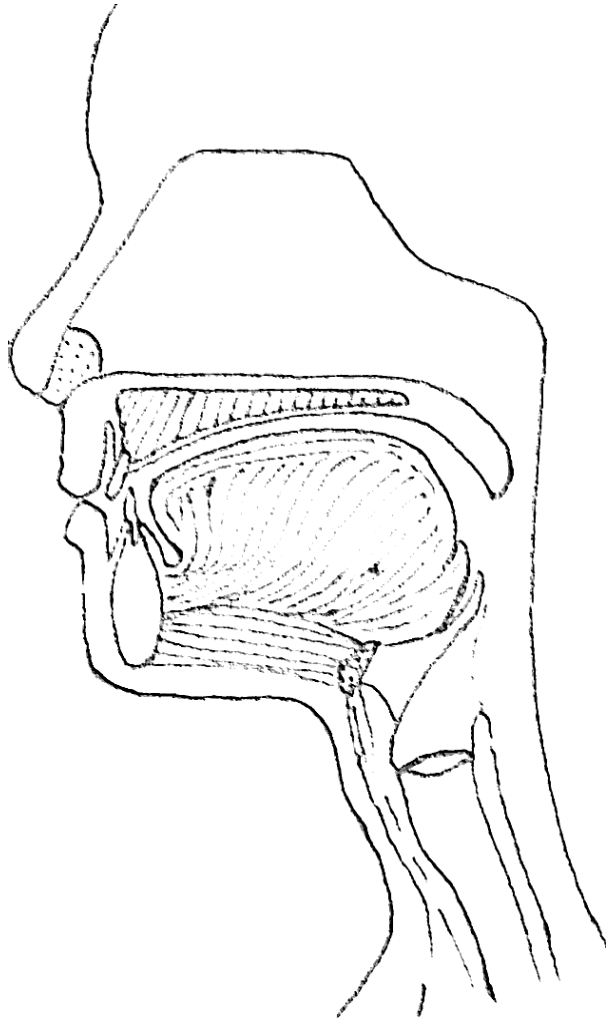
13th International Workshop on Molecular and Physical Gastronomy

Consistencies and Textures

Potential of a newly developed biomimetic setup to better integrate the kinematic, mechanical and surface characteristics of tongue in oral tribological studies of foods



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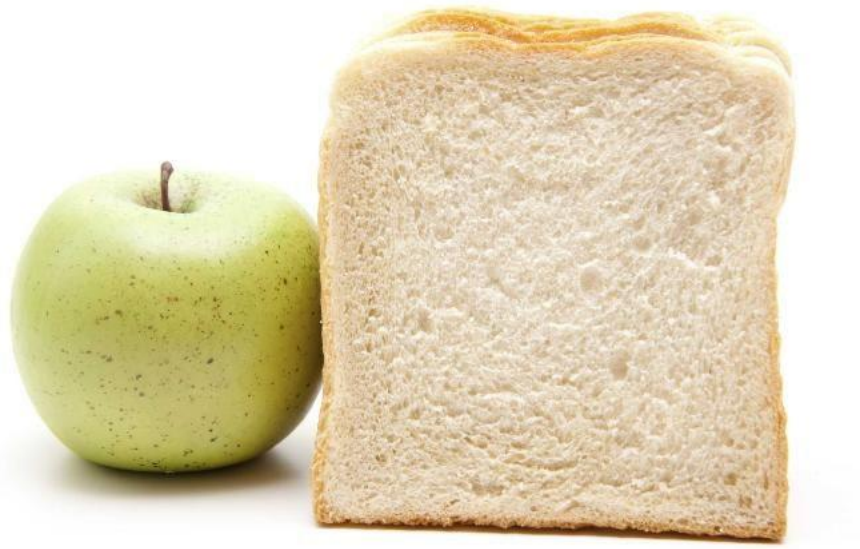
Food texture

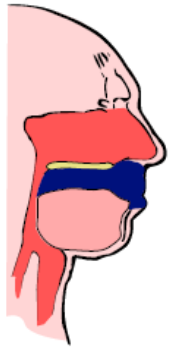
All the rheological and structure (geometrical and surface) attributes of a food product perceptible by means of mechanical, tactile, and where appropriate, visual and auditory receptors’

(ISO, 2008)



Food Oral Processing

Food oral processing is an essential physiological procedure for consumption and digestion of food.



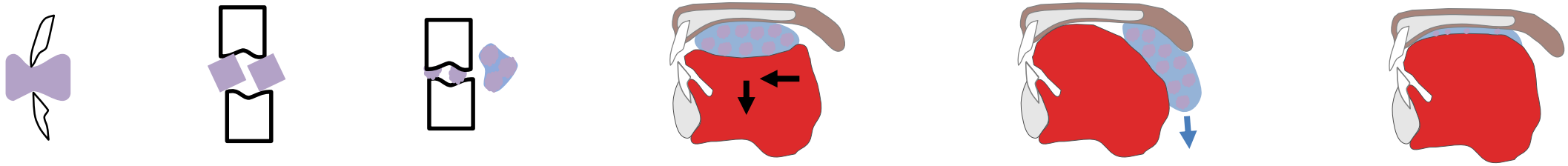
Palatable ?

