NIZO YOUR FOOD RESEARCHERS

Jennifer Aniston (W Magazine photo shoot)

Oral processing in relation to perception of liquid and semi solid food systems

Science and Technology of Food Emulsions, June 2012

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Together to the next level

WAGENINGEN UR For quality of life

TI FOOD NUTRITION

Introducing NIZO food research

- Independent, private contract research company for the food industry
- 200 professionals
- State-of-the-art facilities & food-grade processing centre
- HQ in “Food Valley” in The Netherlands
    - Offices in France, UK, USA, Japan
- ISO 9001:2000 certified

Key question

How can we translate between

Food materials knowledge

(rheological properties, molecular properties, structural dimensions)

and

Sensory perception of structures

(limiting to texture: hard, firm, tough, sticky, slimy, juicy, creamy, gritty, astringent)

Product developers approach

Product developme

composition, structure

- reduced fat
- thickeners
- particles
- aroma's
- sugar replacers

Correlations are often poor

roduct characteristics:

- operties
- not so creamy, thin, slimy, gritty
- ff tastes, off flavours, unbalanced flavours

neasurements:

- v ity, g strength, fracture behavior
- f ction measurement
- droplet and particle size
- aroma and flavour release

Contents

- Discussion of the main hurdles in relating structural and sensory properties
- Elucidating textural perception by the tongue
- Acoustic tribology

Main hurdles

RELATING STRUCTURAL AND SENSORY PROPERTIES

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1. Sensory response is multimodal

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Senses:

Vision

Touch

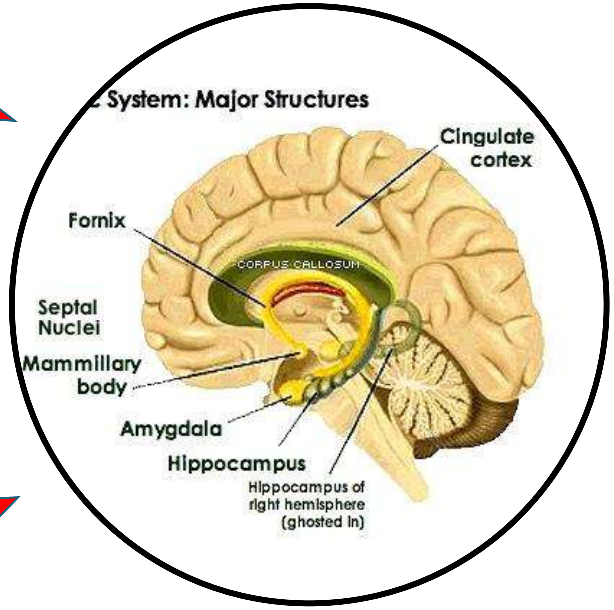
Sound

Mouthfeel

Taste

Smell

Nutritional status



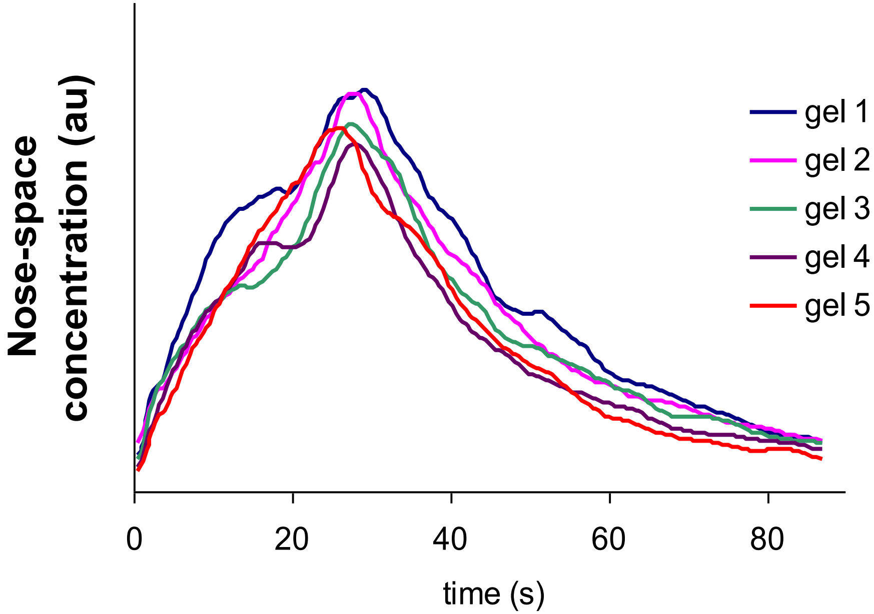
CCK, PYY, Gastrin, vagus nerve

Perception

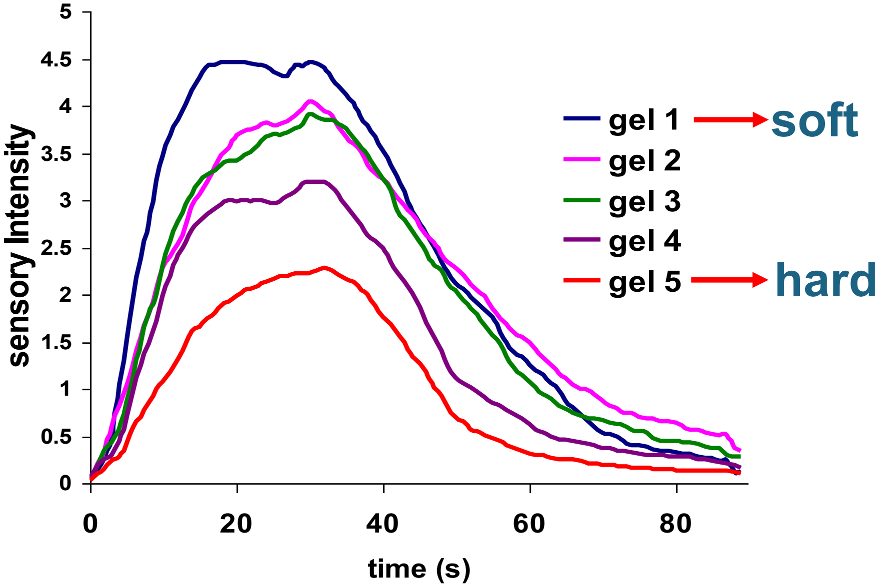
Hedonic consumer response

Cross modal interactions:
texture affecting flavour intensity perception

Nose space



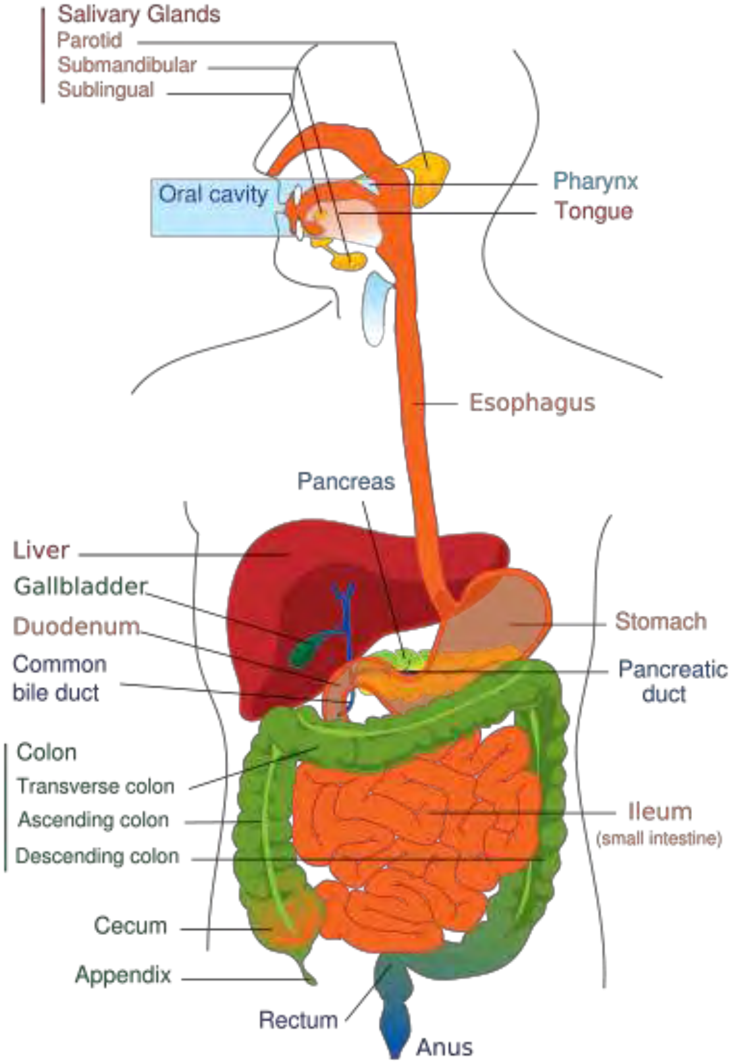
Sensory intensity



Texture-flavour interaction at perception level!

(K. Weel, A. Boelrijk et al., published 2002)

2. Food is processed in the mouth



Mouth function as the first part of the gastrointestinal tract

- Food preparation: mastication and addition of saliva to form a cohesive slippery bolus that is safe to swallow

- Explore food content:
  - Nutritious?
  - Safe or toxic, flavor and aroma?
  - Sharp objects? Fishbones? Undigestible grains?

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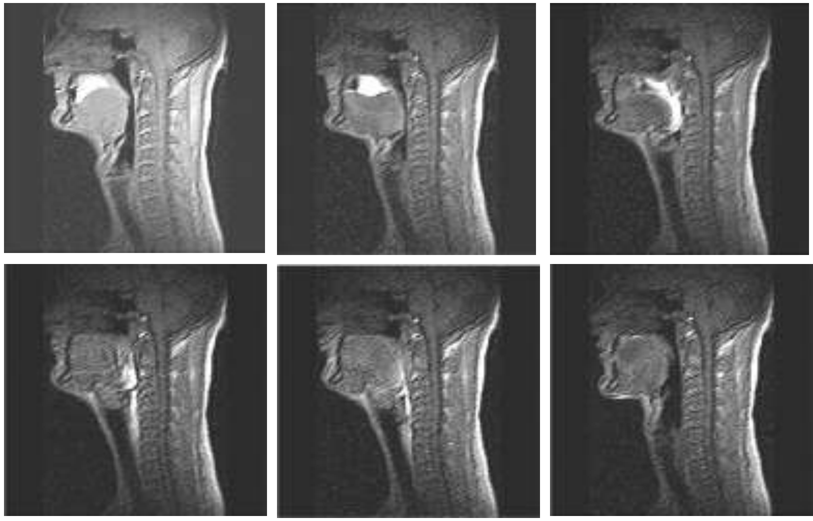
Criterium for swallowing:
LOW RISK OF CHOKING

Risk of choking specific for humans, related to low position of the larynx, allowing a larger vocal range required for speach.



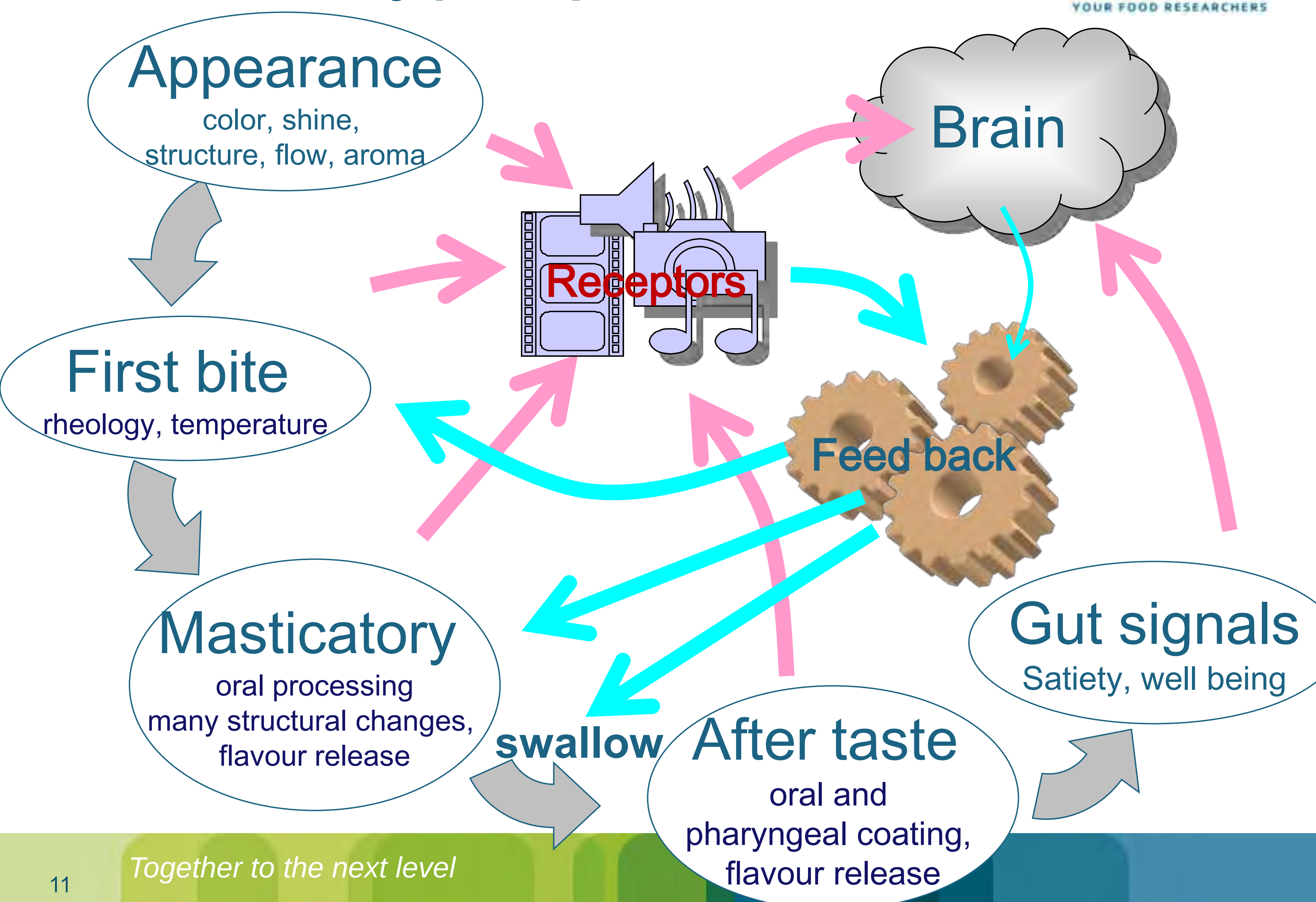
Quick and clean passage through the pharynx into the esophagus, avoiding food spilling into the windpipe:

A "clean" bolus should be formed

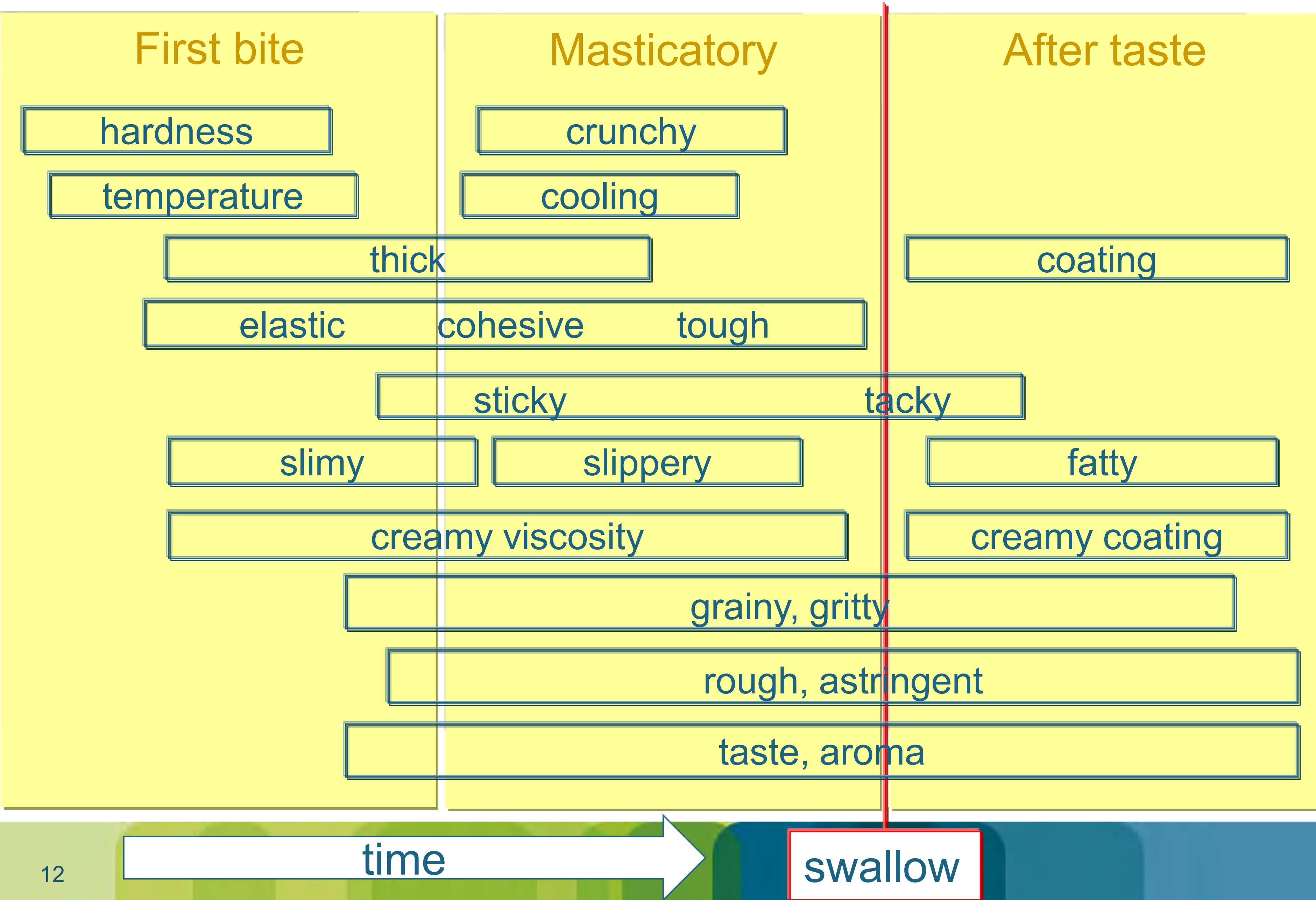
The food bolus should be:

