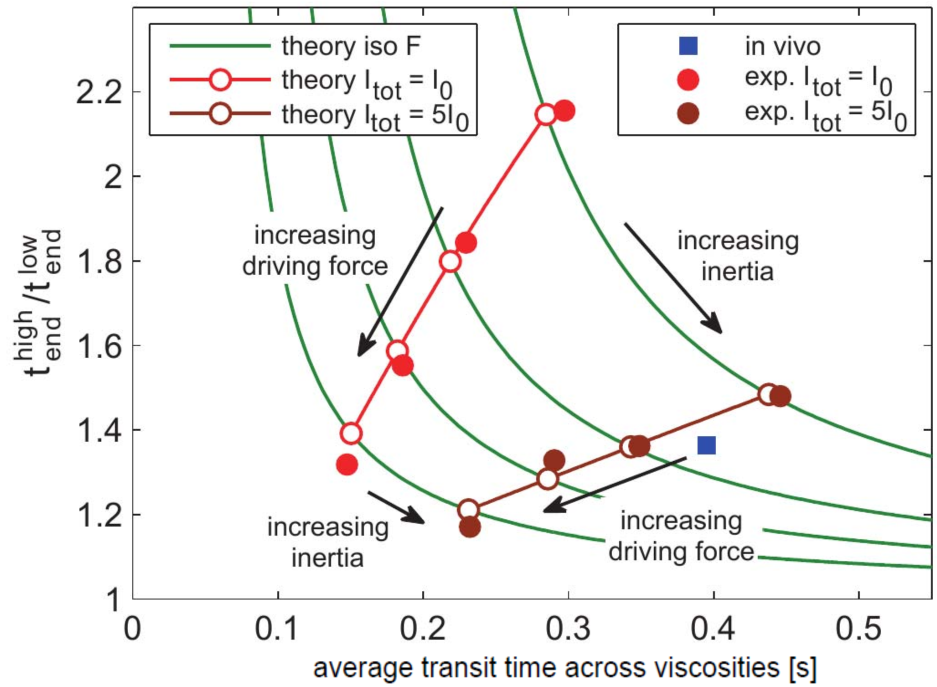
η = 0.79 Pa.s, V = 6 mL, F = 1.4 N, $I = I_0$

Playback at 20% real speed

Clinical trial with reference 03/12, approved by the Comm. Cant. d'Éthique de la Recherche Sur l'Être Humain, Vaud, CH

Mowlavi et al., 2016, Journal of Biomechanics

Quantitative comparison *in vivo* and *in vitro* oral bolus flow



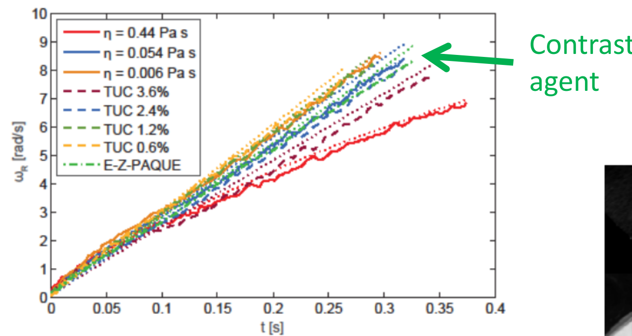
- Very good agreement between theoretical (circles) and experimental (points) data
- A force between 1.4 and 2 N and inertia of $5I_0$ provides the best agreement between the transit times observed *in vivo* and in the our model experiment

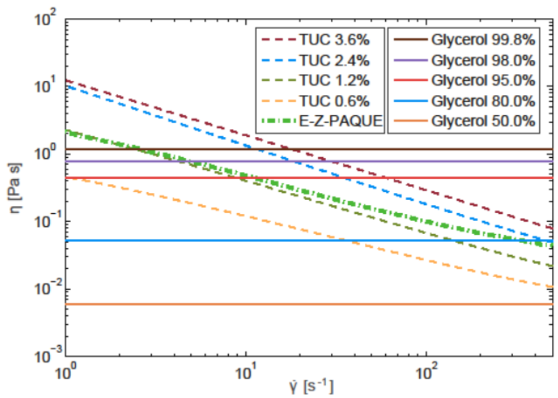
Mowlavi et al., 2016, Journal of Biomechanics

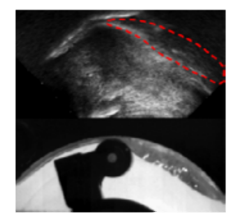
An *in vitro* swallowing model to improve food thickener rheology and the management of dysphagia

Swallowing disorders (dysphagia) can be the consequence of stroke, neurodegenerative conditions or ageing, reduce strongly quality of life and can lead to life-threatening conditions (pneumonia).