Tongue Palate Compression + Mastication

Swallow

Not suitable for Swallowing

First Bite | Mastication | Granulation | Bolus formation | Swallowing | Residue



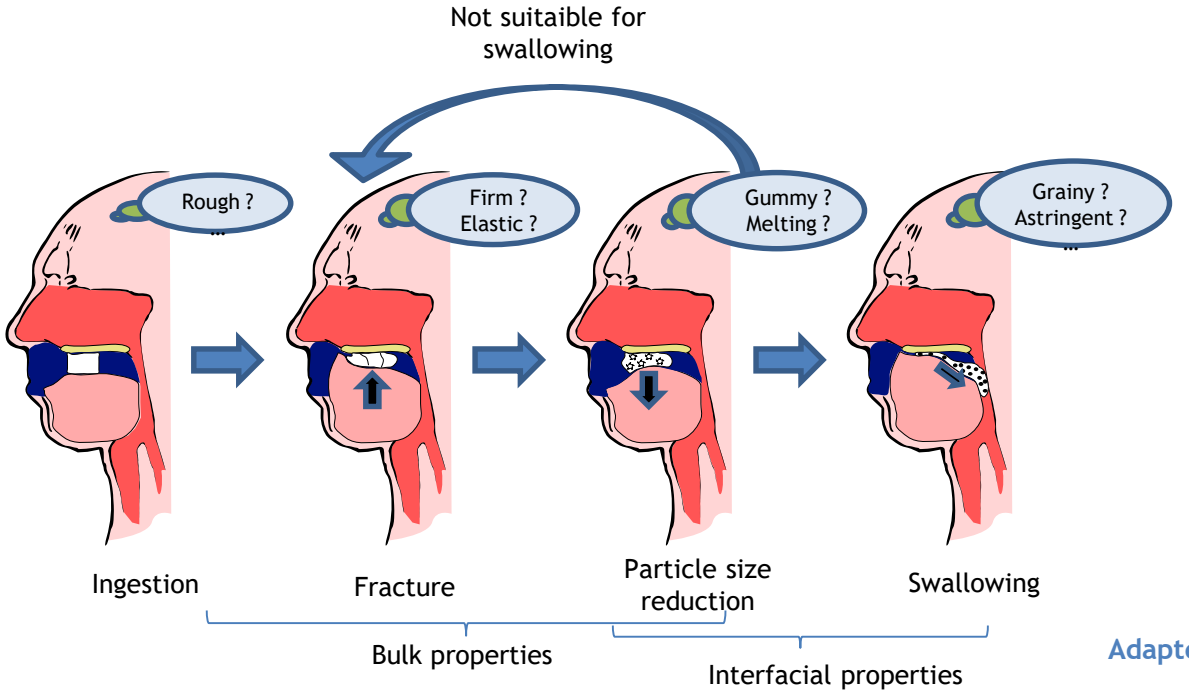
Mechanics

Tribology

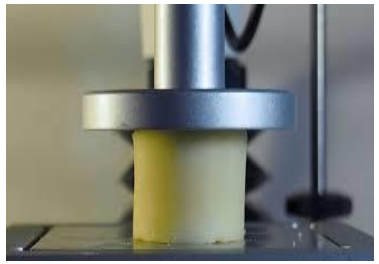
Rheology and tribology

Adapted from Stokes et al, 2013

Dynamics of texture perception

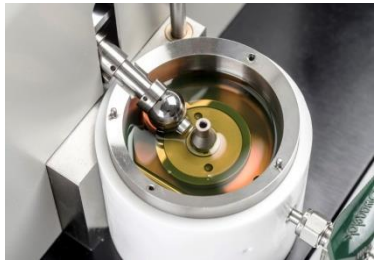


Adapted from Stokes et al.(2013)



Texturometer

Rheometer



Tribometer

4

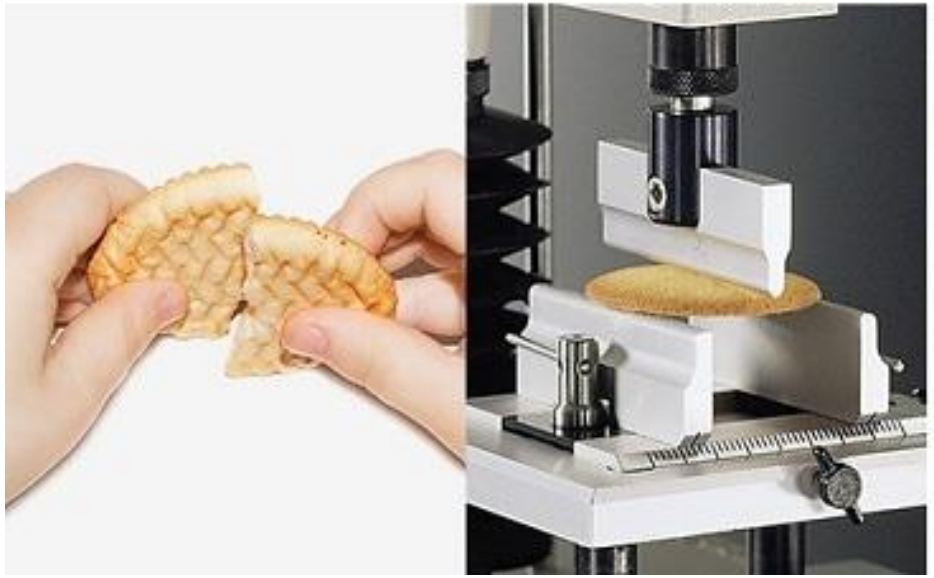


Image: Stable Micro system

D.P. Bolhuis and C.G. Forde

Trends in Food Science & Technology 106 (2020) 445–456

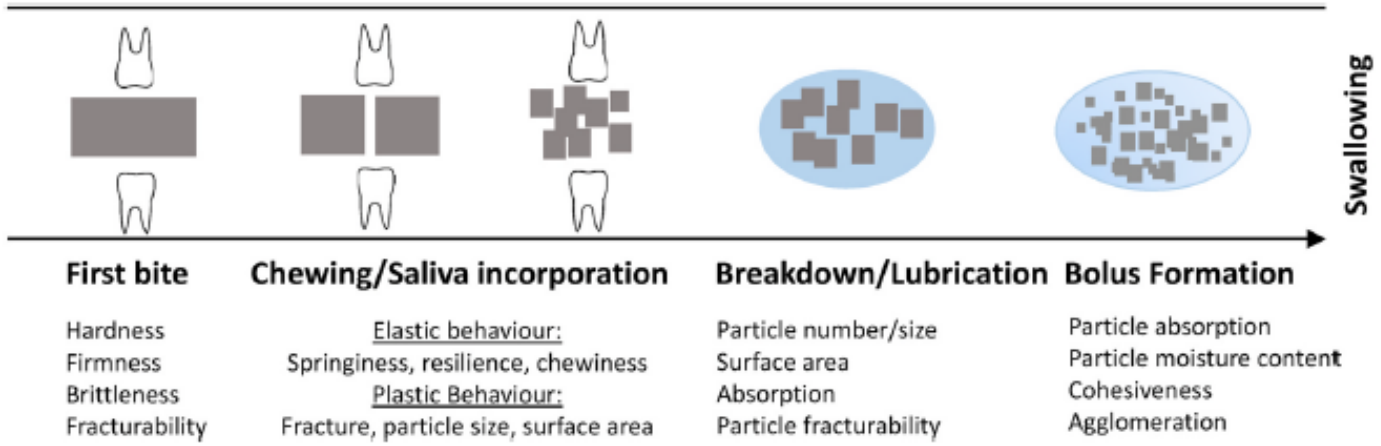


Fig. 1. Illustration of subsequent stages of food breakdown from first bite until swallowing.