- cohesive, not disintegrating into loose particles
- soft and deformable enough to enter the (rather narrow) esophagus
- slippery and not sticking to the mucosa, allowing fast passage

Sensory perception of food



Sensory attributes along the oral processing pathway



Needed

- Better understanding of how foods behave in the mouth
- Better understanding of how food is sensed
- Combine this knowledge with material science for product development

Background research at TIFN

Saliva, tongue surface, palating, chewing

STUDIES ON FOOD EMULSION BEHAVIOUR IN THE MOUTH

Examples of oral processing in relation to perception

- Emulsions
- Emulsion-filled gels

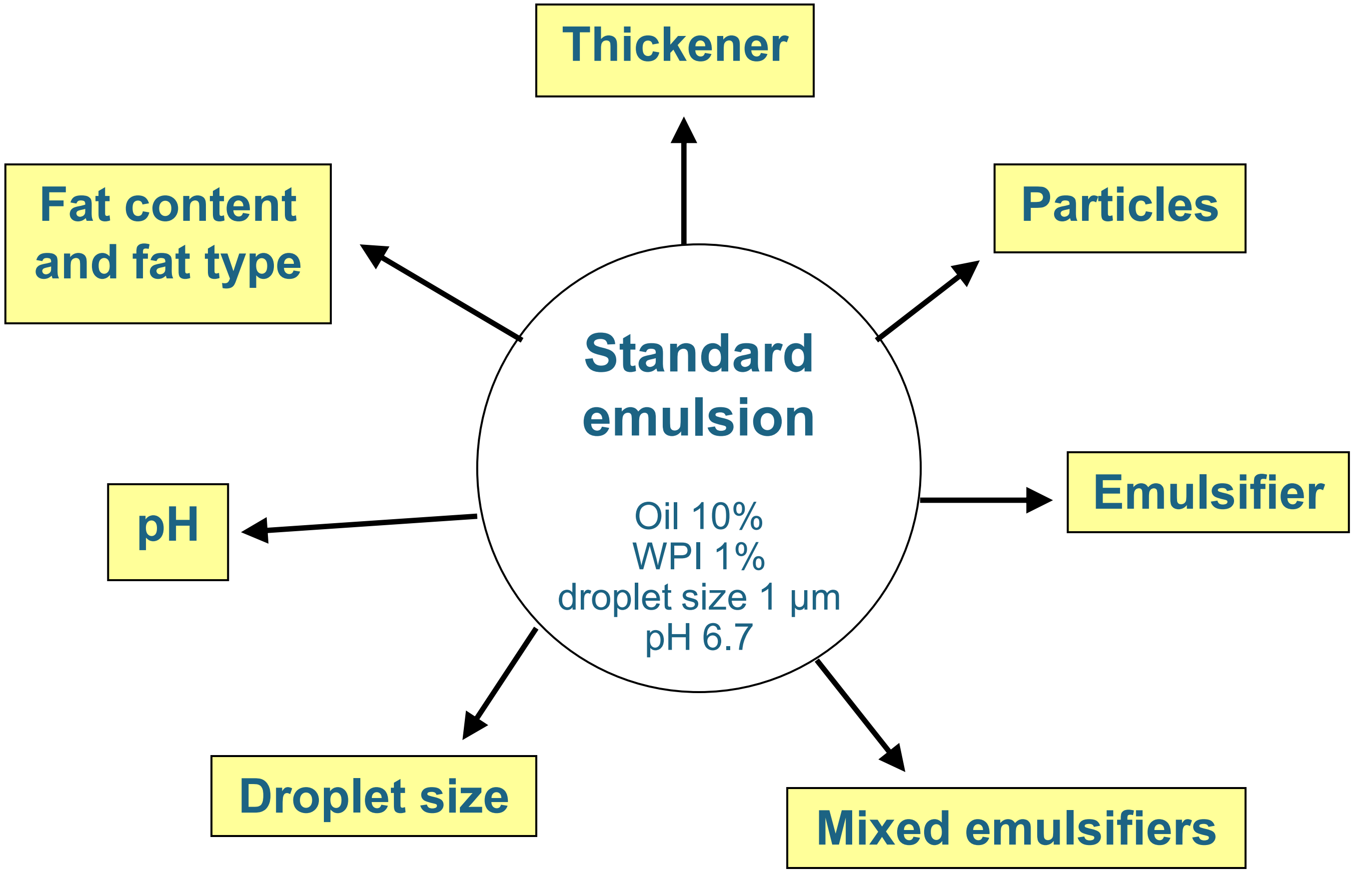
Examples of oral processing in relation to perception

- Emulsions
- Emulsion filled gels

Sensory analysis
Quantitative Descriptive Analysis

- In total 20 studies focussed on the effect of composition and oral processing of model food emulsions
- **A lot of work!** Each study:
  - 8-9 Female panellists (mean age 45-50 years)
  - General training to describe sensory attributes.
  - 2-4 training sessions on samples
  - 2-4 panelling sessions
  - 35 attributes
    - 3 odor (O)
    - 8 taste (T)
    - 9 mouthfeel (MF)
    - 4 aftertaste (AT)
    - 11 afterfeel (AF)

Approach
the first 7 QDA profilings

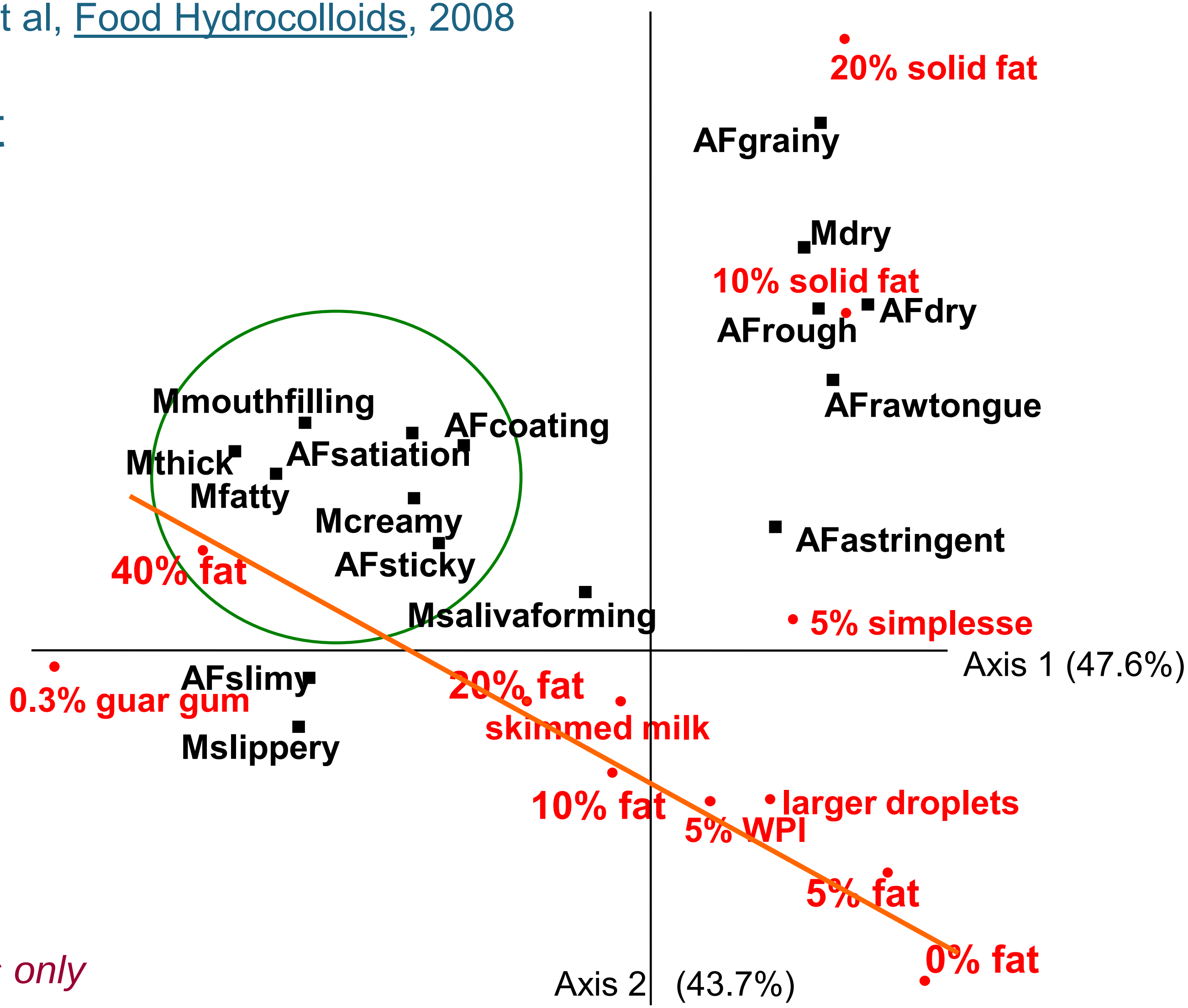


1st QDA profiling:

variation of fat content, thickeners, particles, solid fat

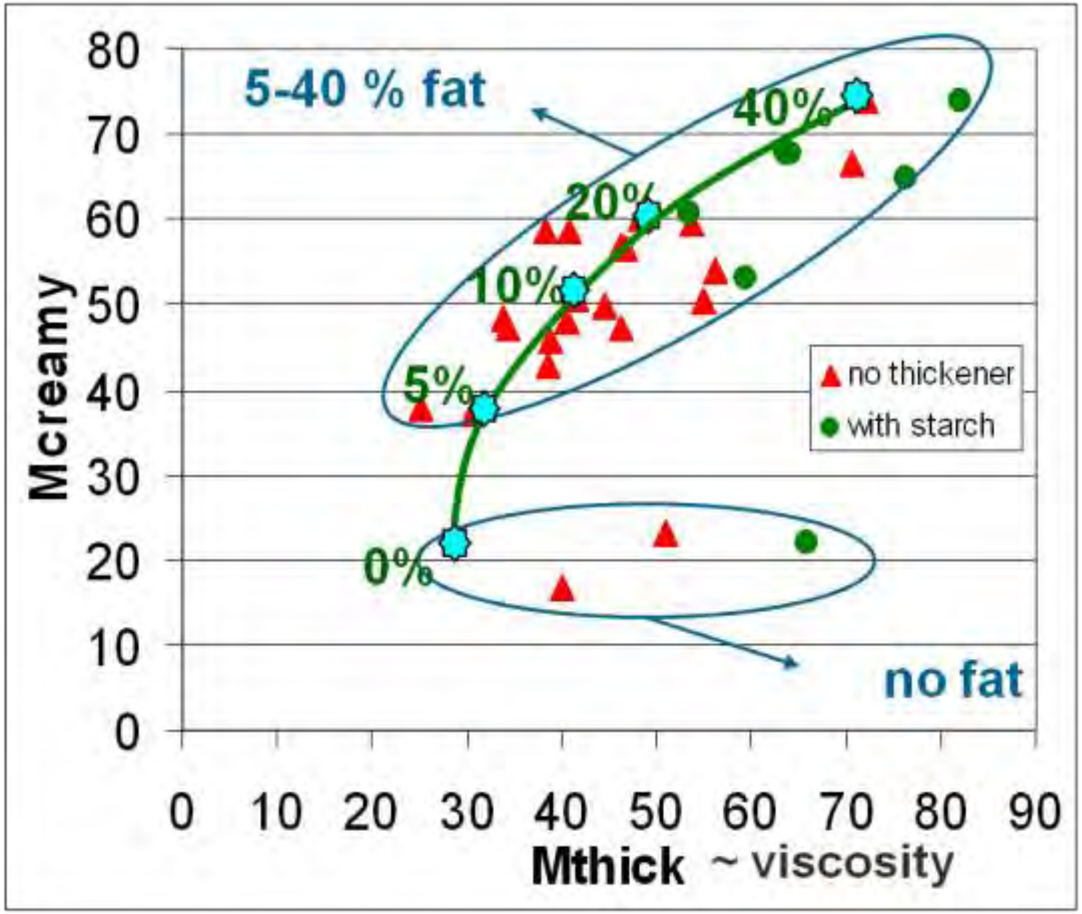
Vingerhoeds et al, Food Hydrocolloids, 2008

PCA plot



Texture attributes only

In low-viscosity systems:
fat improves creaminess separate from thickness



WHY?

Oral behavior of emulsions:
Large structural changes, even for thin liquid emulsions:

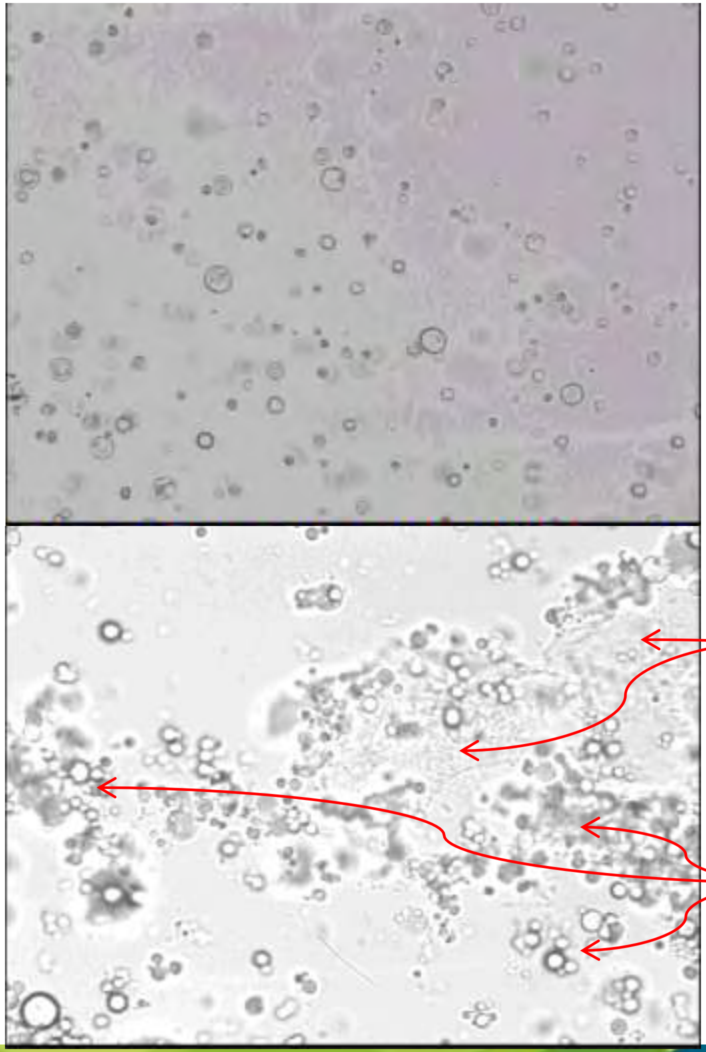
THIS is what you taste!