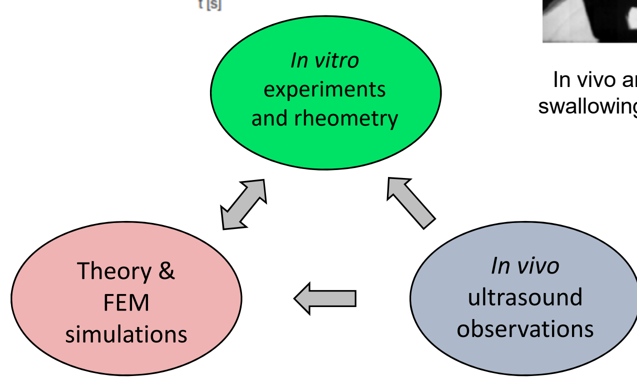
In vitro models are used to pre-screen new food thickener formulations and to match the flow of contrast agents and thickener solutions, improving dysphagia management.





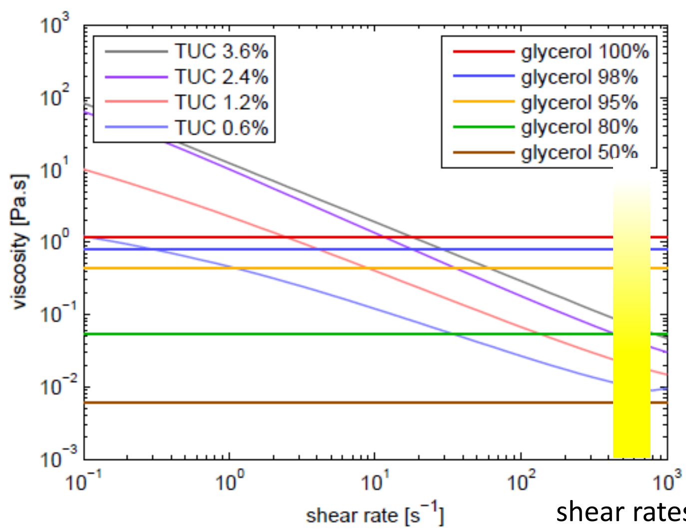


In vivo and in vitro swallowing dynamics

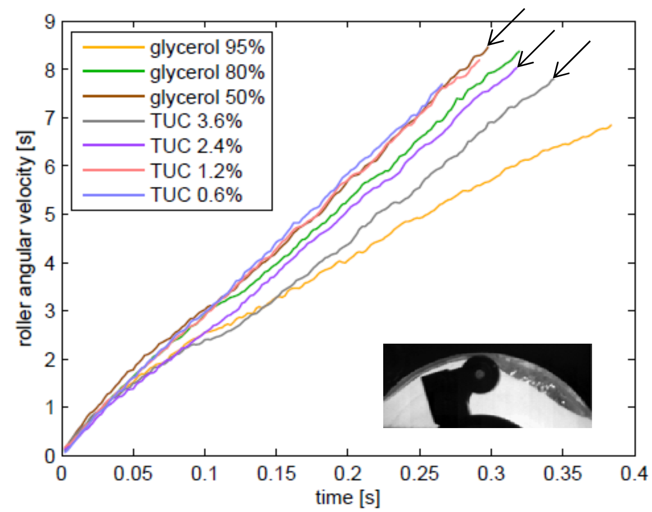


Hayoun et al., 2015, Journal of Biomechanics
Mowlavi et al., 2016, Journal of Biomechanics
Popa Nita et al. Patent WO 2016012403 A1