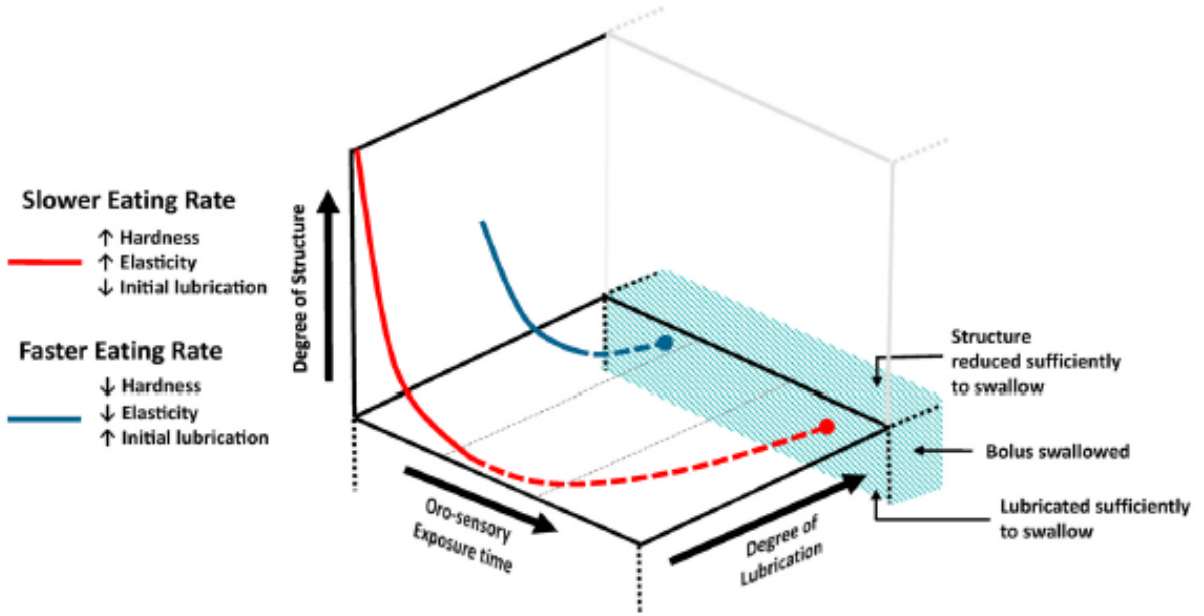


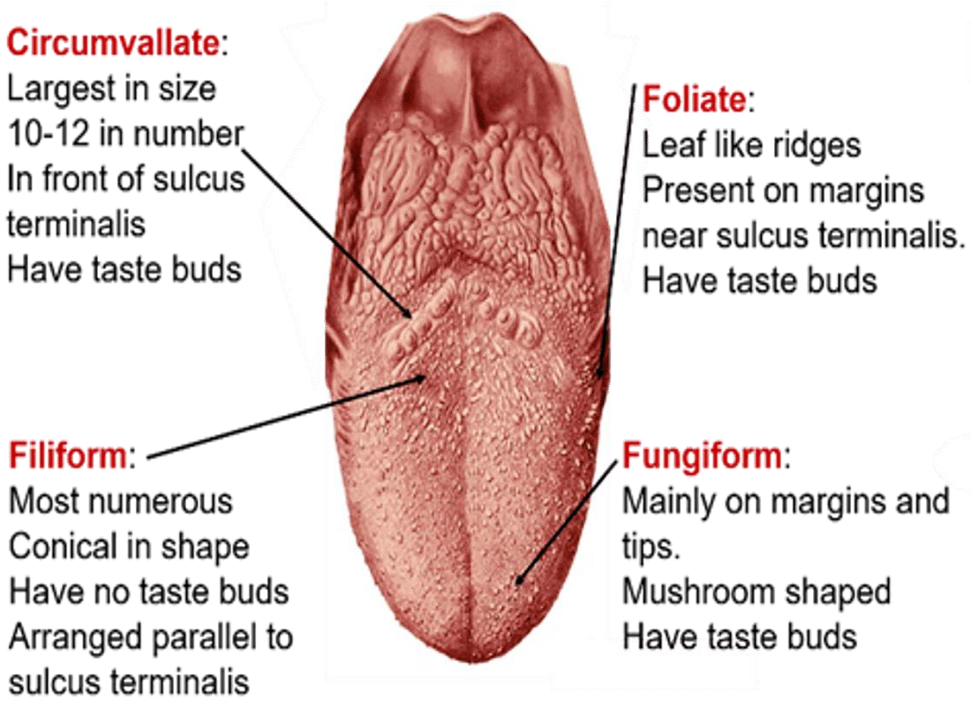
Fig. 2. Food oral breakdown pathway (Adapted from Hutchings and lillford, 1988)) illustrating faster and slower eating in response to changes in elasticity, hardness and lubrication. In this hypothetical example, the food lower in hardness and elasticity and higher in initial lubrication is processed more quickly into a bolus that is safe to swallow which result in a faster eating rate.

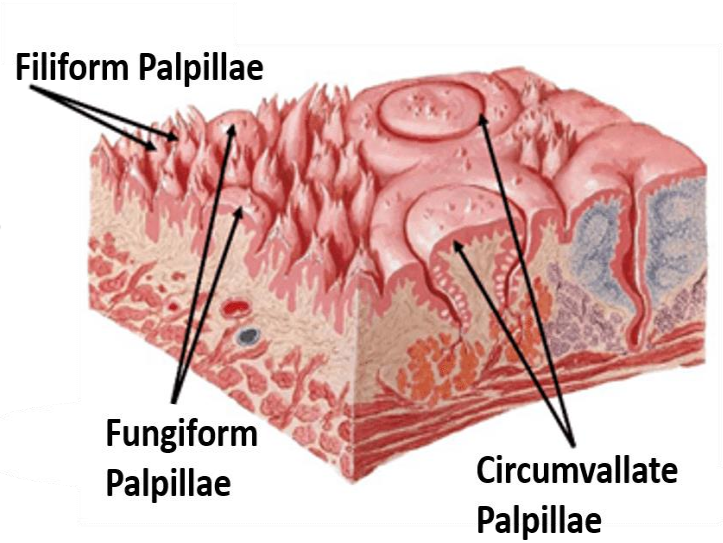
Role of tongue

- 8 muscles
- E ~ 10 kPa (“relaxed”)
- E ~ 120 kPa (“contracted”)