40 % dairy emulsion (cream)

100x dilution with bidest

cream

after 1 min
in mouth



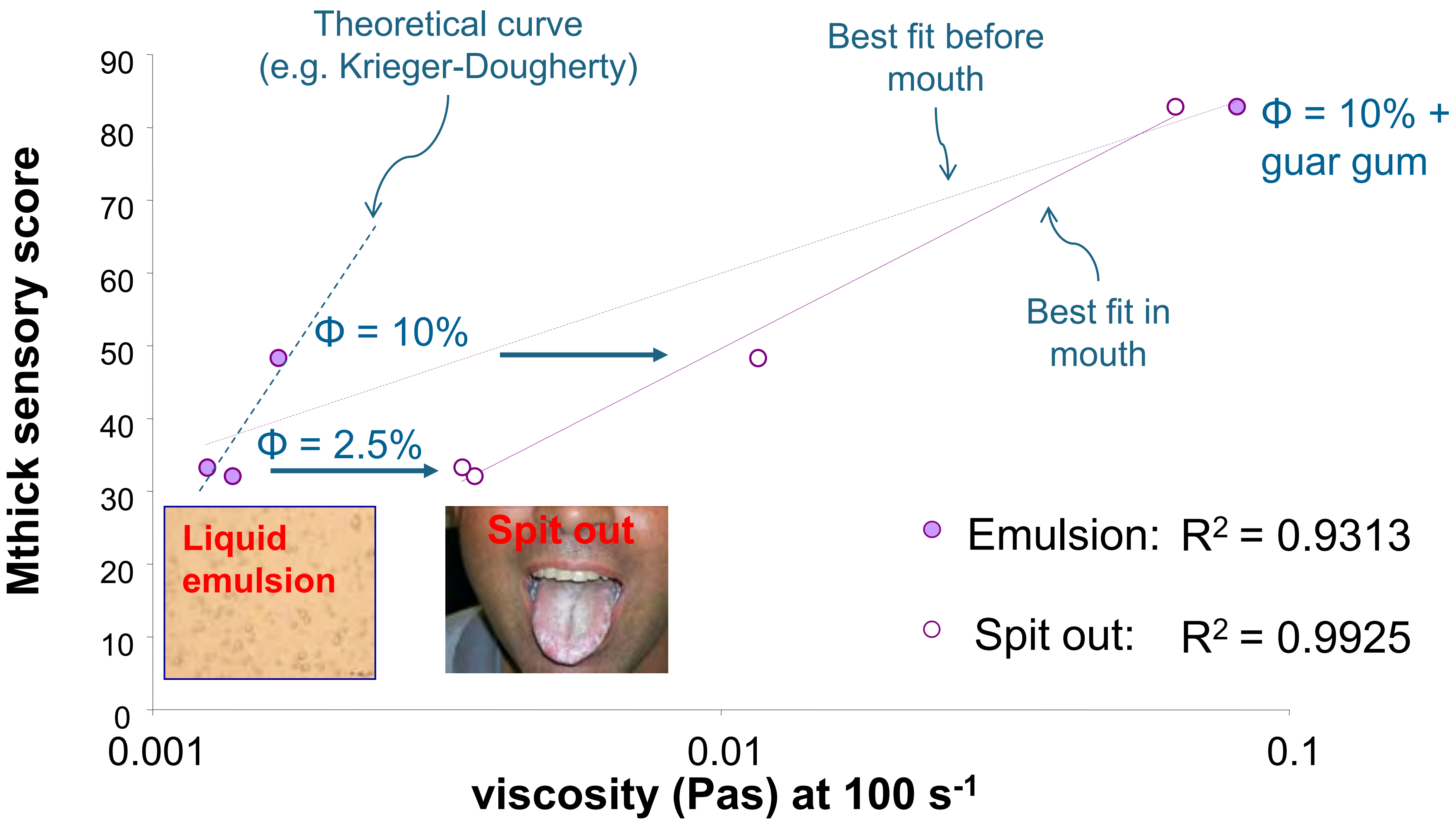
Epithelial cells

Droplets and cells bound together by a ropy mucous mass from saliva and tongue surface

Emulsion viscosity & perceived thickness

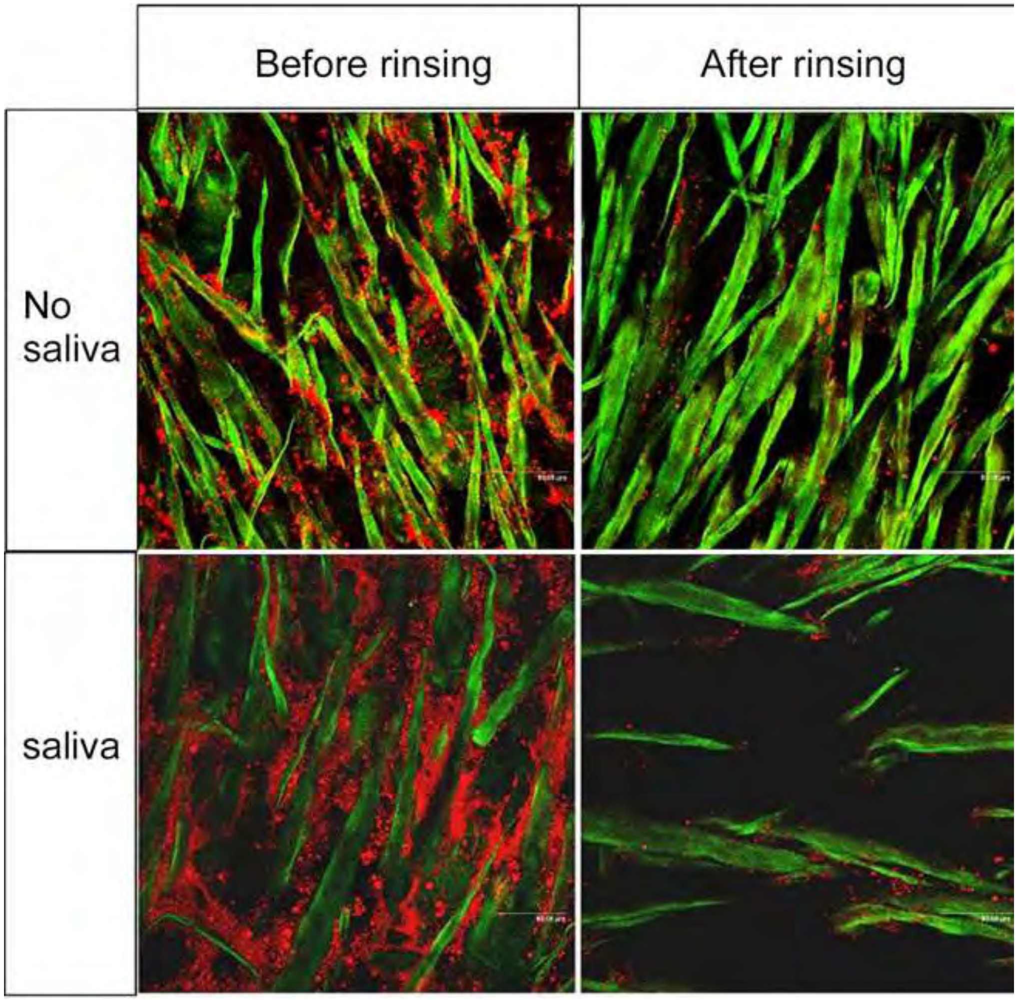
WPI-stabilized emulsions (ξ=potential < 0)

(Vingerhoeds et al. Food Hydrocolloids, 23(3) (2009), 773-785.)



Interaction with the tongue

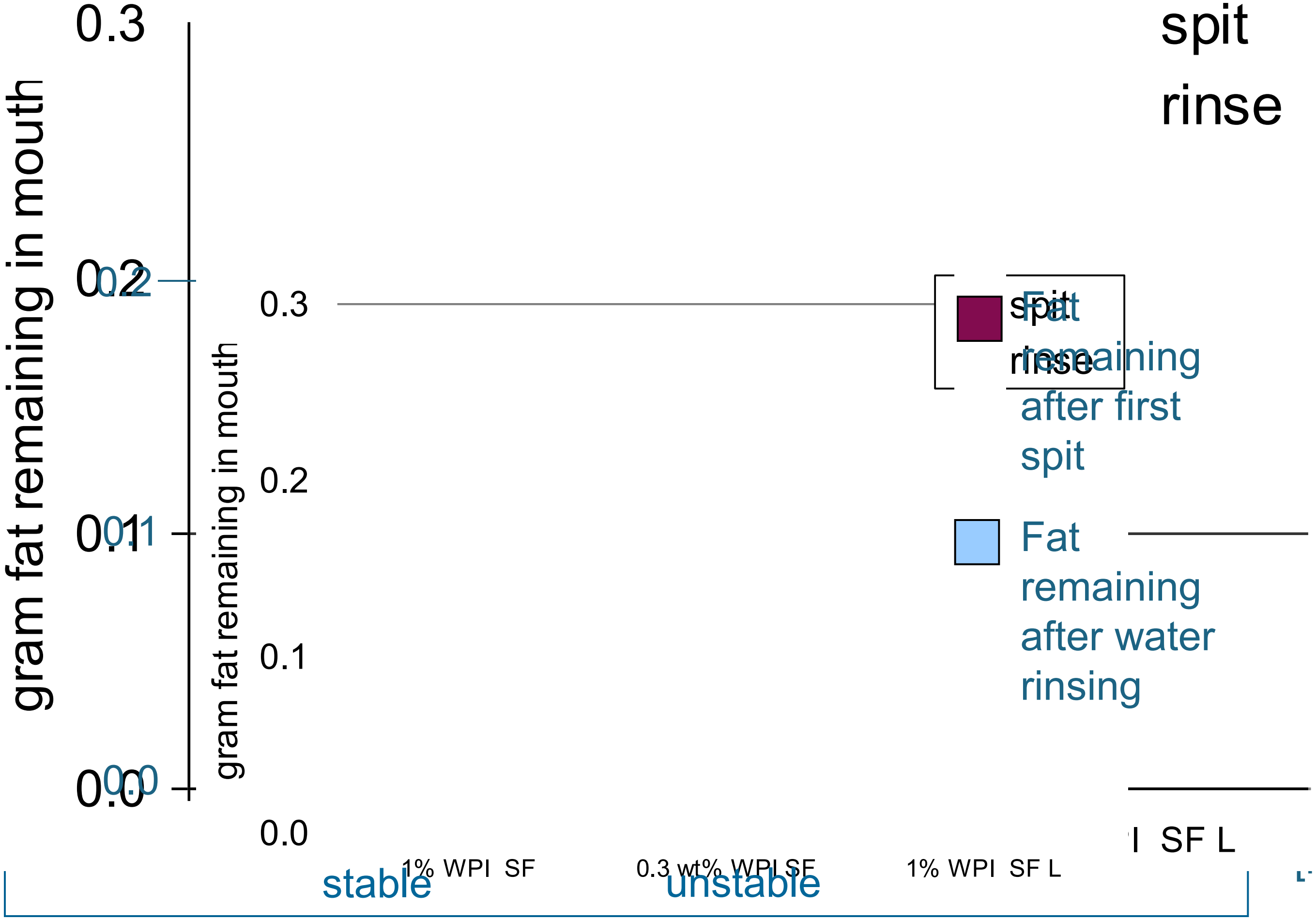
PhD study of Diane Dresselhuis



Visualization of fat retention on piglet tongue

CSLM image (Nile blue staining)
500×500 μm
10 wt% SF oil; 1 wt% WPI
red: oil; green: tongue papillae

Dresselhuis et al., Journal of Colloid and Interface Science (2008)



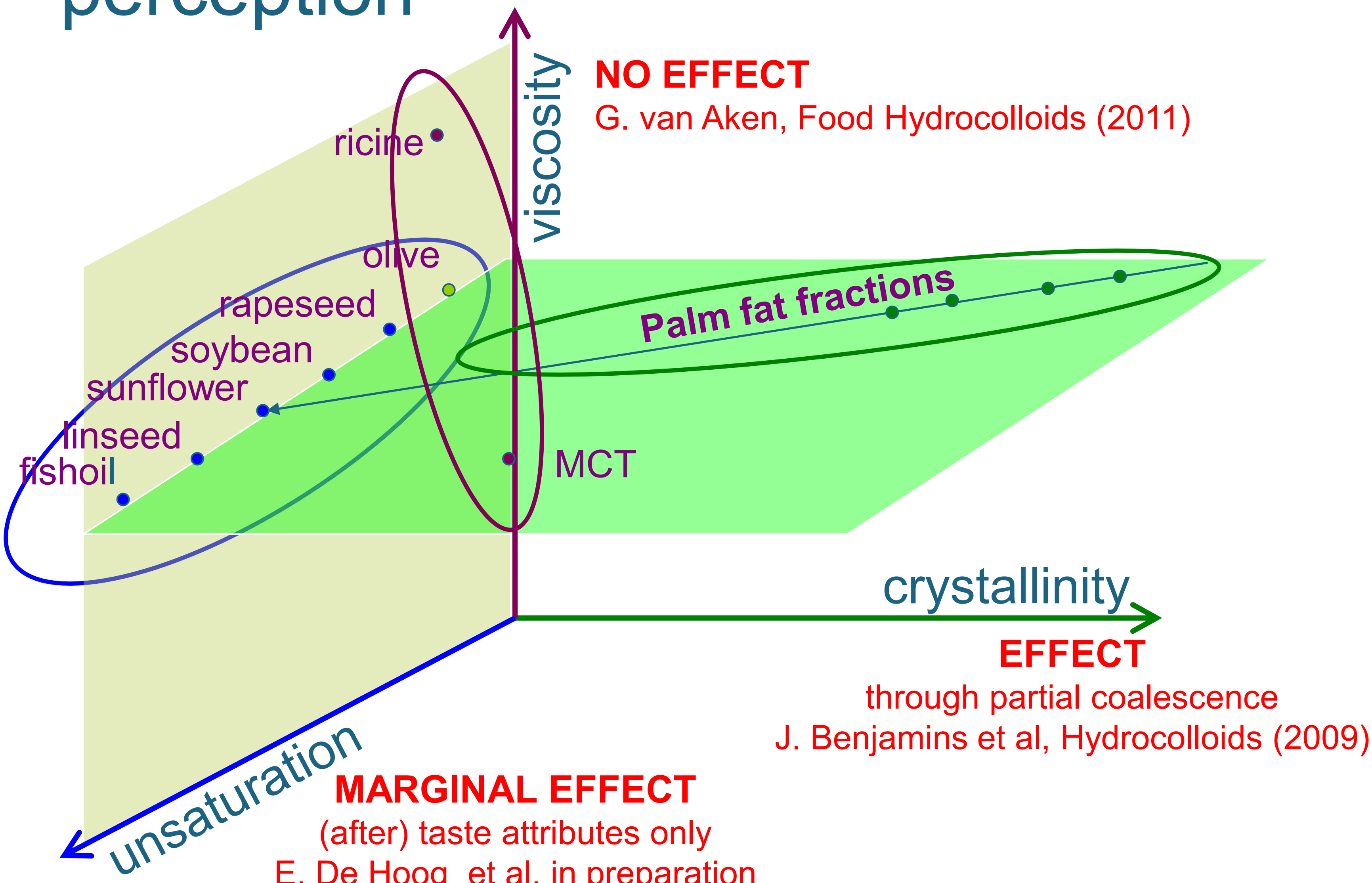
o/w emulsion
7% SF (sunflower oil)
bilized with protein WPI

	stable	unstable
PI 5]	1	0.3
[3,2] m]	0.92	1.15
051 s^{-1}) [...Pa s]	1.6	1.4

Fat adhesion and retention larger for more unstable emulsions → increased creaminess

Dresselhuis et al., Journal of Colloid and Interface Science (2008)

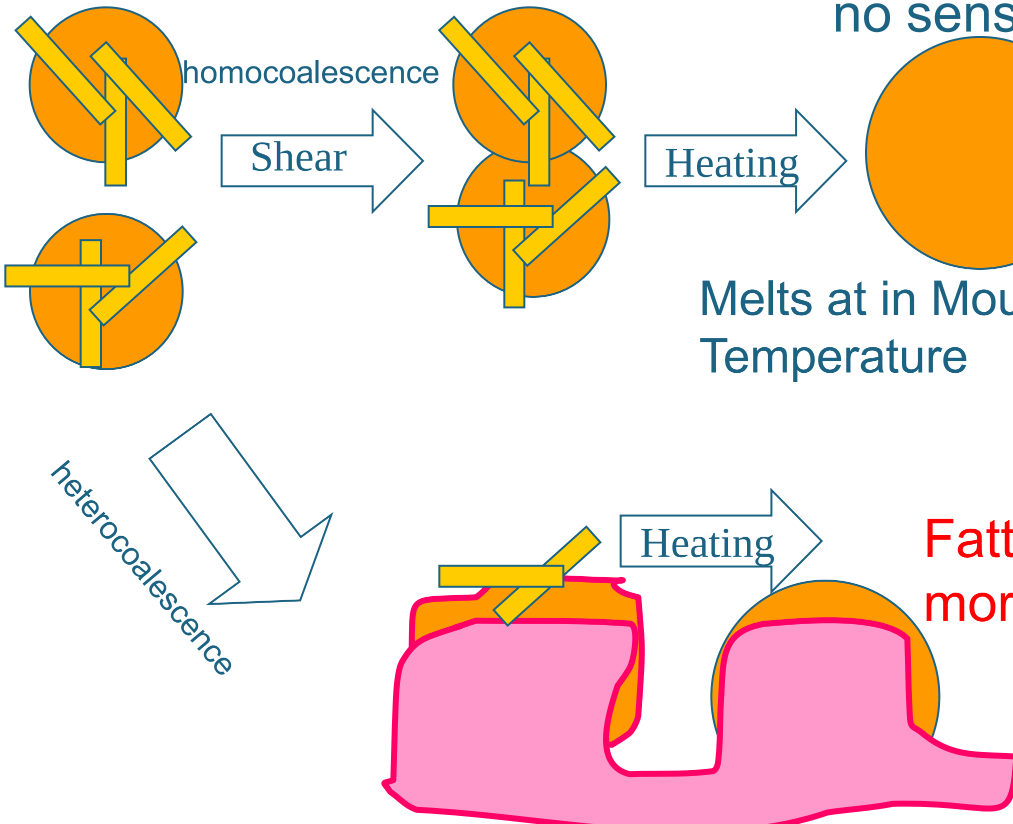
Effect of fat type on tactile oral perception



Partial coalescence by fat crystals

Viscous:
more creamy

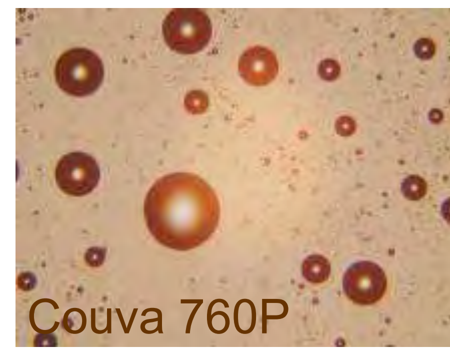
Larger droplets:
no sensory effect



Melts at in Mouth Temperature

Fatty layer:
more creamy

Spit-outs:



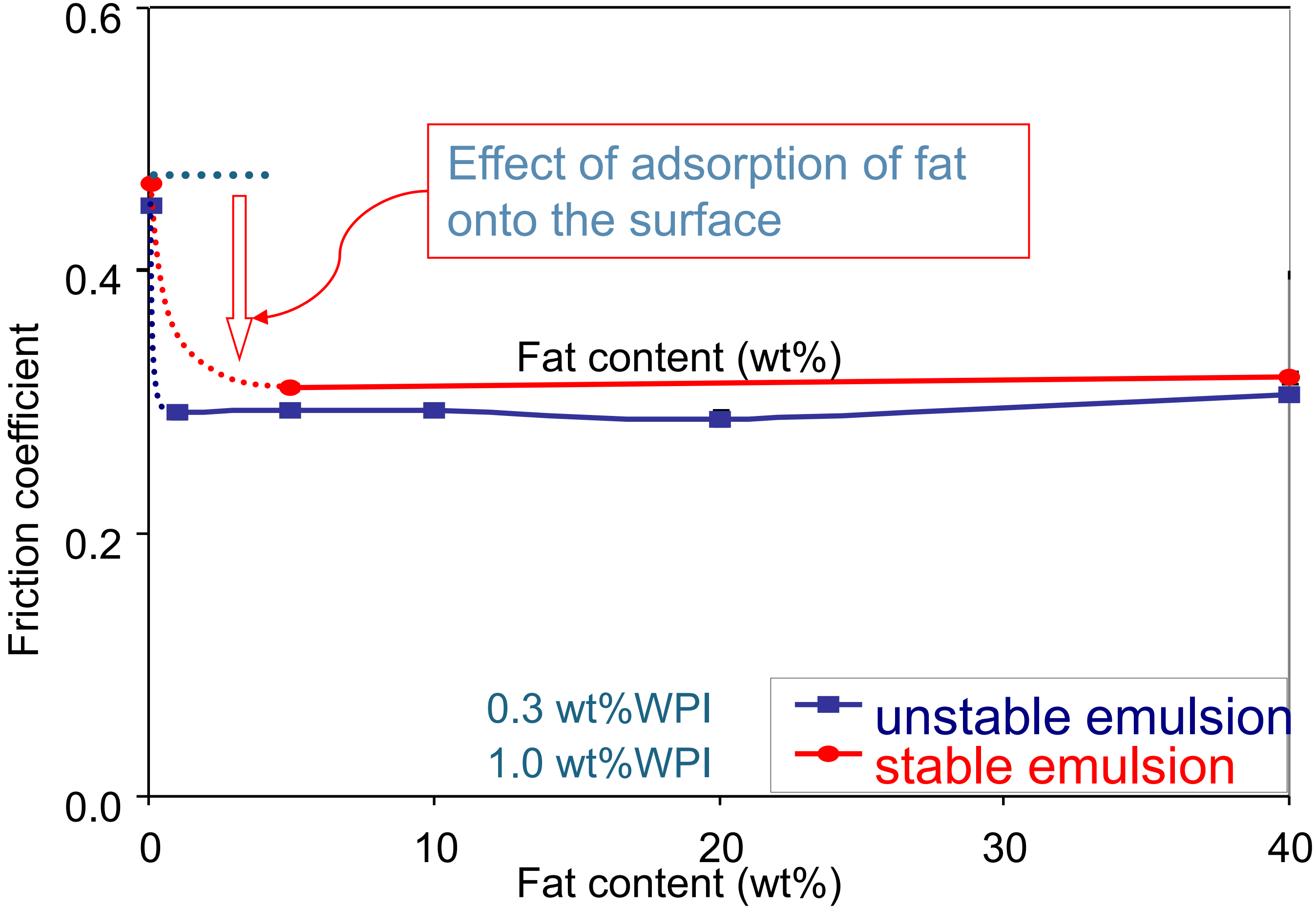
field of view: 3 x 4 mm

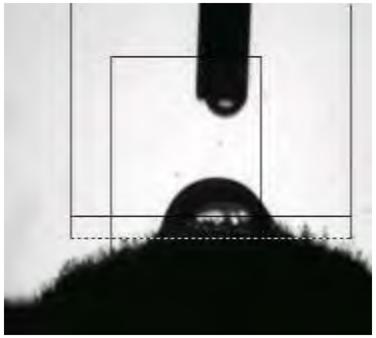
Jan Benjamins

Effect of the deposition of a fatty layer on the tongue

Friction between PDMS (hydrophobic) and glass (boundary friction regime)

Dresselhuis et al. Food Biophysics (2007)



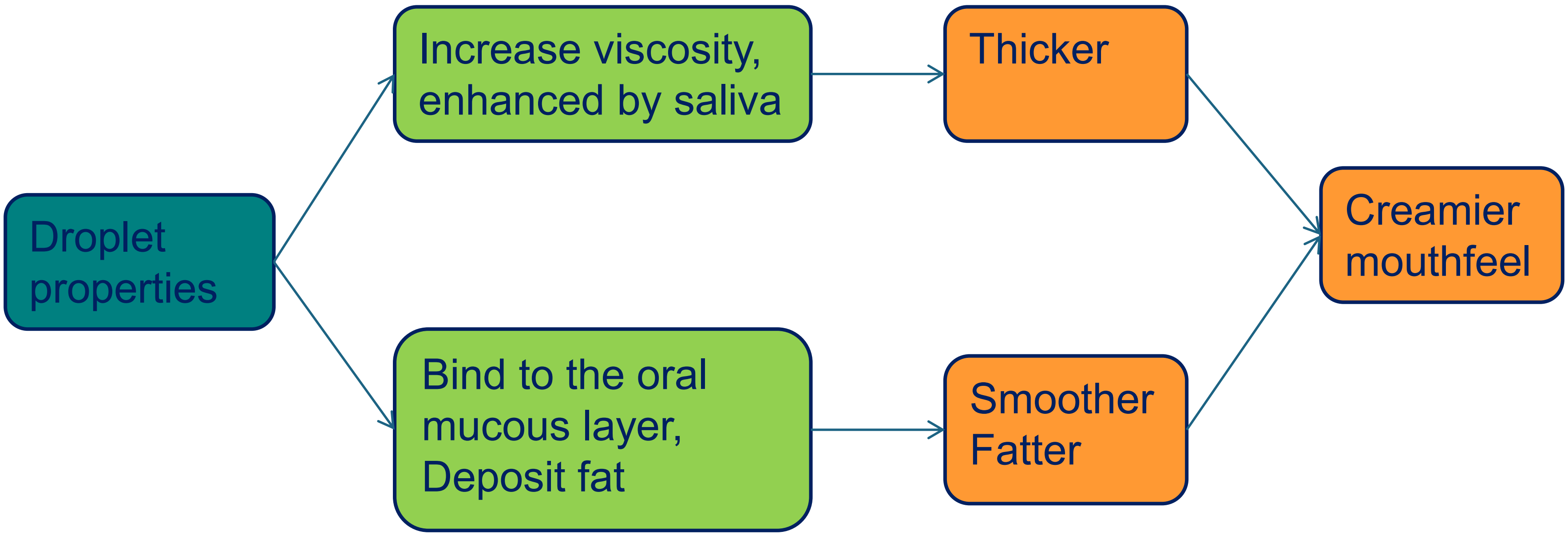


Dewetting of saliva from the oral surfaces

Fat reduces the friction, but an increase in fat content has no further effect

Liquid emulsions

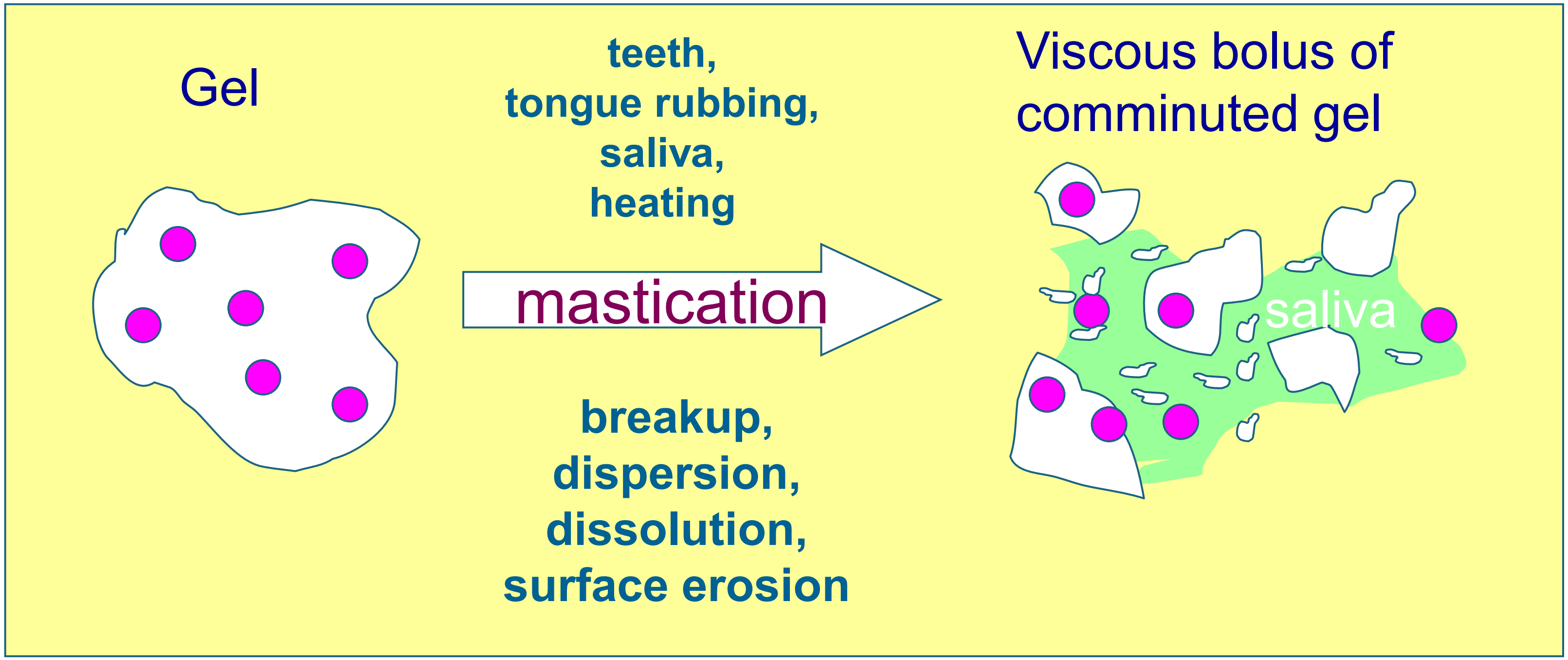
sensory properties related to oral behavior



Examples of oral processing in relation to perception

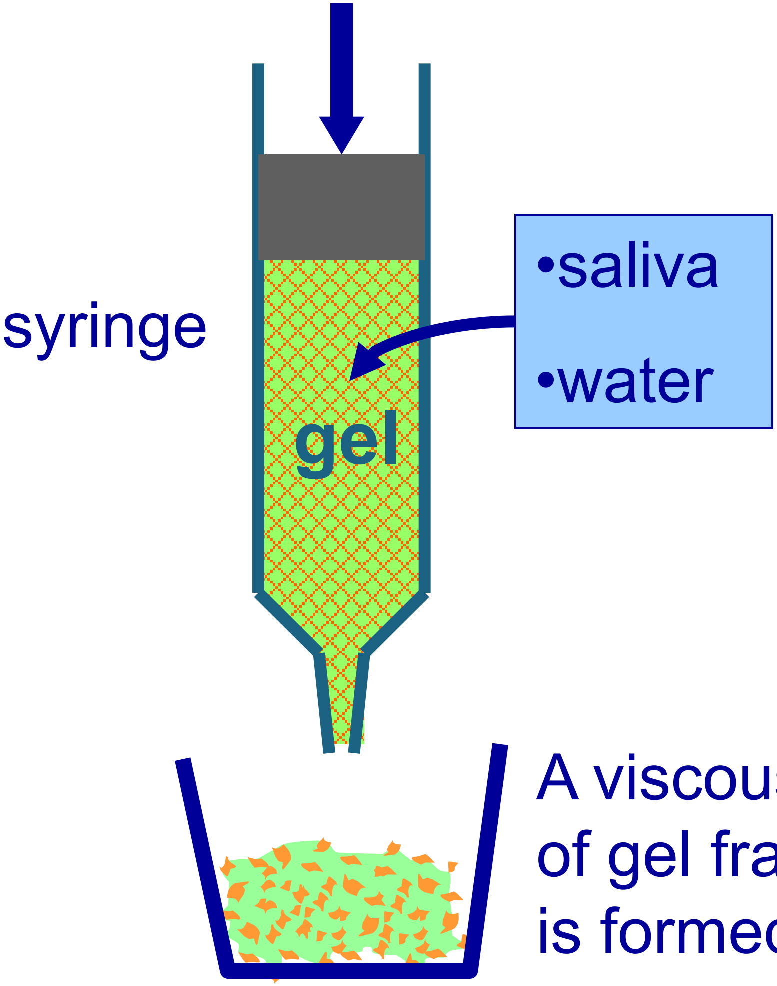
- Emulsions
- Emulsion filled gels

Oral processing of emulsion-filled gels

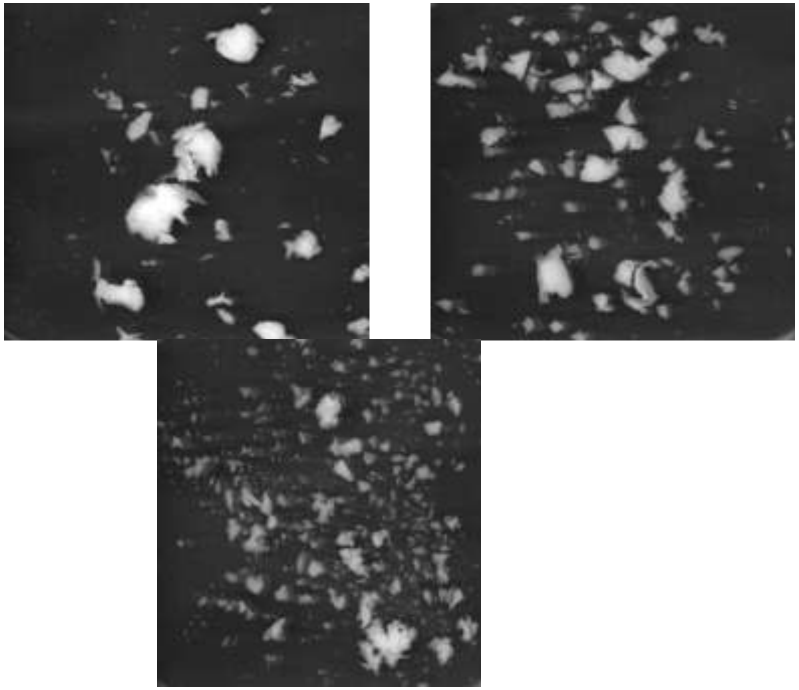


Sala et al., Food Hydrocolloids (2009), 23 (5) (2009), 1381-1393

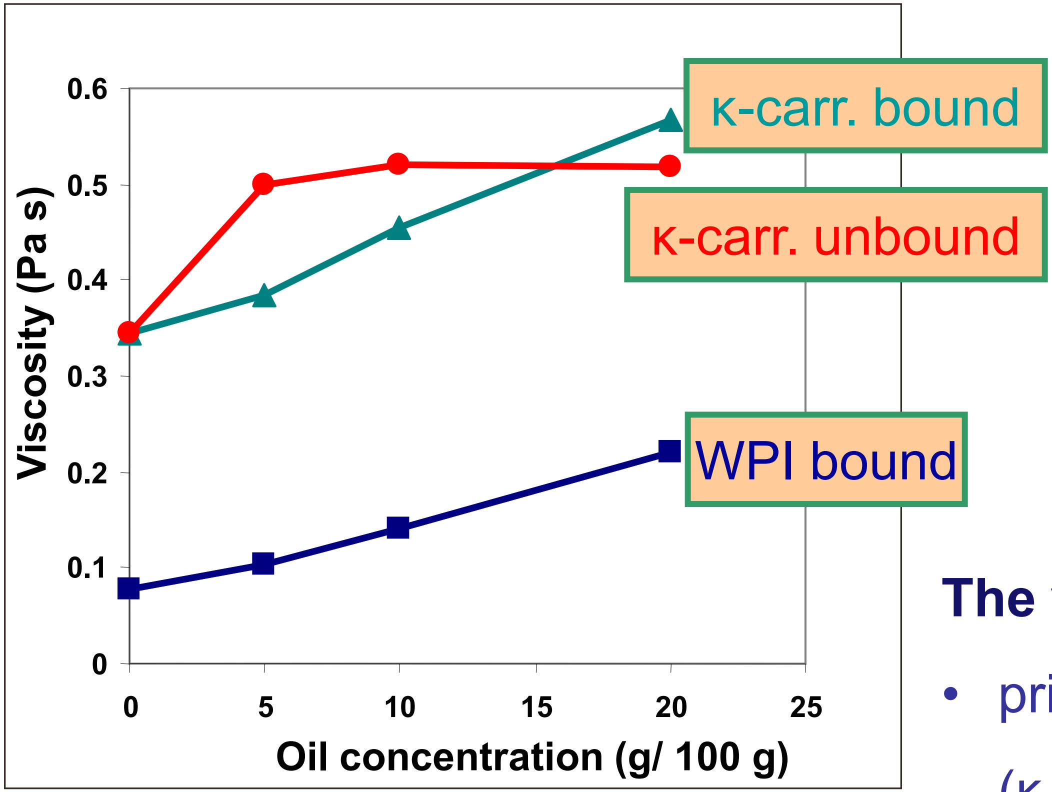
The comminuted gel:
in vitro and in expectorate