Shear thinning liquids flow *in vitro* like low-mid viscosity Newtonian liquids



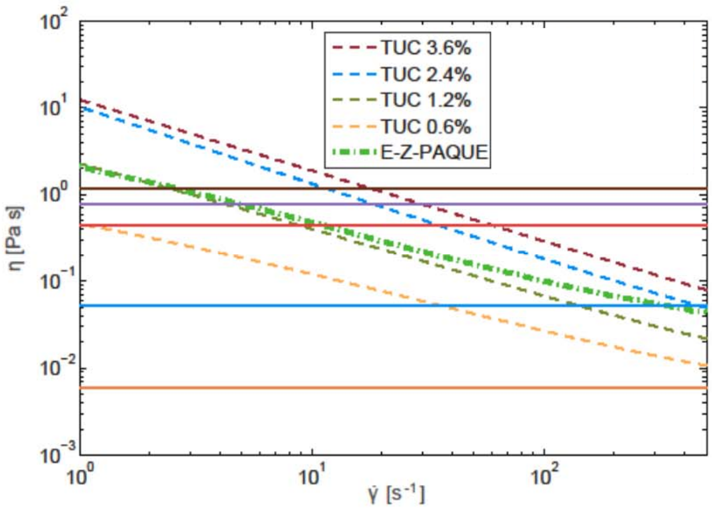
shear rates experienced

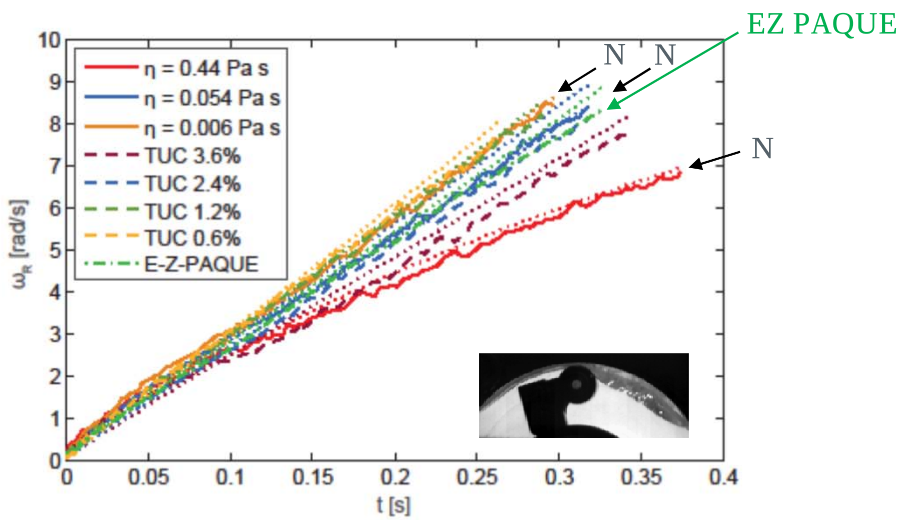


- The shear thinning liquids considered, behave like low to mid viscosity newtonian fluids

marco.ramaioli@inra.fr

The high density of Contrast Agents (EZ PAQUE) for Video Fluoroscopy does not influence their flow





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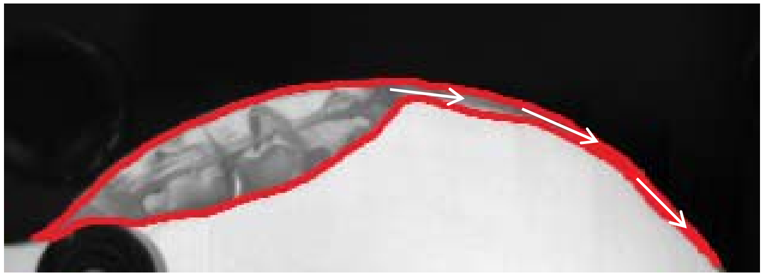
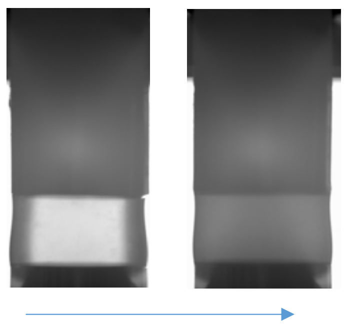
Uncontrolled swallows are reduced *in vitro* with shear thinning boluses



- Low viscosity Newtonian boluses can leak ahead of the bolus before swallowing is triggered, probably due to uncontrolled vibrations.
- Although shear thinning solutions show similar transit time as low viscosity newtonian fluids, they do not show this uncontrolled leaking due to their high viscosity at low shear rates

The apparent extensional viscosity influences the shape of the bolus exiting from the *in vitro* oral cavity.