Ishihara et al, 2013

Topography





Role of Saliva

Roughness: 10 µm <papillae height <110 µm

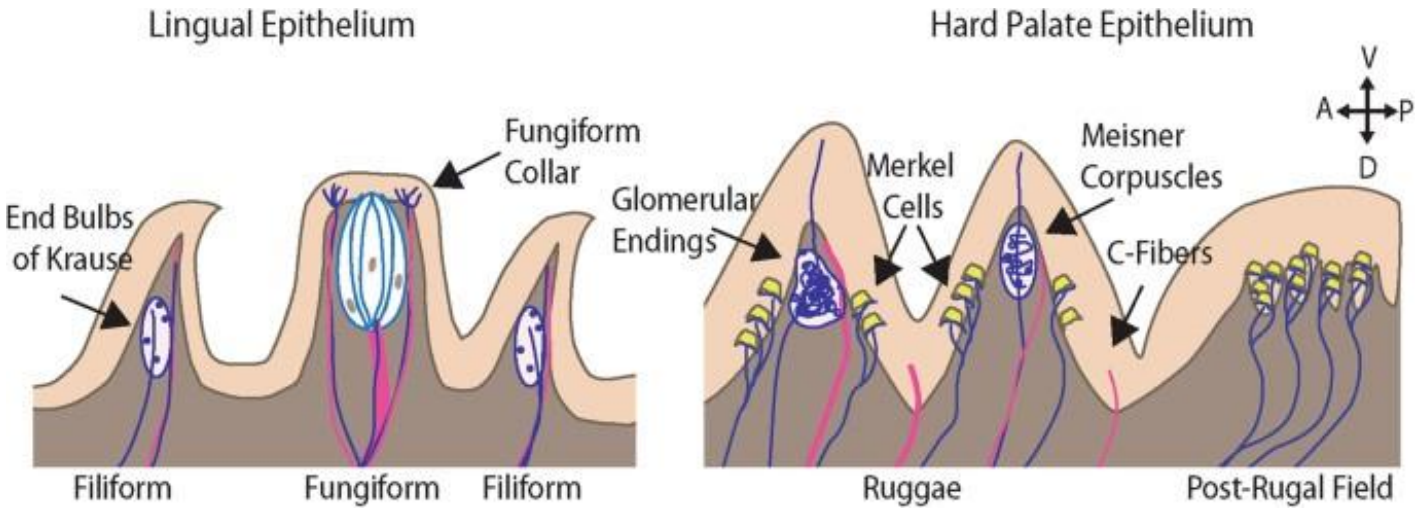
Uemori et al, 2012; Nagaoka et al, 2001

Papillae width: Fungiform: 878 ± 97 µm Filliform: 355 ± 40 µm

Andablo-Reyes et al., 2020

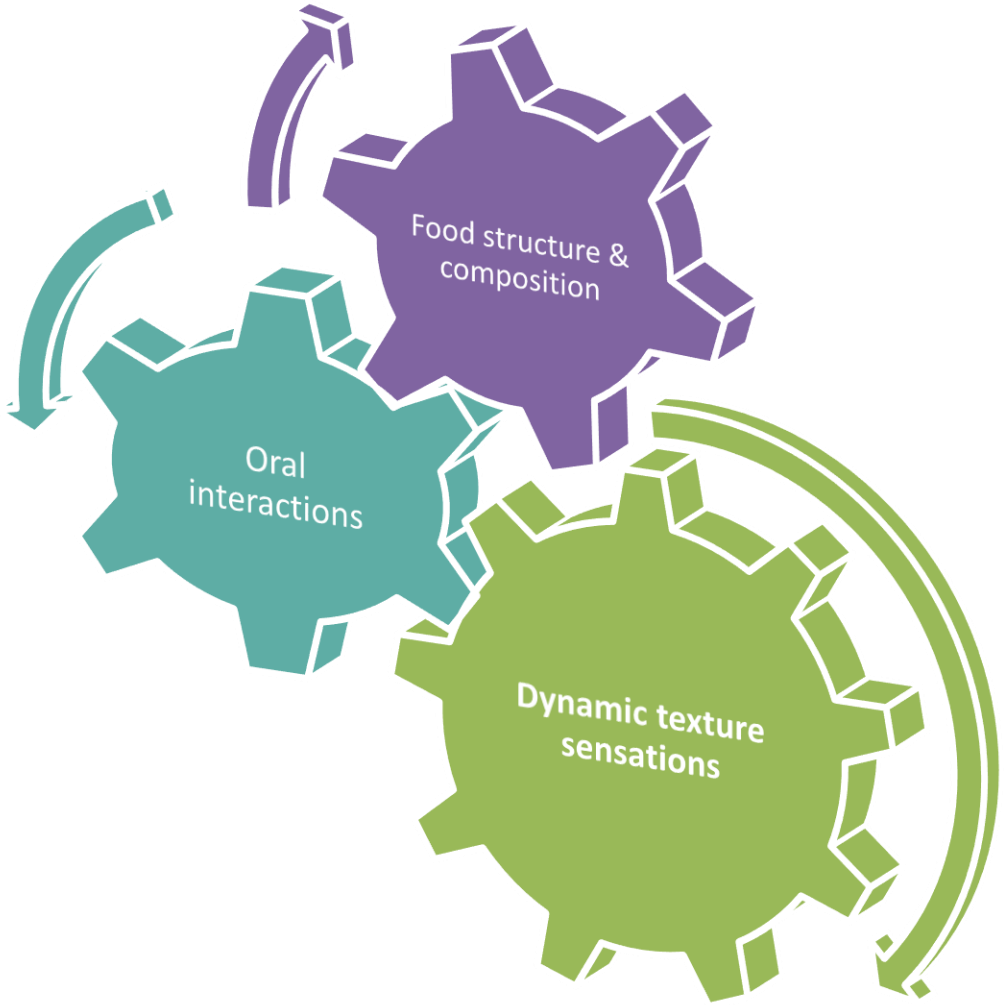
Mechanoreceptors

3 types of mechano-receptors
(static or dynamic stimuli)



Slow adapting and rapid adapting

Haggard and de Boer, 2014


Food structure & composition
Oral interactions
Dynamic texture sensations

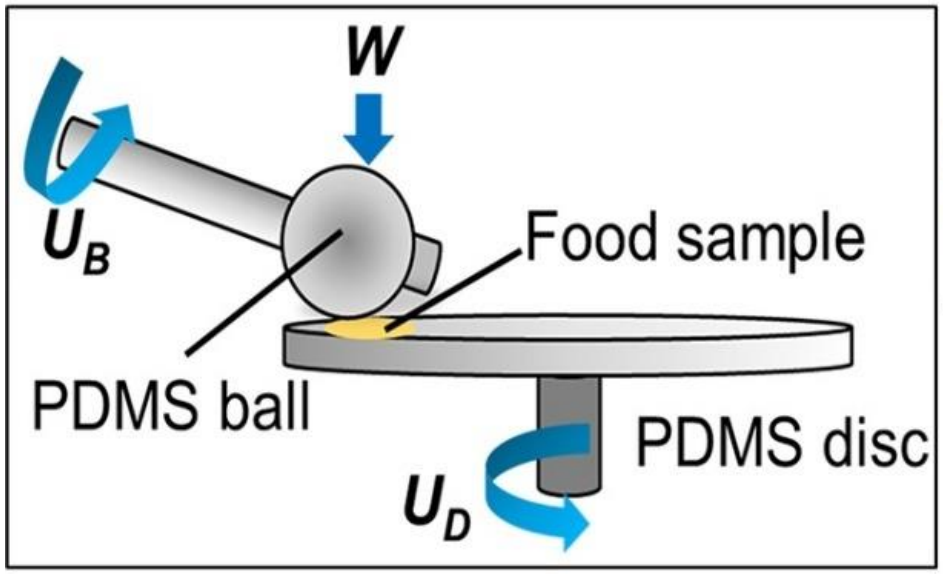
Why is it Important ?