A viscous paste of gel fragments is formed

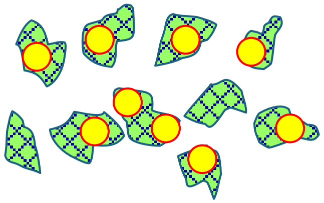


Viscosity of comminuted gel increases with oil content

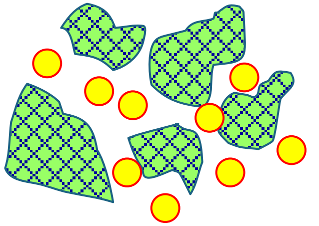


Shear rate= 100 s^{-1}

Bound droplets:



Unbound droplets:



The viscosity of the comminuted gel:

- primarily depends on the matrix (κ-carrageenan > WPI)
- increases with the oil content
- depends on droplet-matrix interaction

In vitro masticated gels: effects of gel type and fat content

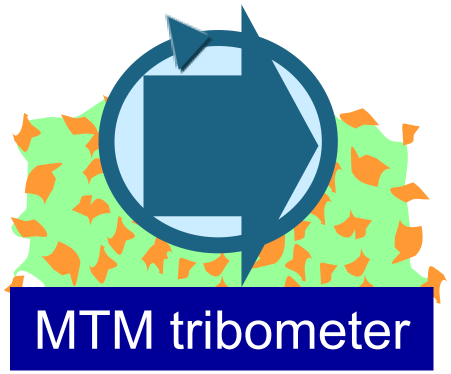
Emulsified oil:

- Increases the <u>viscosity</u> of the masticated bolus

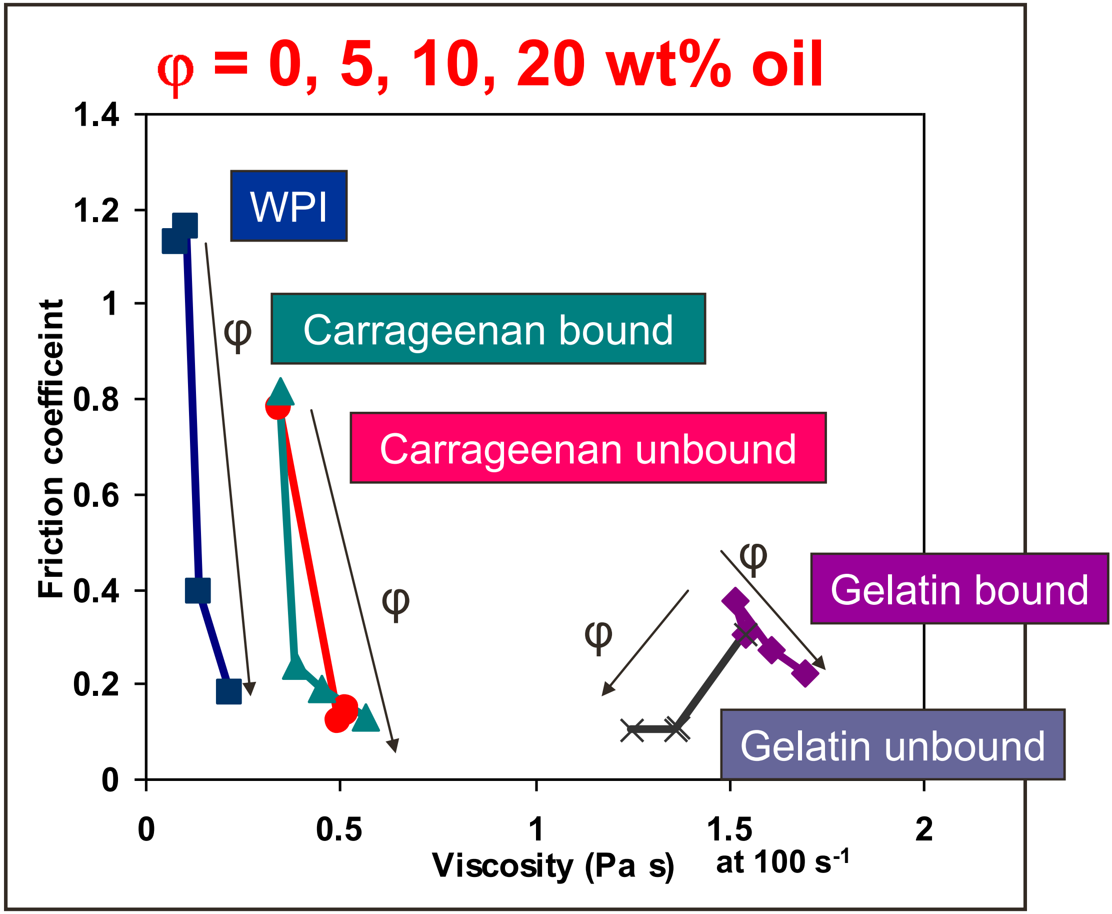
  (for gelatin unbound opposite)

- decreases the <u>friction</u> of the masticated bolus

  (large effect)



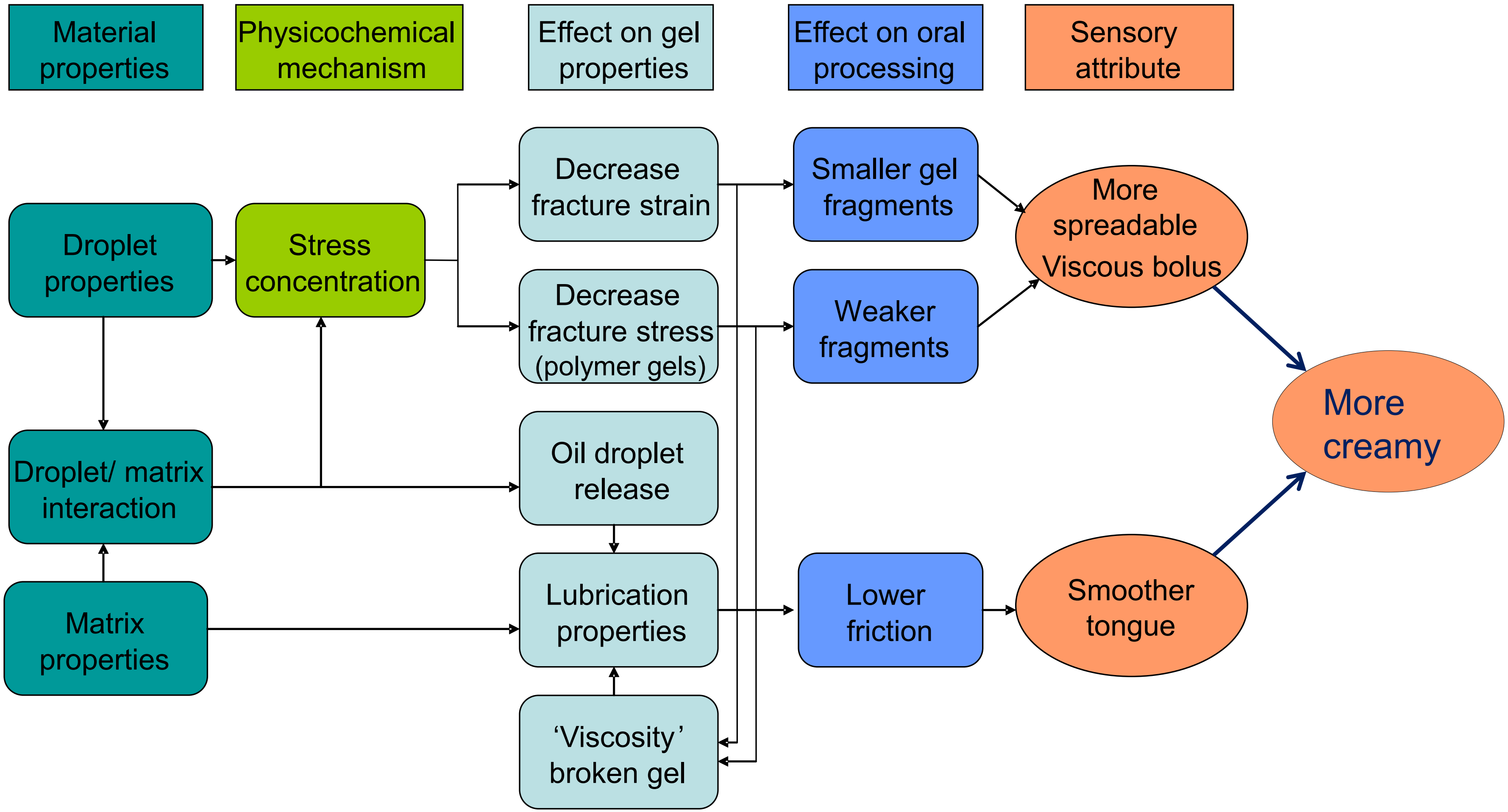
(rubber versus stainless steel)



Chojnicka et al., Food Hydrocolloids (2009), 23, 1038-1046

Emulsion filled gels

sensory properties related to oral behavior (after Guido Sala)

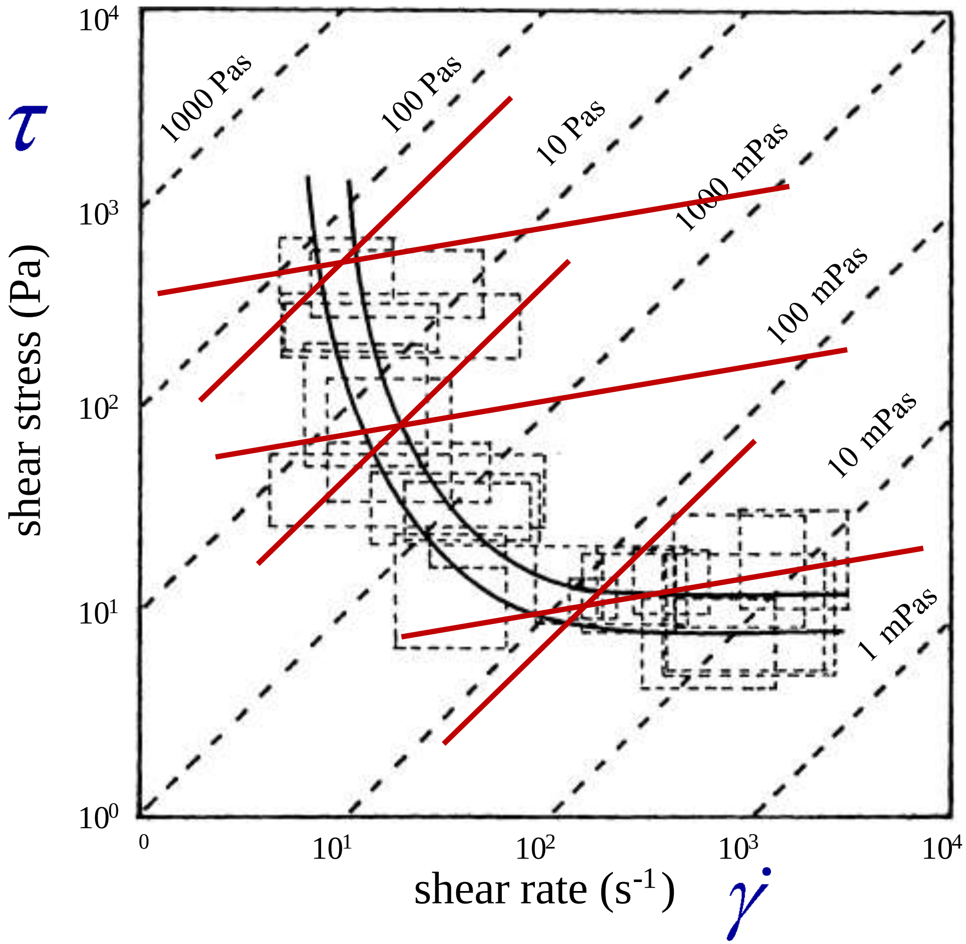


Toward understanding

TACTILE PERCEPTION BY THE TONGUE

Main regimes thickness perception

Curve from: Shama, F. and P. Sherman (1973). J. Texture Studies **4**: 111-118.

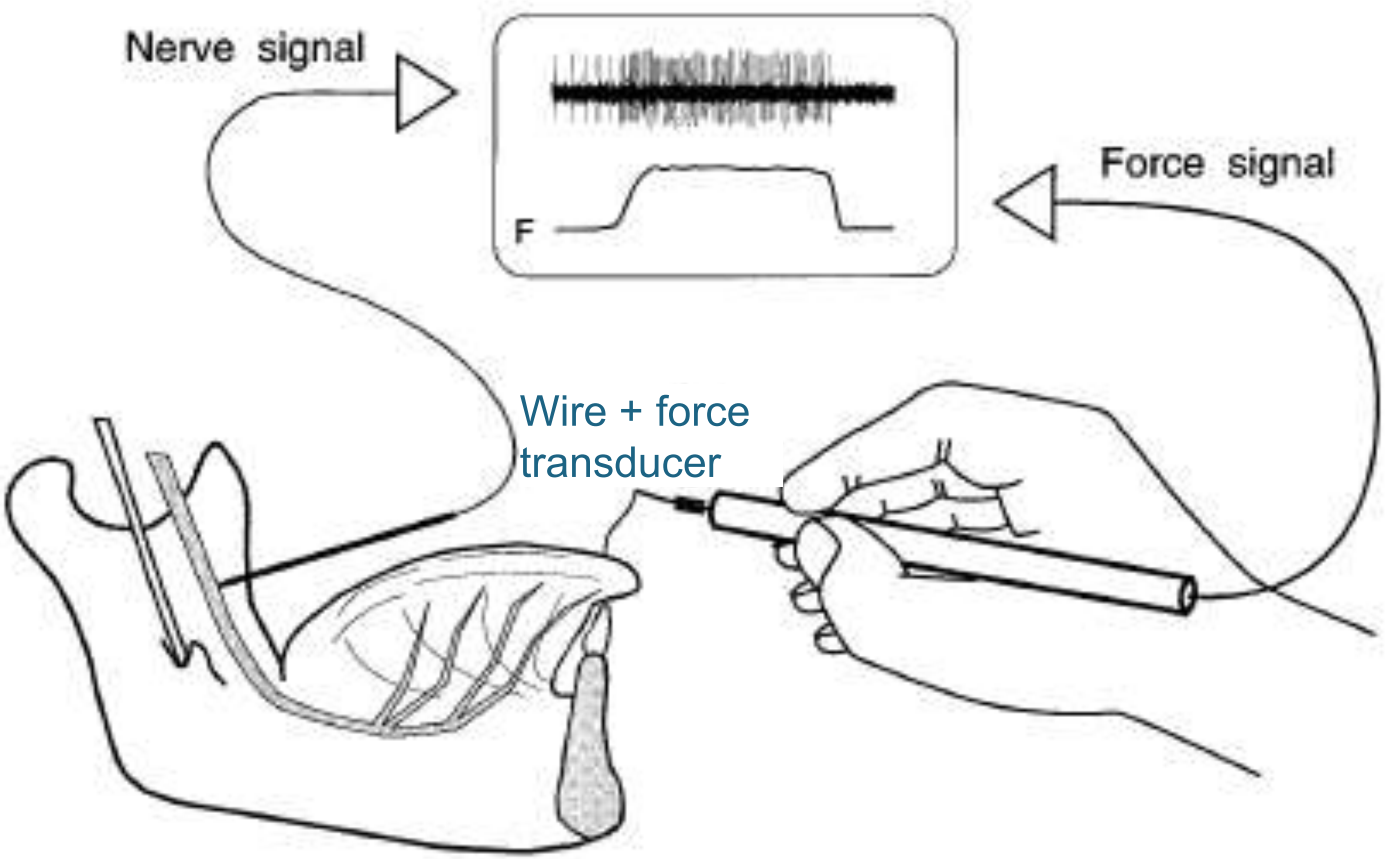


Plot shear-stress versus shear-rate curves for food materials with very different shear thinning behaviour

Identify windows of food materials with similar perceived thickness

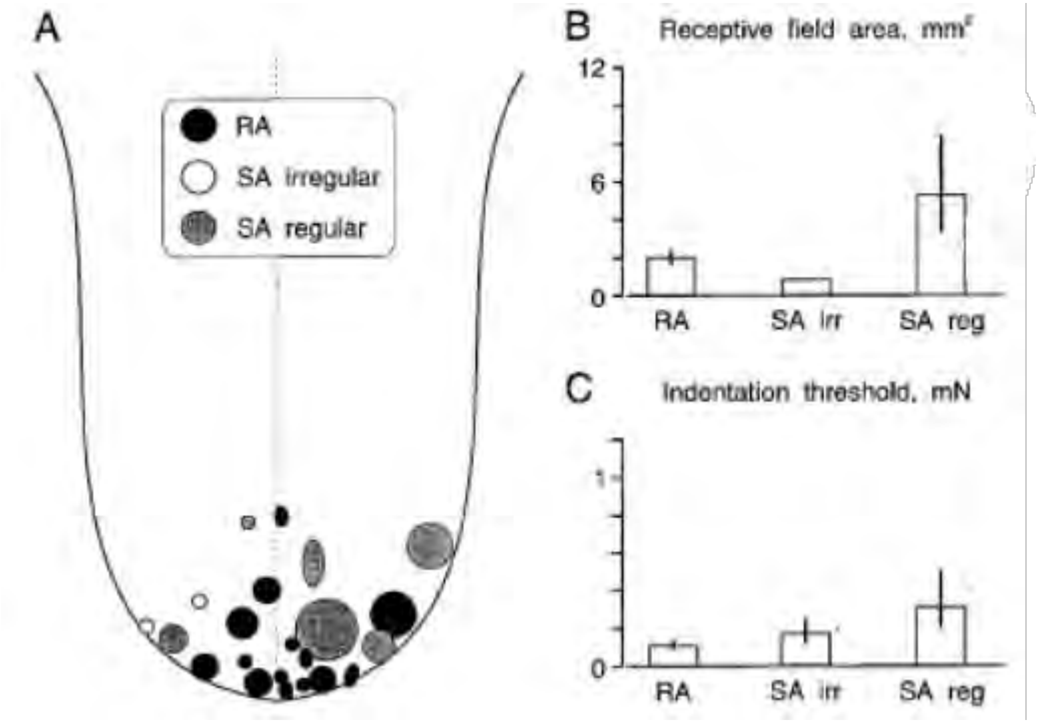
How can we explain the shape of this curve?