Recorded at 1500 fps
Playback speed 15 x slower than real time



Increasing concentration

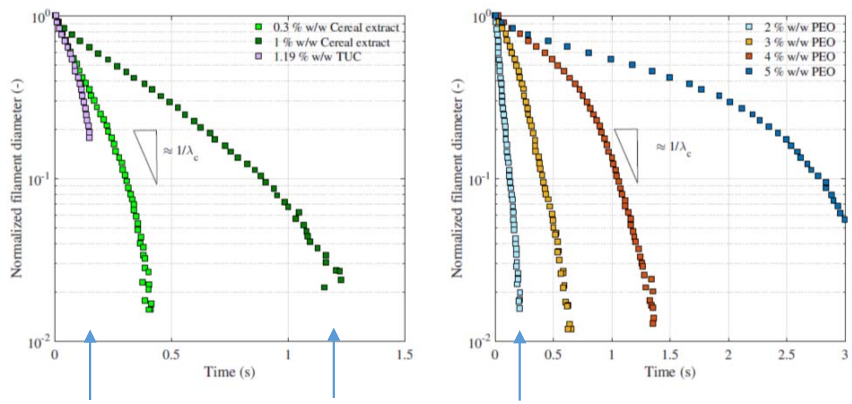


Fig. 5 Profiles of the capillary thinning for aqueous solutions of TUC and a cereal extract (left) and aqueous solutions of 2 to 5 % w/w PEO (right).

Liquid sample	Remaining volume	IDDSI level
1.19 % w/w TUC	4.9 (0.3)	Level 2
0.3 % w/w cereal extract	2.9 (0.3)	Level 1
1 % w/w cereal extract	5.3 (0.2)	Level 2
2% w/w PEO	7.0 (0.2)	Level 2
3% w/w PEO	9.5 (0.2)	Level 3
4% w/w PEO	9.9 (0.1)	Level 3
5% w/w PEO	10.0 (0.1)	Level 4

marco.ramaioli@inra.fr

M.Marconati, 2019

The apparent extensional viscosity influences the shape of the bolus exiting from the *in vitro* oral cavity.