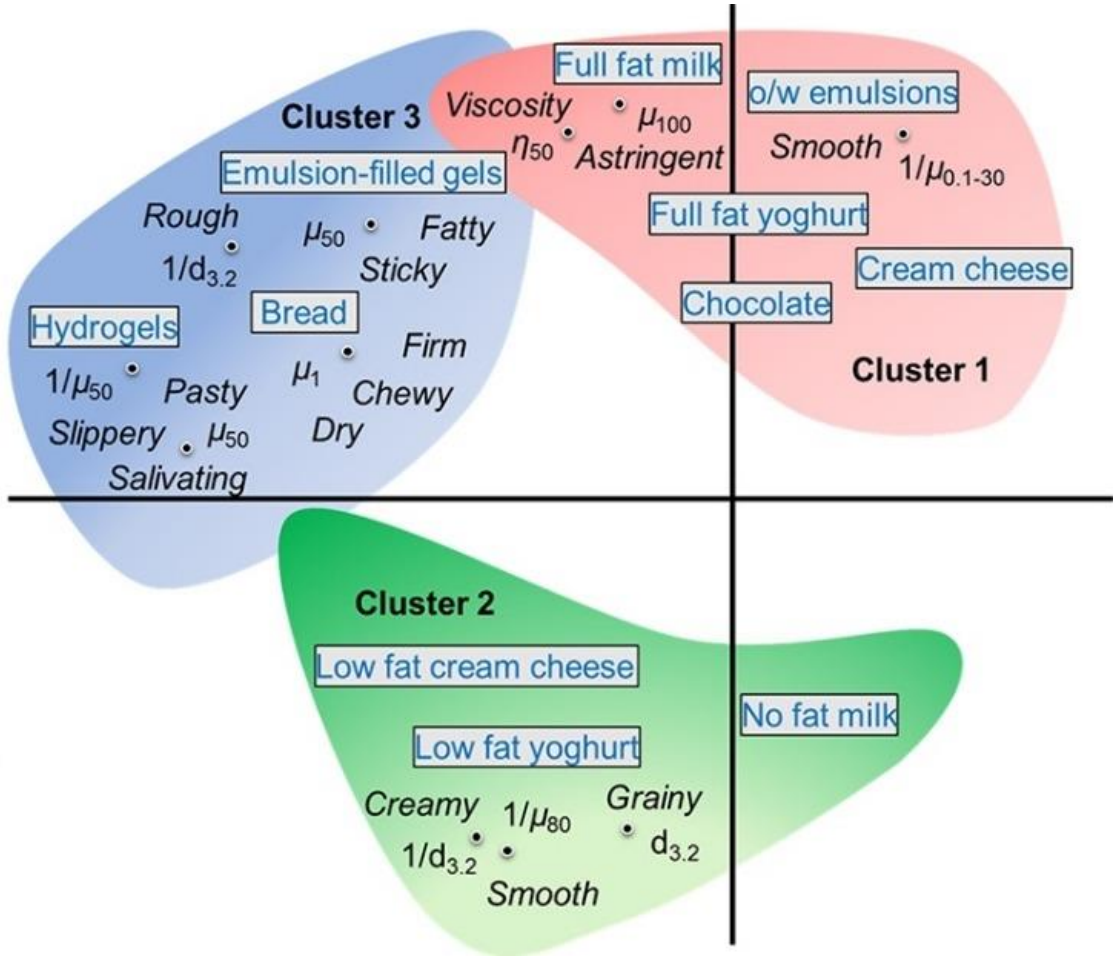
To better understand and model consumer's overall sensorial perception of food, it becomes important to map the dynamics of texture perceptions .

This will help us to design food for specifics consumers; such as

- Different populations around the world
- Elderly
- Infants
- People with special needs (Dysphagia; loss of perception of texture due to chemotherapy etc)

Tribology and texture perception





Batchelor et all, 2015

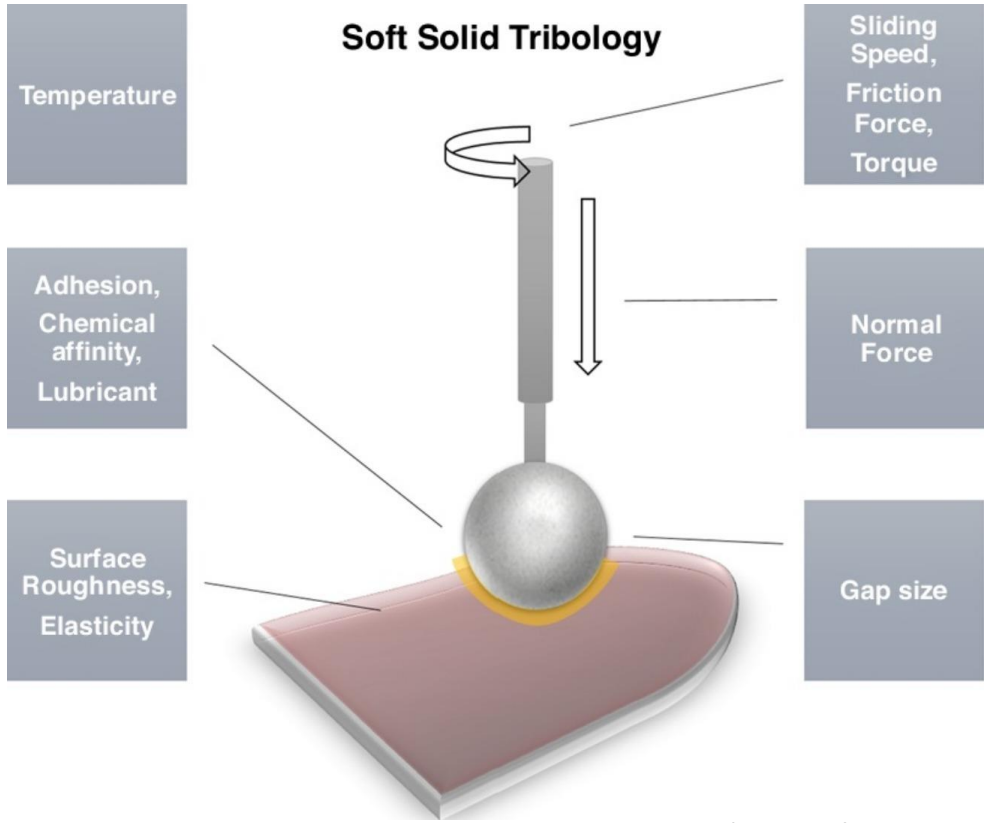
Tribology is a system property

Pradal and Stokes (2016) have rightly said that tribology is a system property, it depends collectively on:

- **Measurement system**
ball-on-disc/pin-on-disc, sliding/rolling/mixture of the two)

- **Surfaces**
(soft/hard/viscoelasticity, hydrophilic/hydrophobic and rough/smooth)