Sensitivity of the mechanoreceptors in the tongue



M. Trulsson, G.K. Essick, J. Neurophys. 1997(77), 737-748

Receptor types and sensitivities



Slowly Adapting receptors: sensitive to constant forces

Rapidly Adapting receptors: sensitive to force variations

Assuming that forces on each RA receptor are additive:

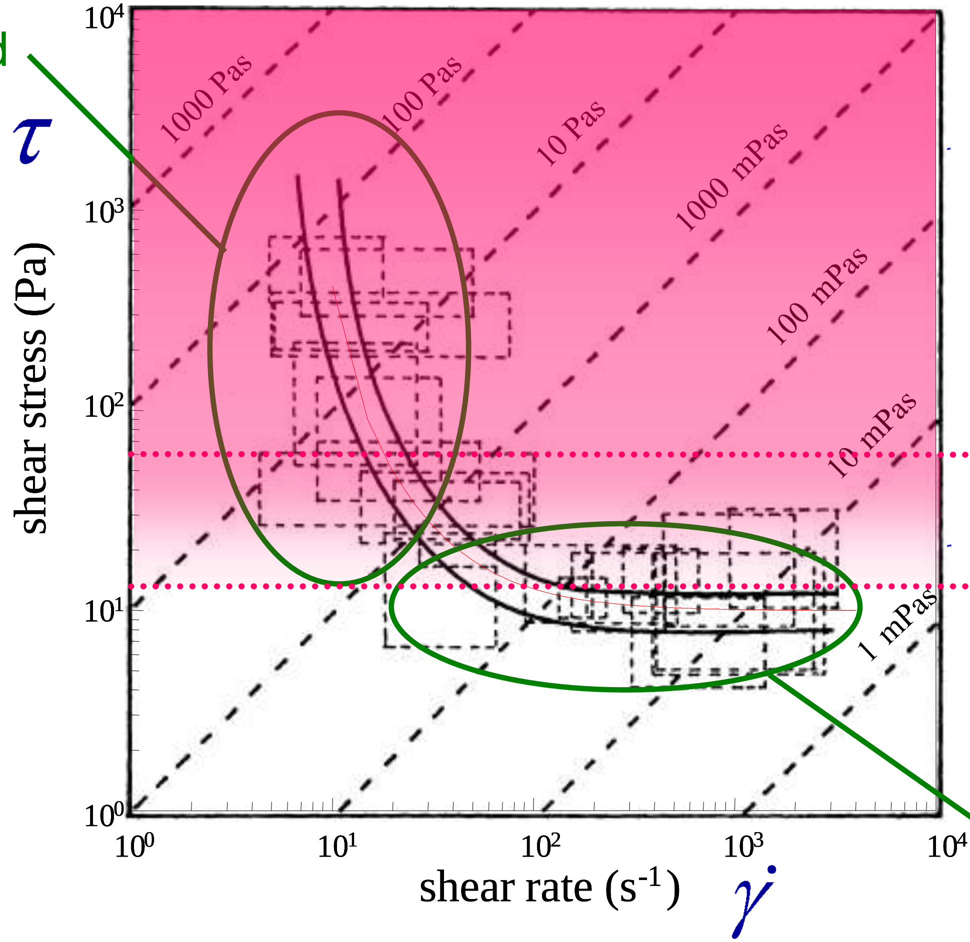
- Lower stress threshold of about 12 Pa
- Average stress threshold of about 60 Pa

M. Trulsson, G.K. Essick, J. Neurophys. 1997(77), 737-748

Main regimes thickness perception

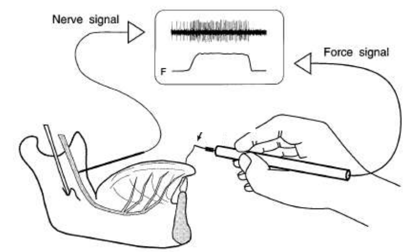
Curve from: Shama, F. and P. Sherman (1973). <u>J. Texture Studies</u> **4**: 111-118.

Viscous forces perceived



Sensitivity RA receptors

Trullson, Essick, J. Neurophys. 1997(77), 737-748



Average stress thresshold

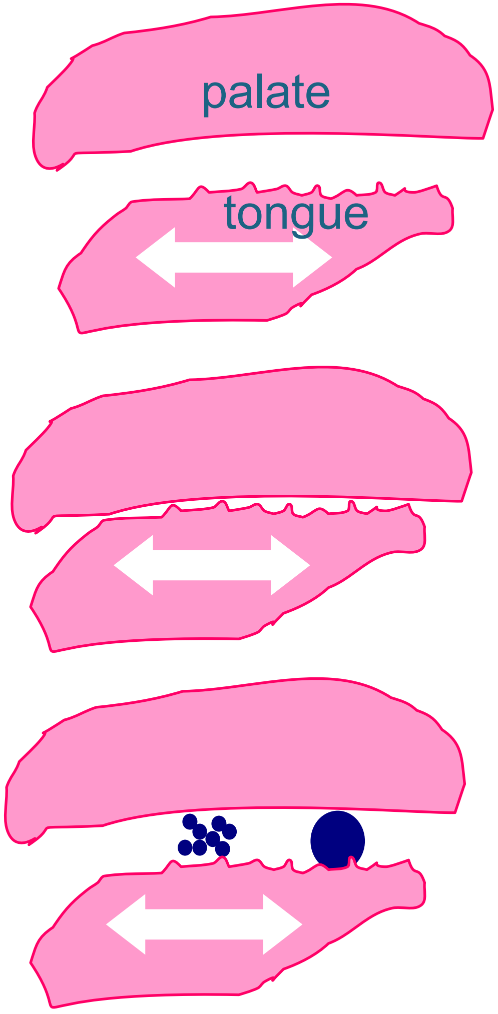
Lower stress thresshold

Thickness not necessarily related to perceived viscous forces

Van Aken, G.A., Modelling texture perception by soft epithelial surfaces, <u>Soft Matter</u>, 2010, 6, 826–834

What produces the forces sensed by the tongue?

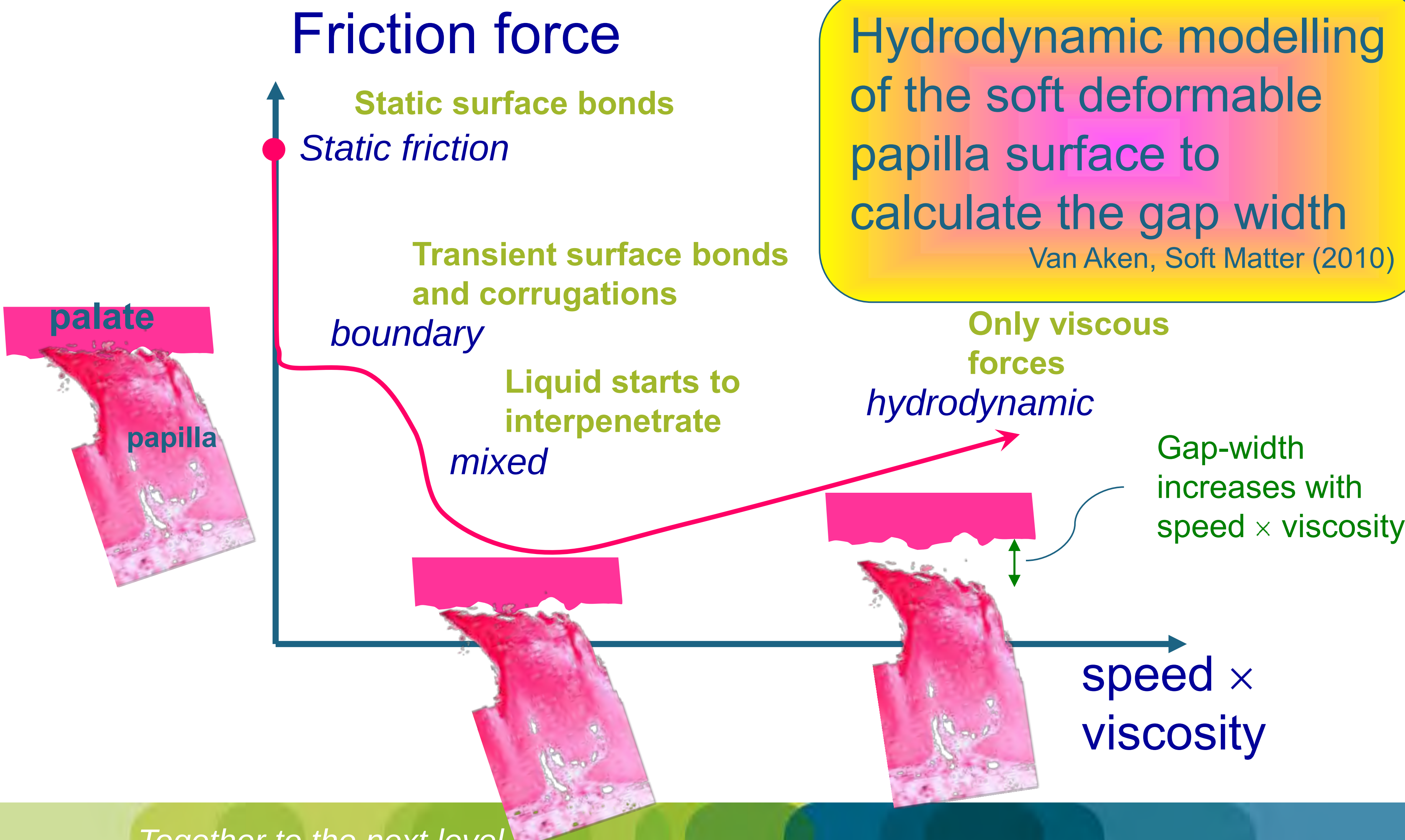
- Viscous forces of the fluid in motion relative to the tongue surface
- Friction of tongue and palate in contact
- Particles grinding between tongue and palate



Tribological regimes (Stribeck curve)

Hydrodynamic modelling of the soft deformable papilla surface to calculate the gap width

Van Aken, Soft Matter (2010)



Papilla surface roughness and deformability

Load dependence of contact area (OTC)