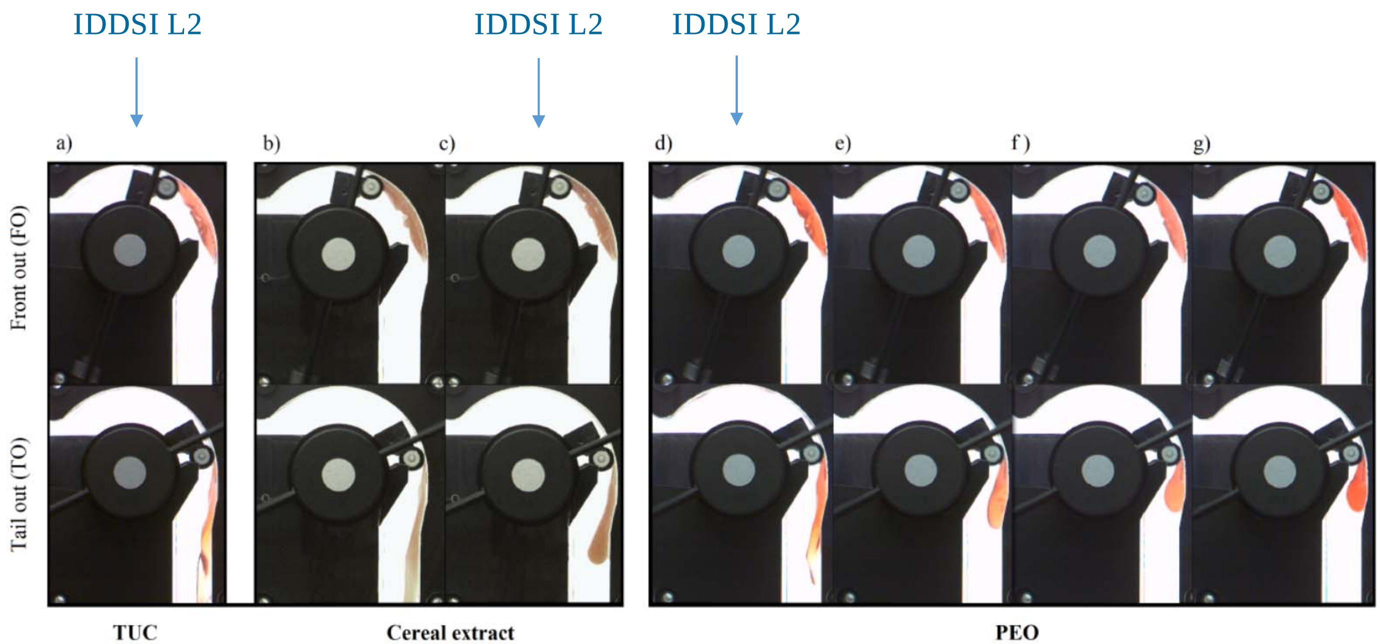


Fig. 8 Screenshots from the *in vitro* experiment. From left to right the instant of bolus front out (top row) and tail out (bottom row) for a) 1.19% w/w TUC (*Nectar-thick*), b) 0.3 % w/w cereal extract, c) 1 % w/w cereal extract and d)-e) acqueous solutions of 2 to 5% w/w PEO.

M.Marconati, 2019

marco.ramaioli@inra.fr

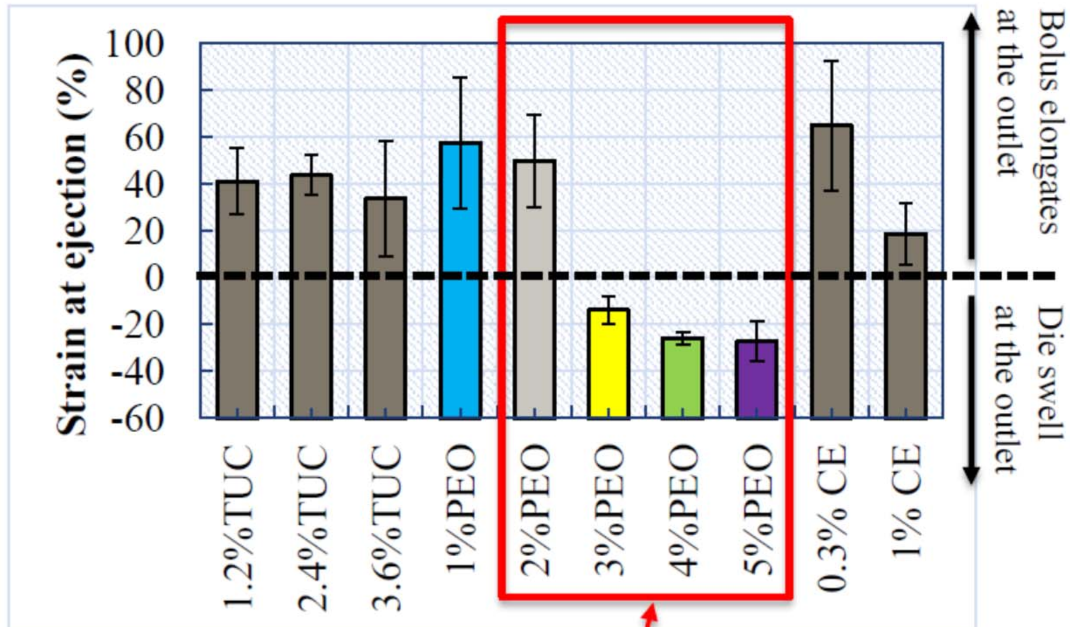
Extensional properties can dominate the transition from the oral cavity to the pharynx