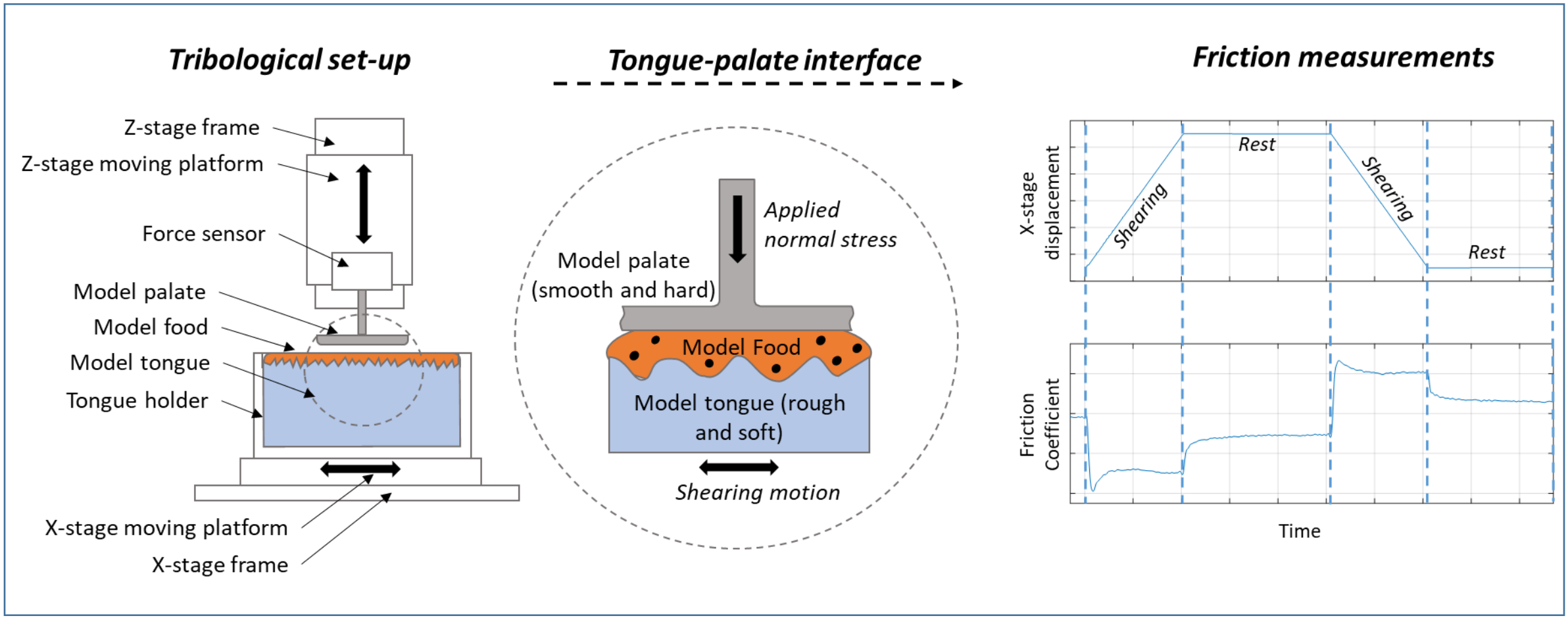
- **Lubricant (food)**
Rheology and heterogeneity, which includes the presence of particles, droplets, air, and surface active ingredients.



Rudge et al, 2019

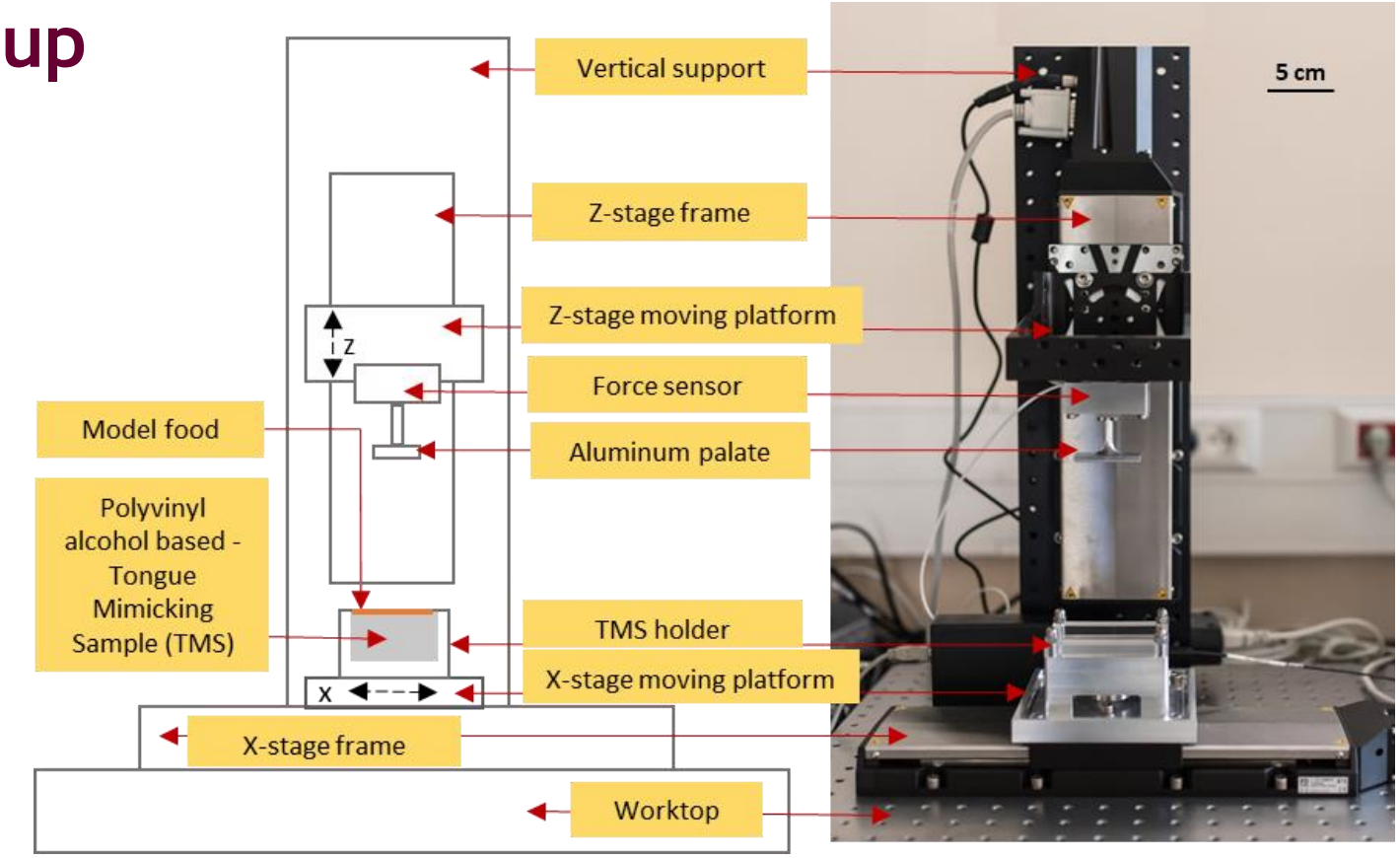
Need for a physiologically relevant system