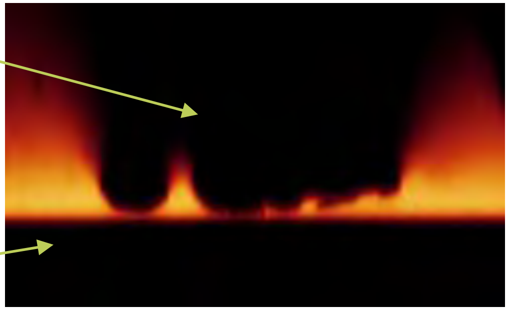
Frame size:
75 µm * 125 µm

Papilla surface roughness ~ 20 µm

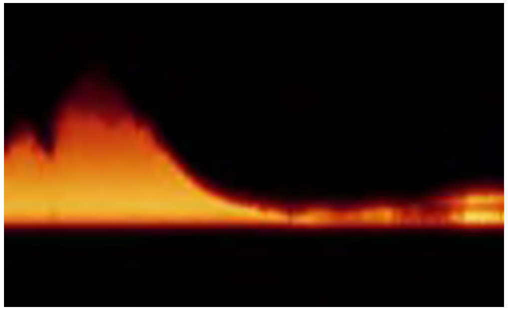
40 kPa

Filiform papilla

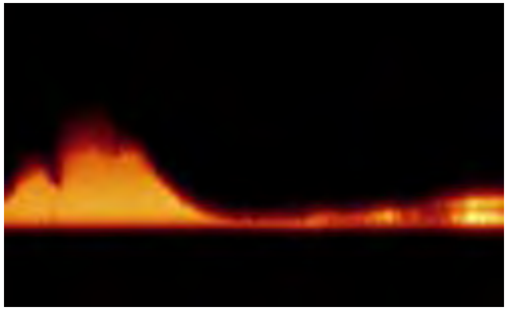
Glass slide



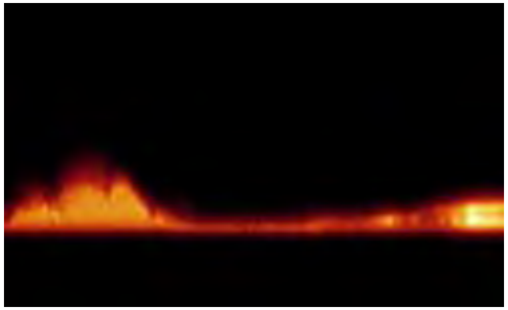
0 g load



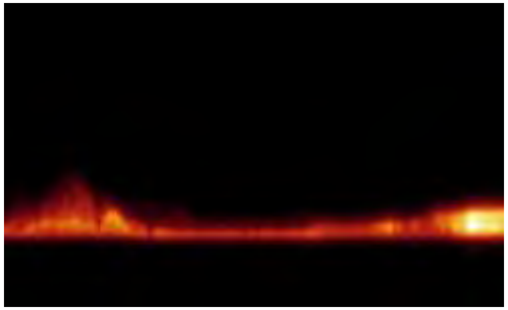
48,10 g load



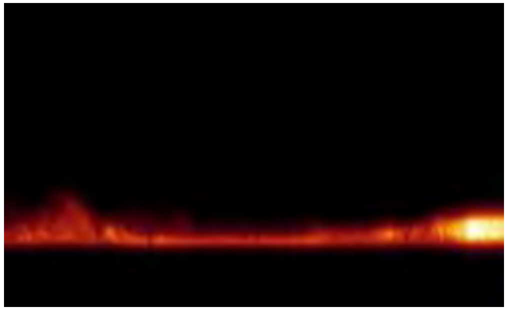
68,09 g load



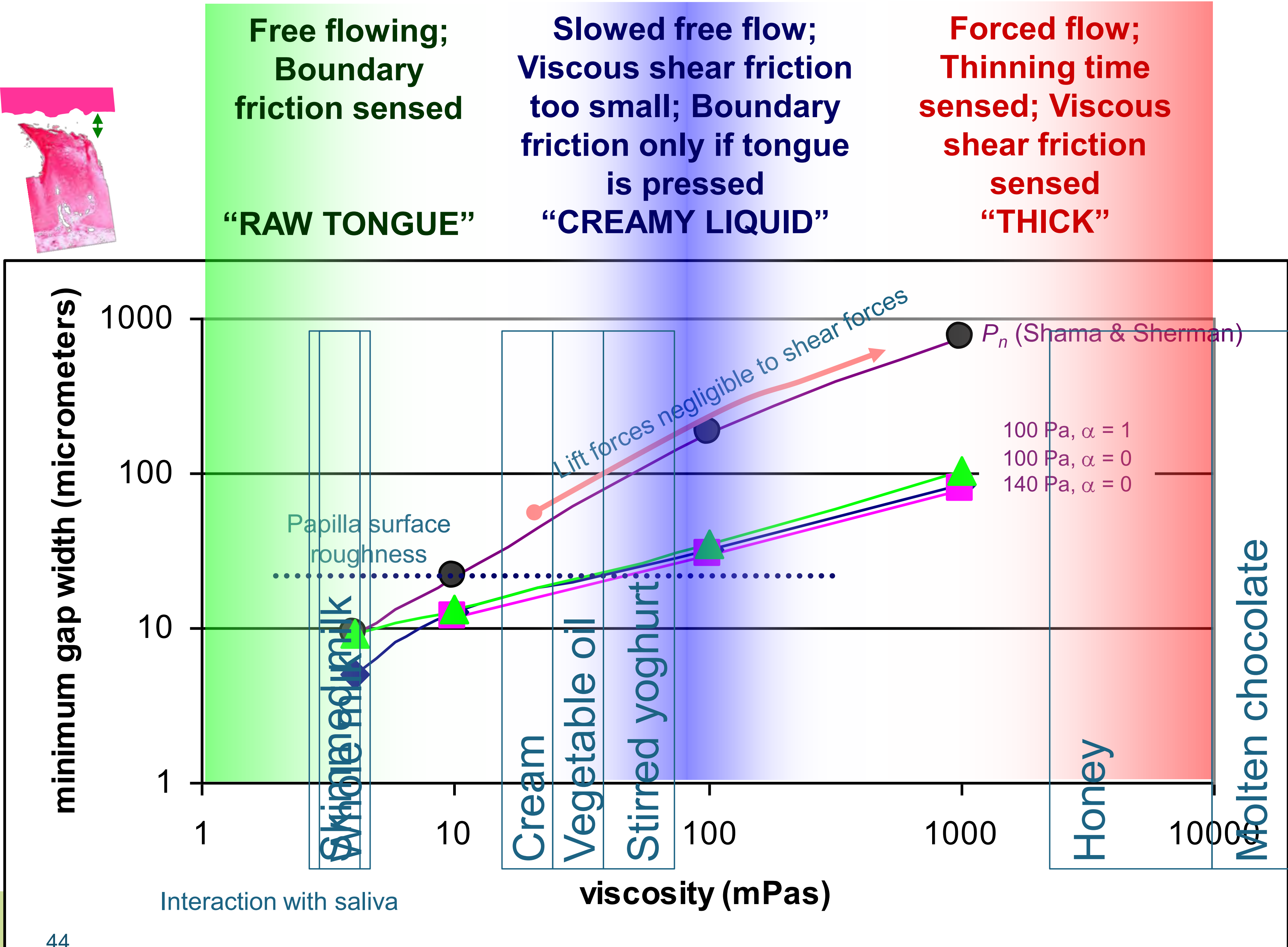
96,89 g load



153,01 g load

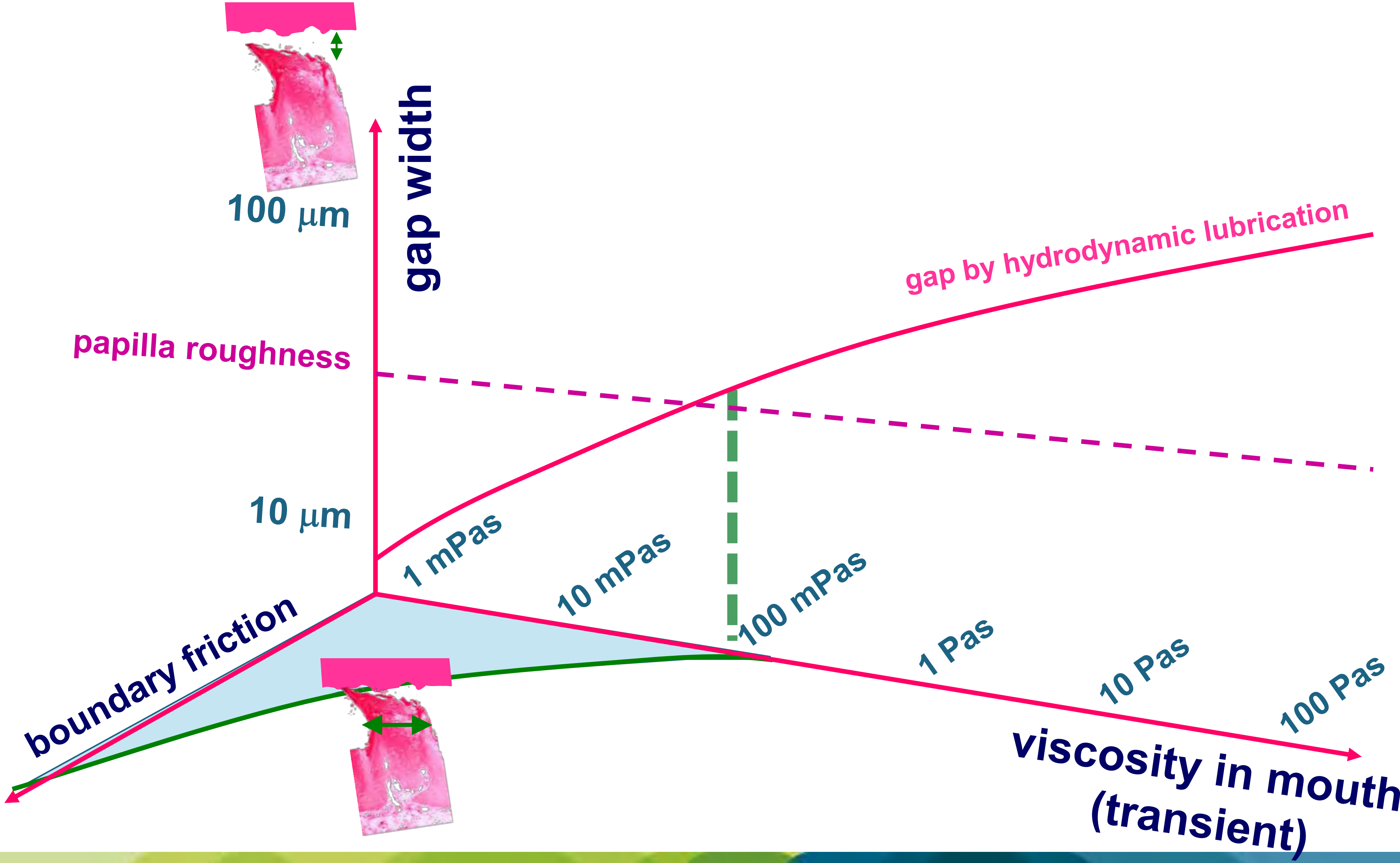


209,7 g load



Free flowing; Boundary friction sensed
"RAW TONGUE"
Slowed free flow; Viscous shear friction too small; Boundary friction only if tongue is pressed
"CREAMY LIQUID"
Forced flow; Thinning time sensed; Viscous shear friction sensed
"THICK"
minimum gap width (micrometers)
1000
100
10
1
Lift forces negligible to shear forces
P_n (Shama & Sherman)
100 Pa, α = 1
100 Pa, α = 0
140 Pa, α = 0
Papilla surface roughness
Skimmed milk
Whole milk
Cream
Vegetable oil
Stirred yoghurt
Honey
Molten chocolate
1
10
100
1000
10000
viscosity (mPas)
Interaction with saliva

Fluidic food bolus: relevant forces and dimensions



Tactile perception of a fluidic food bolus

Solids: breakdown path of fracturing an dissolution important

Normal hard cheese

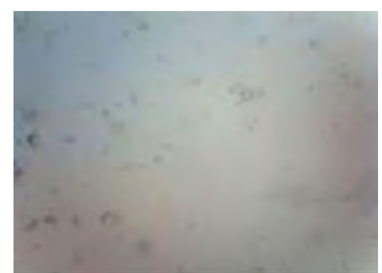
Forgeable particles, quickly hydrating

Viscous emulsion of coalesced droplets

Low-fat hard cheese

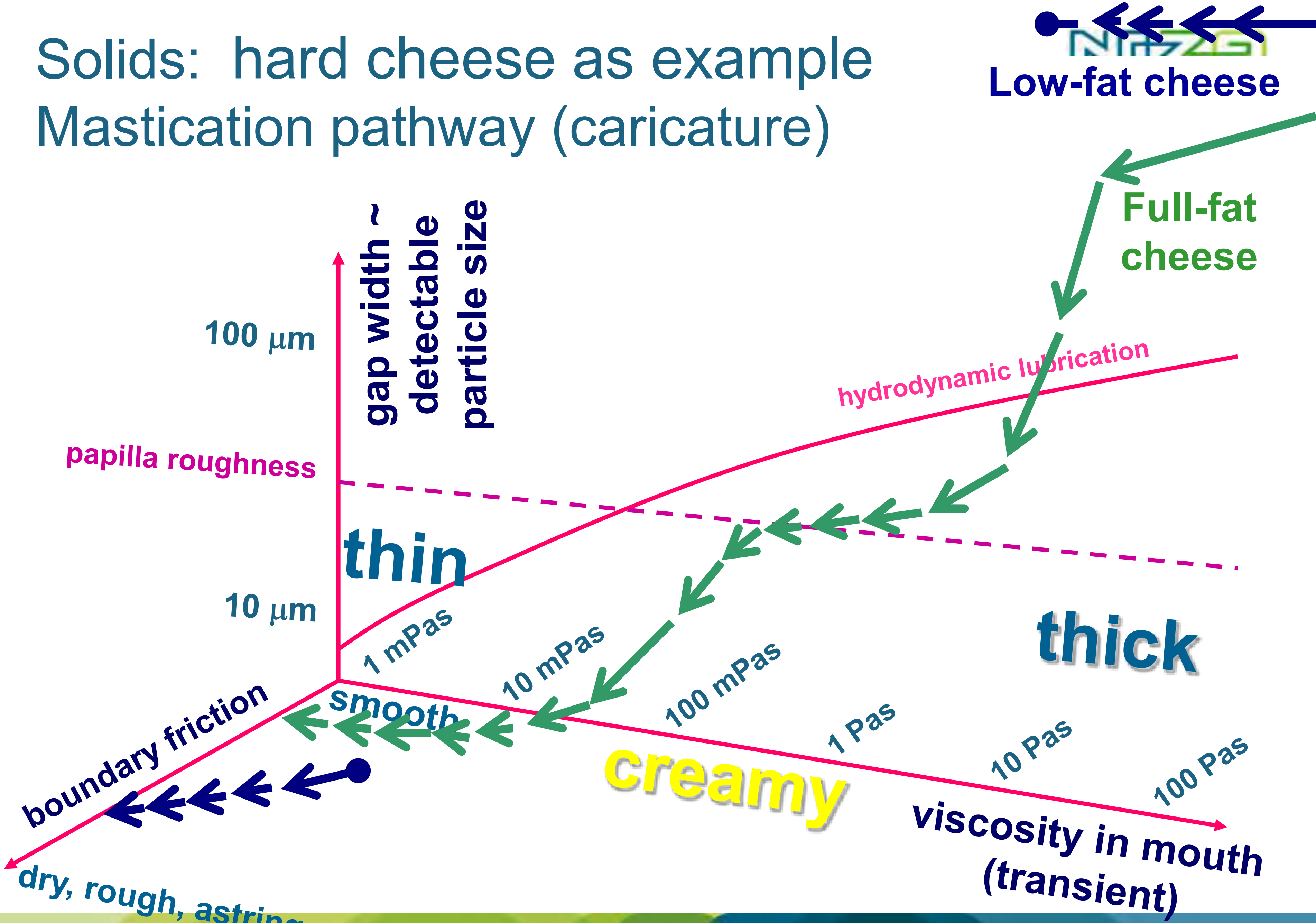
separation

Slowly hydrating dense cheese particles



Thin dilute emulsion of small droplets

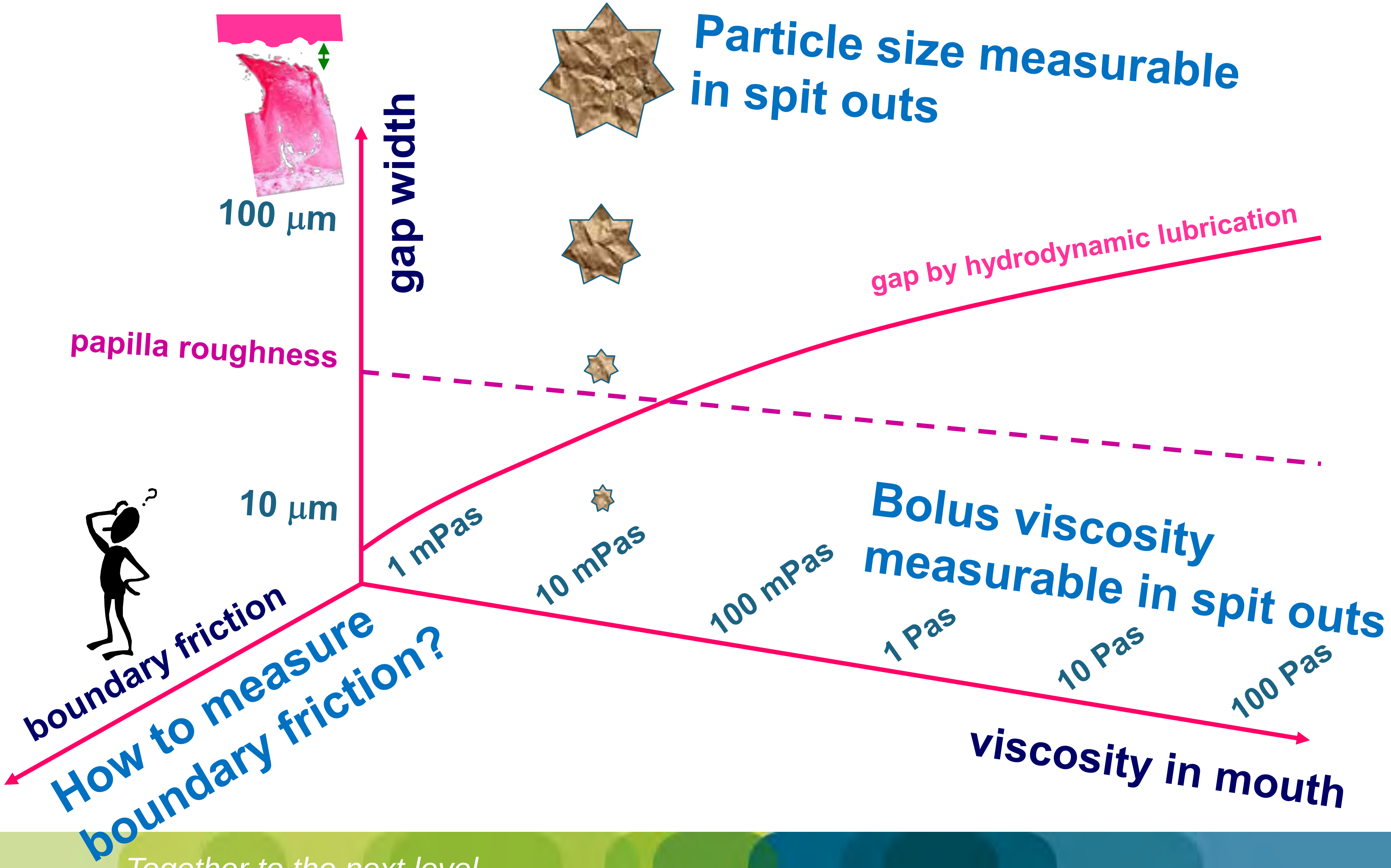
Solids: hard cheese as example
Mastication pathway (caricature)



Thickness
Grittiness
Astringent

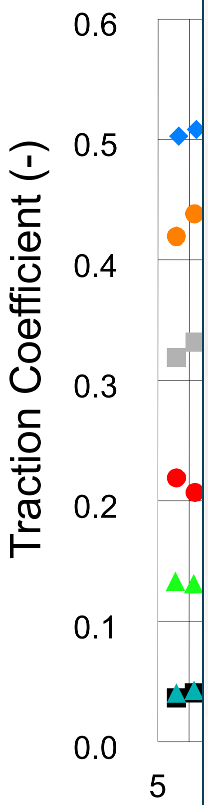
PHYSICAL MEASUREMENT

Tactile perception of a fluidic food bolus



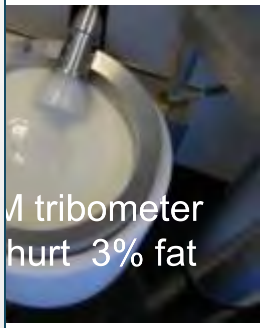
Liquid and soft semi solids: tribological studies

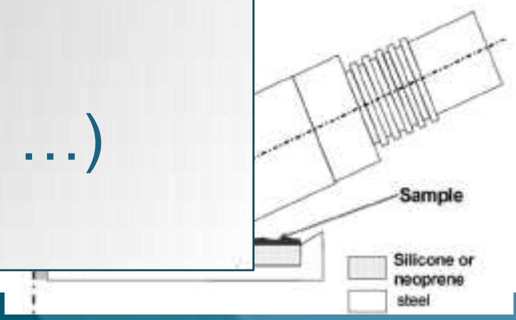
Els de Hoog
Hans Tromp



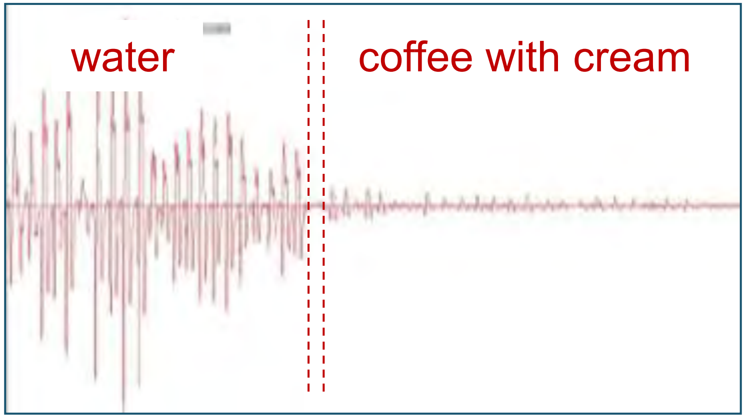
?