Thin cohesive boli

Low fragmentation

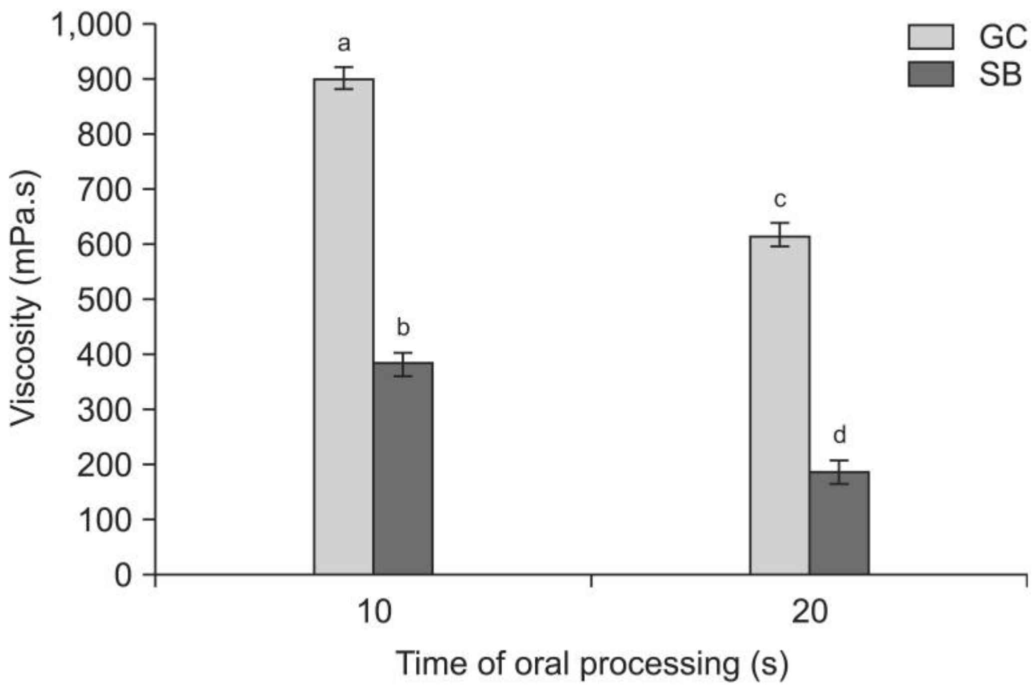
Thick cohesive boli

Longer transit times and die swell



M.Marconati, 2019

Beware of Food – Saliva Interactions!

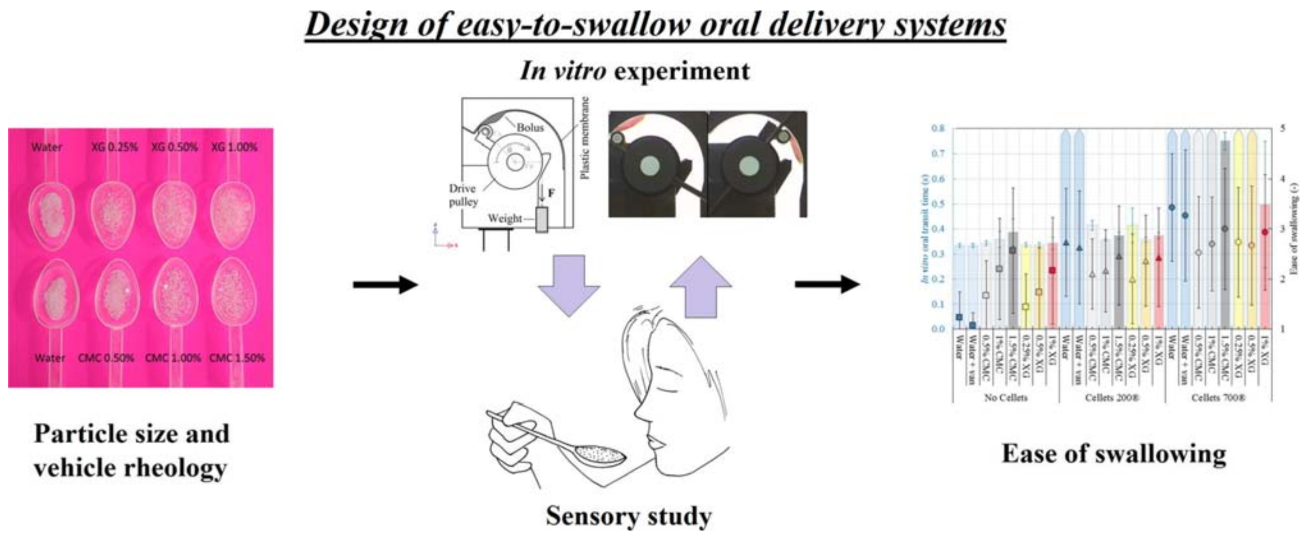


Ann Rehabil Med. 2015 Oct; 39(5): 772–777. PMCID: PMC4654084
Published online 2015 Oct 26. doi: 10.5535/arm.2015.39.5.772 PMID: 26605175