Conceptualization



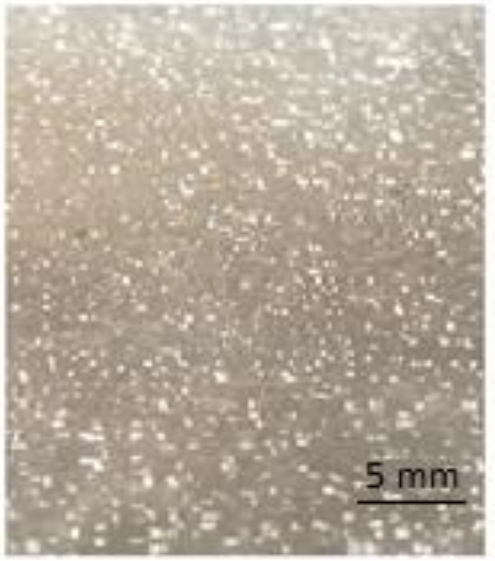
Srivastava et al, 2021

Setup



Srivastava et al, 2020

Conceptualization of artificial tongues



- PVA (Polyvinyl alcohol) is a polymer that forms a hydrogel on freezing.
- The rigidity of the hydrogel can be regulated by controlling the freeze-thaw cycles.

Model Food

Cottage Cheese
(Diluted in water: 50% w/w)
(Yoplait, Calin Extra 0%)

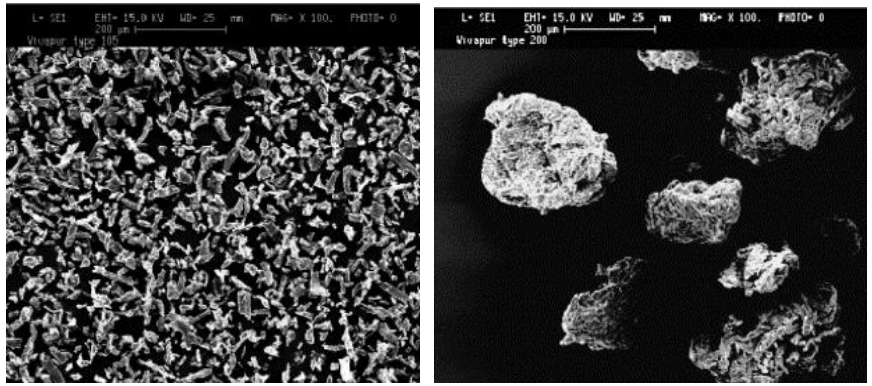
+

Particles
(VIVAPUR®)

=

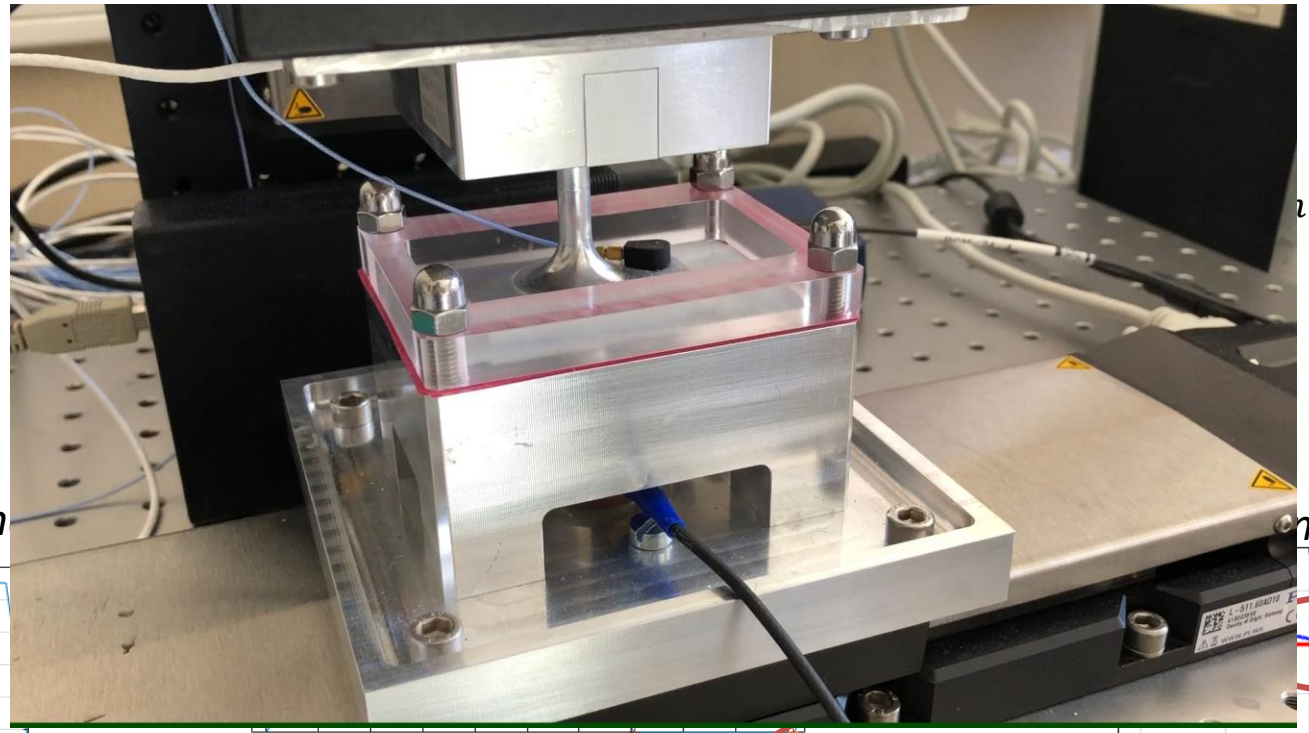
Particle Suspensions

VIVAPUR®	
COMPOSITION	Microcrystalline Cellulose
SHAPE	Heterogeneous
SIZE	15 and 250 µm



Scanning electron microscopy of Vivapur samples at 100 x magnification. Left: Vivapur 105 (small particle used in this thesis, 15 µm); Right: Vivapur 200 (large particle used in this thesis, 250 µm); Di Martino et al. (2004)