- Which speed?
- Which load?
- What about the interaction with saliva?
- What about the actual oral surfaces?
    - Papillae
    - Mucous epithelial layer
    - Variability (individuals, pre-meals, …)

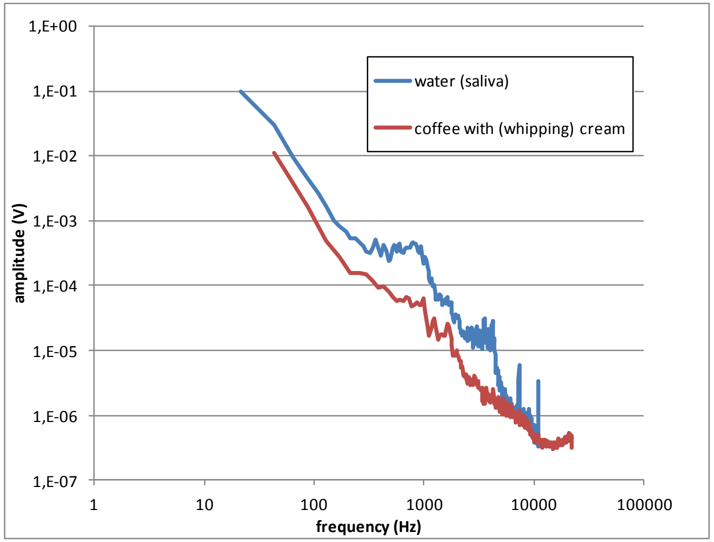




(NEW)
Acoustic emission measurement
of the *in vivo* scraping sound of the tongue



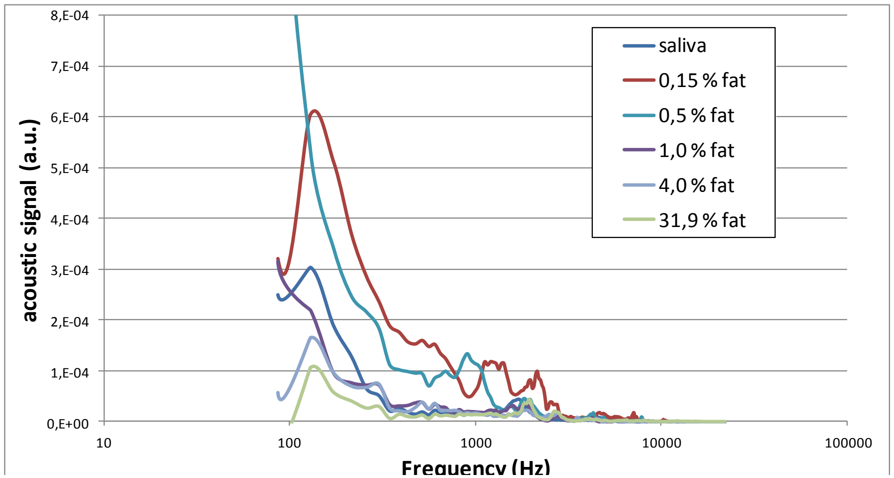
Line voltage as a function of time

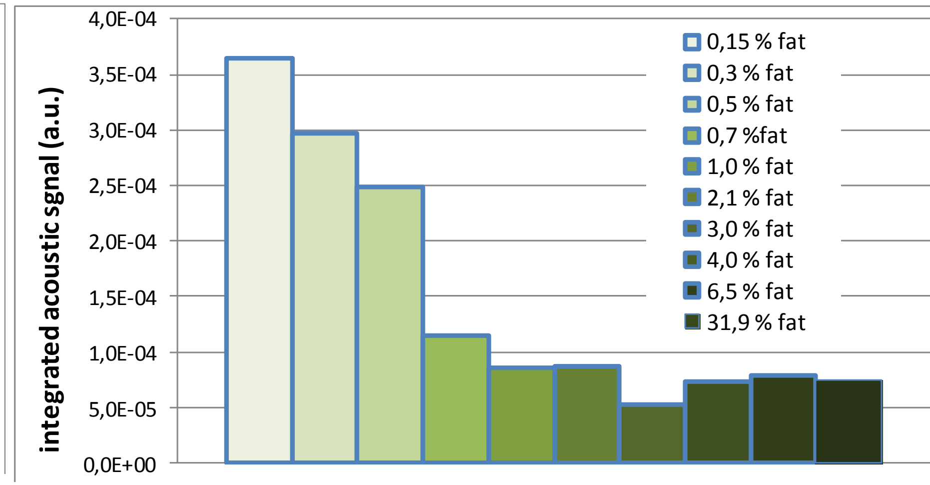


Corresponding frequency spectrum of the cleaned signal

Example: Water - coffee with (whipping) cream

Fat content of milk



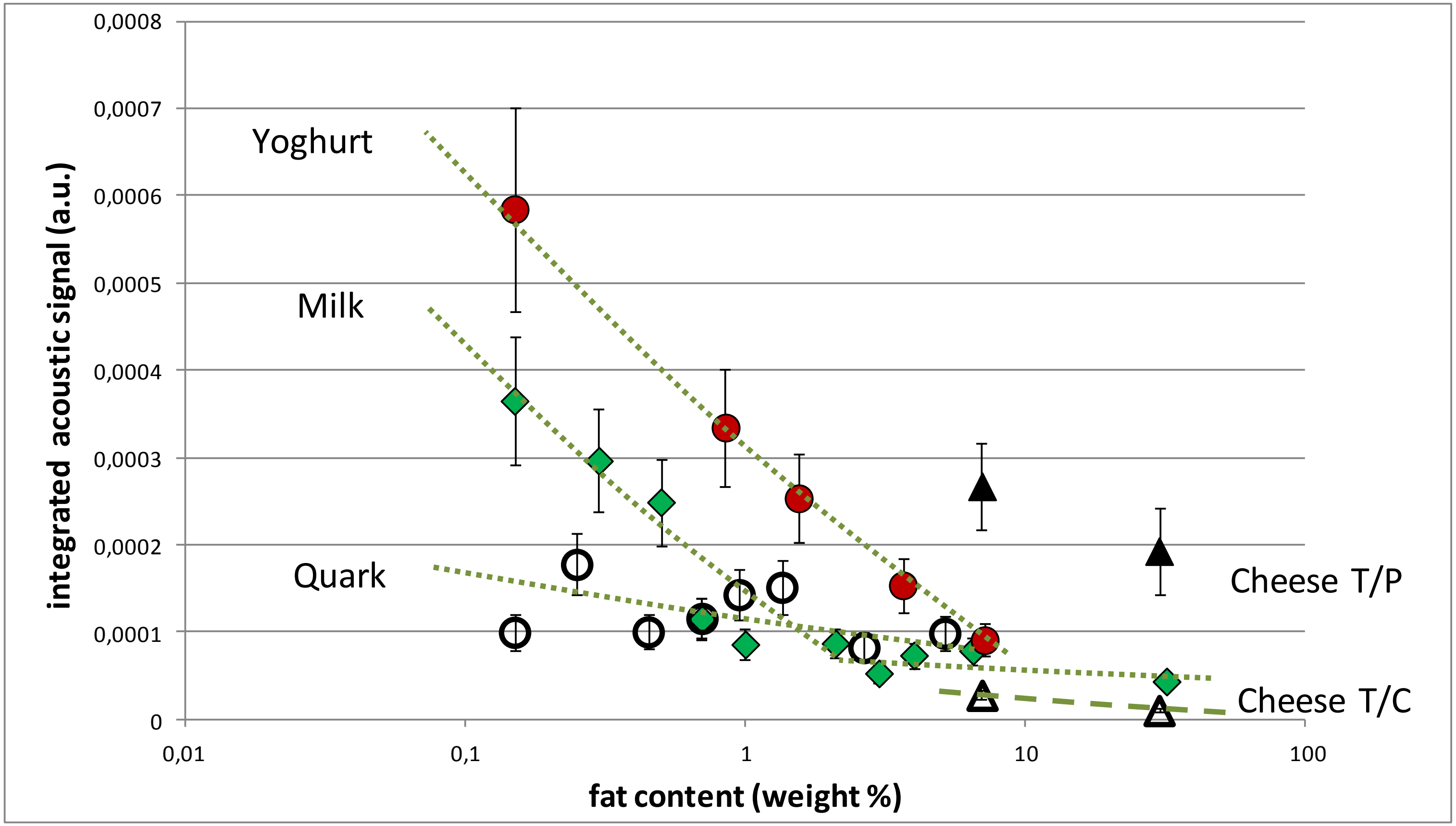


Interpretation:

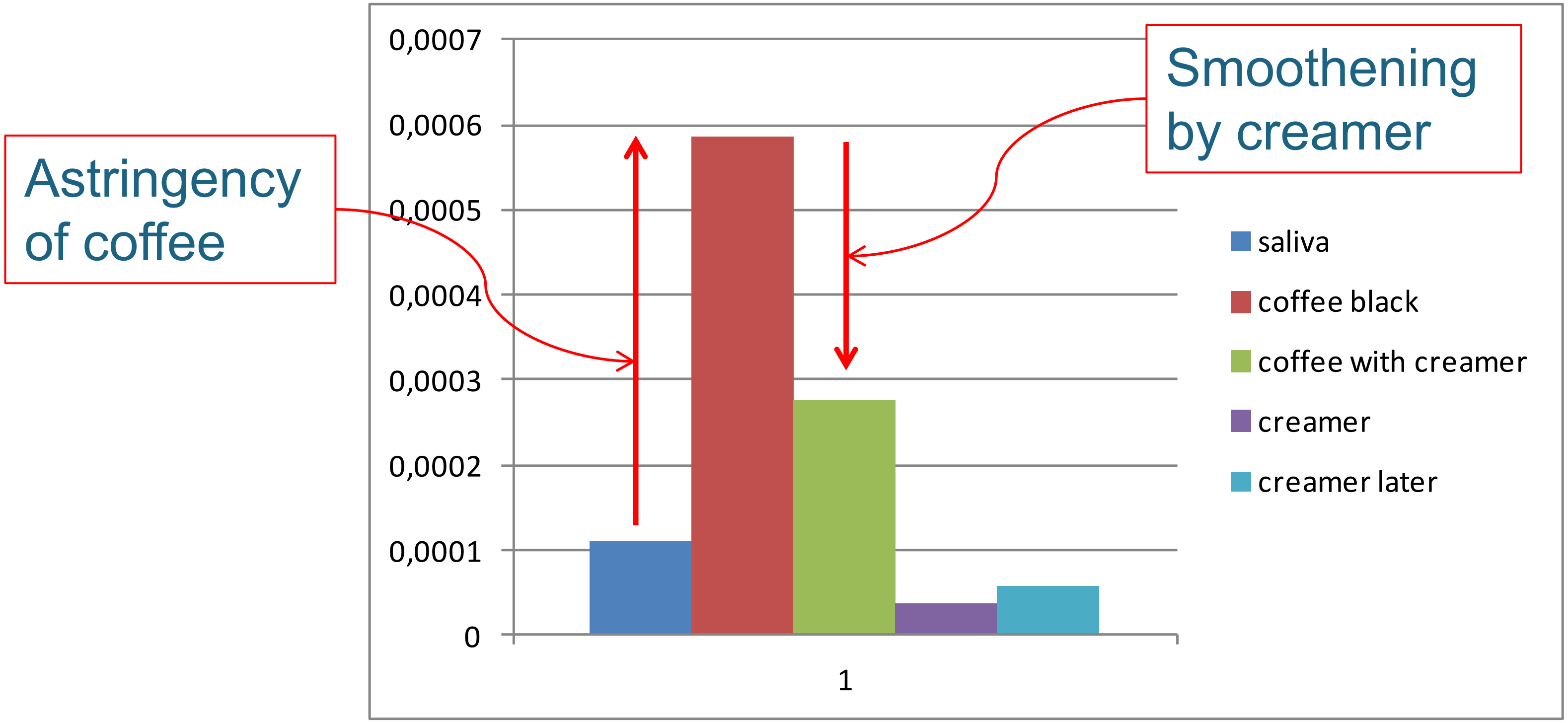
- tongue friction increased by milk protein (not observed by conventional tribology), but is reduced in the presence of emulsified fat
- translates to: skimmed milk more rough/dry/astringent than saliva, but milk fat emulsion makes it smoother by improving lubrication

Together to the next level

Comparison between dairy products



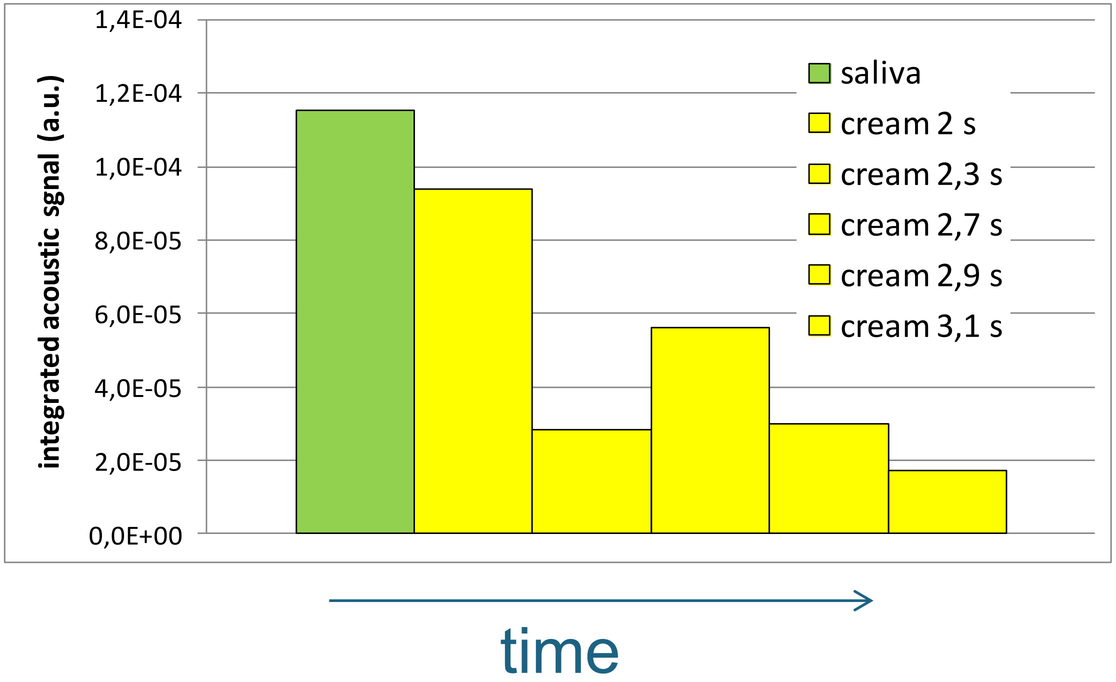
Effect of half-fat creamer on coffee



Astringency of coffee: acidity and phenolic compound bind the lubricating salivary mucins,

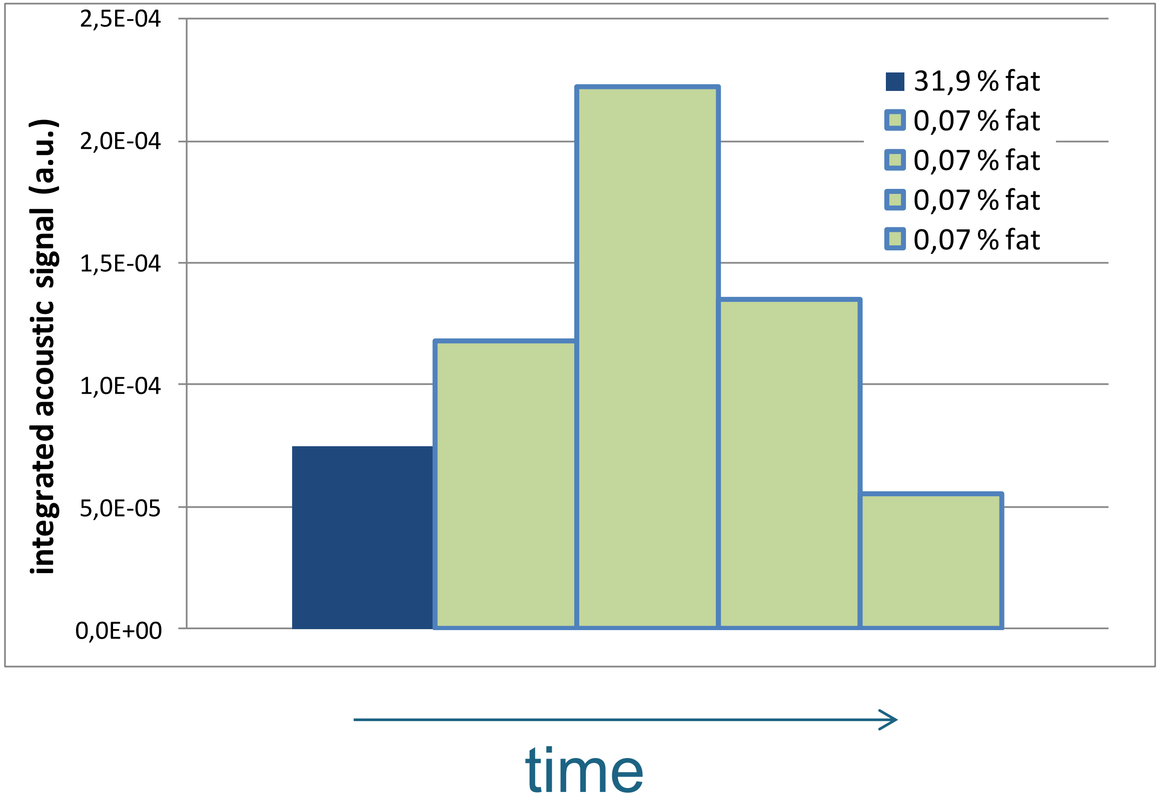
Kinetics

system: cream after saliva



Observed are the effects of inhomogeneous mixing and finally a replacement of native mucosal layer by a lubricating fat layer

Kinetics
system: skimmed milk after cream



Observed are the effects of replacing the lubricating fatty coating with milk protein, followed by wear of the asperities on the papilla surface

Applications acoustic tribology

- Measurement tool for rough/astringent mouthfeel
    - Low fat products
    - Astrigent products
    - High protein products
- Measurement tool for surface textures
    - Fabrics, wood, etc.
    - Good-grip surfaces
    - Non sweaty, non sticky

Publication in preparation

CONCLUSIONS

Conclusions

- Sensory food properties are often not directly related to food properties “on the shelf”

- Sensory food properties can be much better related to the food properties in the mouth, which change during mastication.
- A toolbox is available for accessing the effects of mastication and sensory correlation.

Creating the future together

Together to the next level