The Effect of Oral Processing on the Viscosity of Thickened Drinks for Patients With Dysphagia

Katleen J. R. Vallons, PhD,[1] Lizette A. A. C. M. Oudhuis, PhD,[1,2] Harold J. Helmens, Msc,[1,2] and Cor Kistemaker, Ing[3]

In vitro swallowing of multiparticulate systems



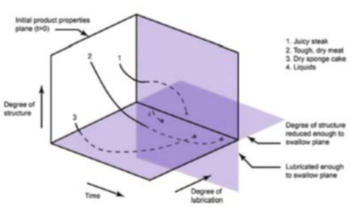
Both *in vivo* and *in vitro* tests reported easier swallowing for smaller multi-particulates. Water thin liquids appeared not optimal for complete oral clearance of the solids. The sensory study did not highlight significant differences between the levels of thickness of the hydrocolloids.

Conversely, more discriminant results were obtained from *in vitro* tests, suggesting that a minimum critical viscosity is necessary to enable a smooth swallow, but increasing too much the carrier concentration affects swallowing negatively.

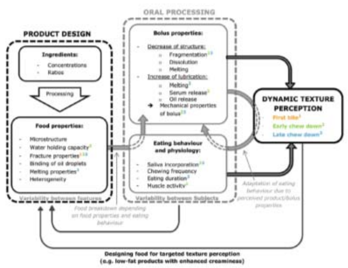
M.Marconati, 2019

Take Home Messages & Open Questions

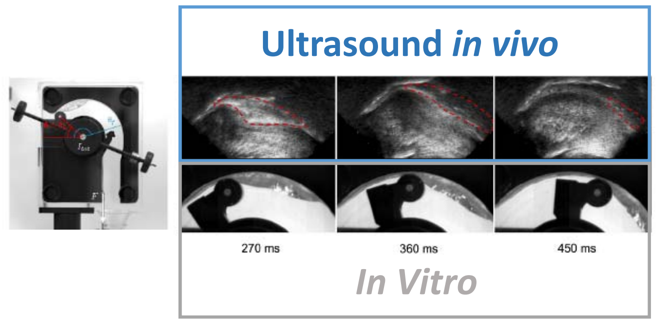
Even for liquid and semisolid boluses, different rheological properties influence different aspects of the Food Oral Properties, Perception and Swallowing.
Saliva can affect the rheological properties of the bolus (dilution, hydrolysis, etc)



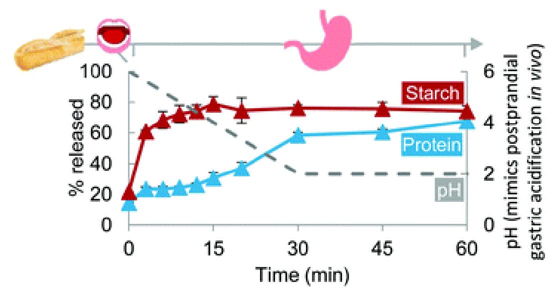
J. B. Hutchings and P. J. Lillford, J. Texture Stud., 1988



Devezeaux de Lavergne et al., Food and Function, 2018.



Hayoun et al., J.Biomech., 2015.
Mowlavi et al., J.Biomech., 2016.



Freitas et al., Food and Function, 2018.

We would like to understand **quantitatively** :

1. The link **product structure -> rheological / mechanical properties** -> **texture perception**
2. **How saliva hydrates food and forms a bolus?** What is the impact of **xerostomia** in elderly?

   How does **tongue control** complex fluids in mouth?

   What makes some food **easy to swallow and adapted to weaning babies or to elderly?**

Thanks a lot! Questions?

Acknowledgments: Nestlé Research (Research Sponsor)
M.Marconati, S.Mowlavi and P. Hayoun (Biomechanics of swallowing)

marco.ramaioli@inra.fr

https://www.linkedin.com/in/marco-ramaioli/

@MarcoRamaioli

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