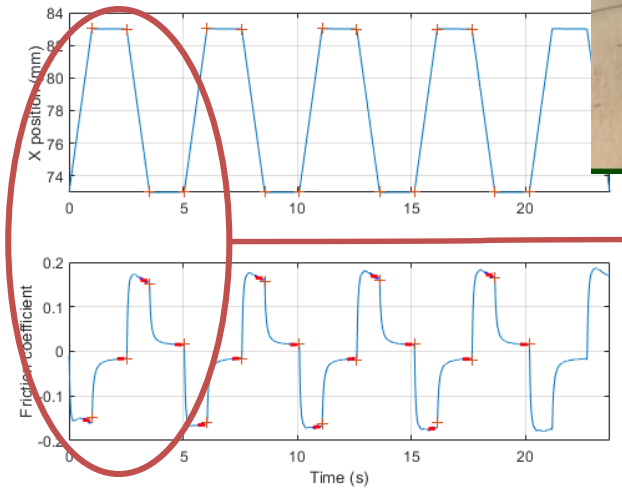
Friction measurement

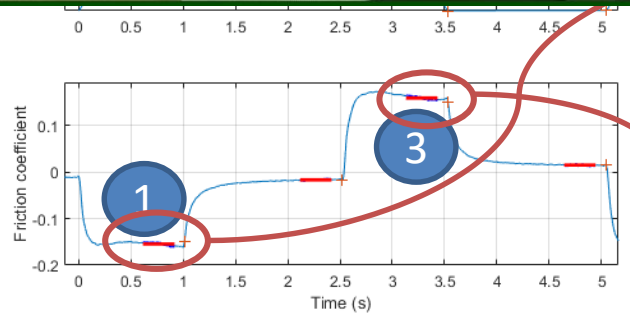


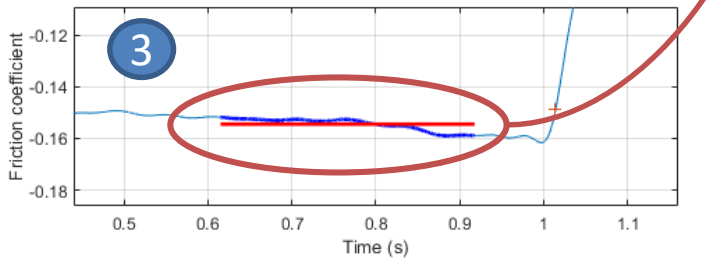
$(1) + f_{mean}(3))$

Example of a full sequen

ng on specific windows

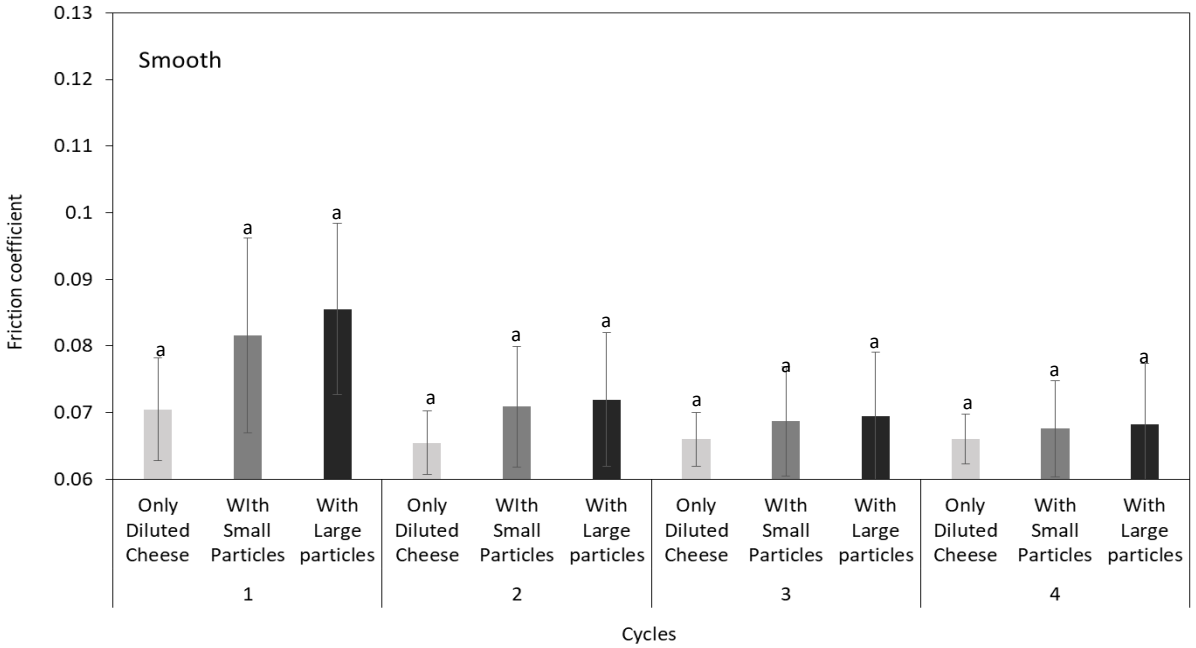


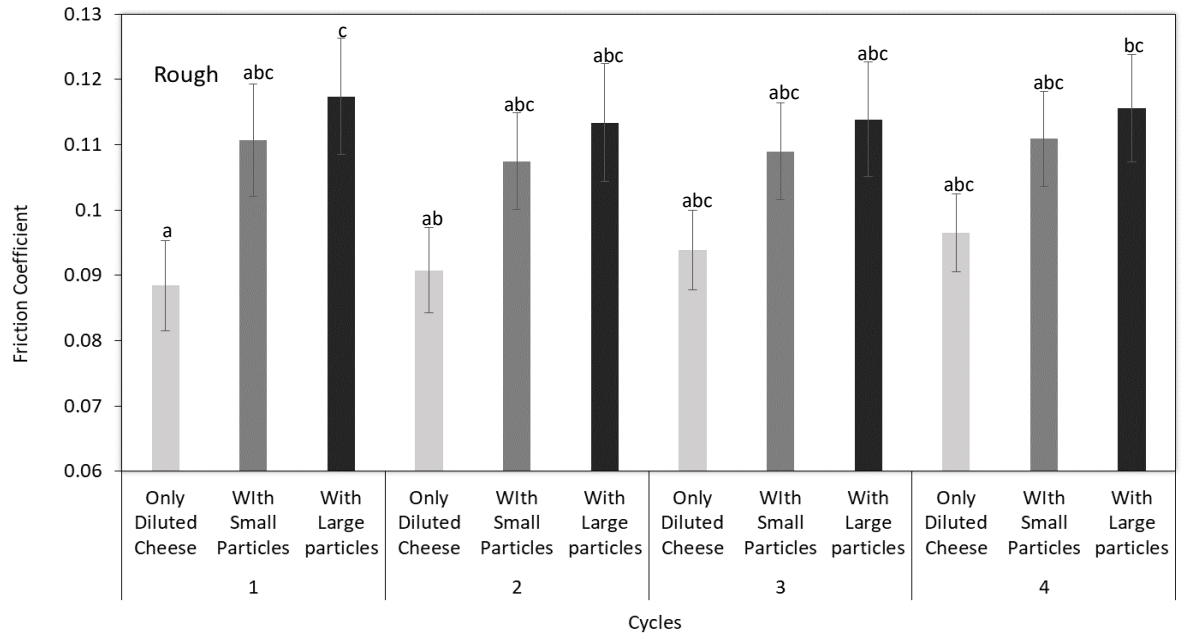




Effect of surface roughness

Rough tongue mimics (50.17 ± 1.46 kPa)
Normal stress: 9 kPa; Shearing velocity:10 mm/s





An evident impact of surface roughness on friction coefficient values (p-values < 0.0001 for rough vs. soft).

- *On rough surface, friction coefficient remains stable w.r.t shearing cycle*

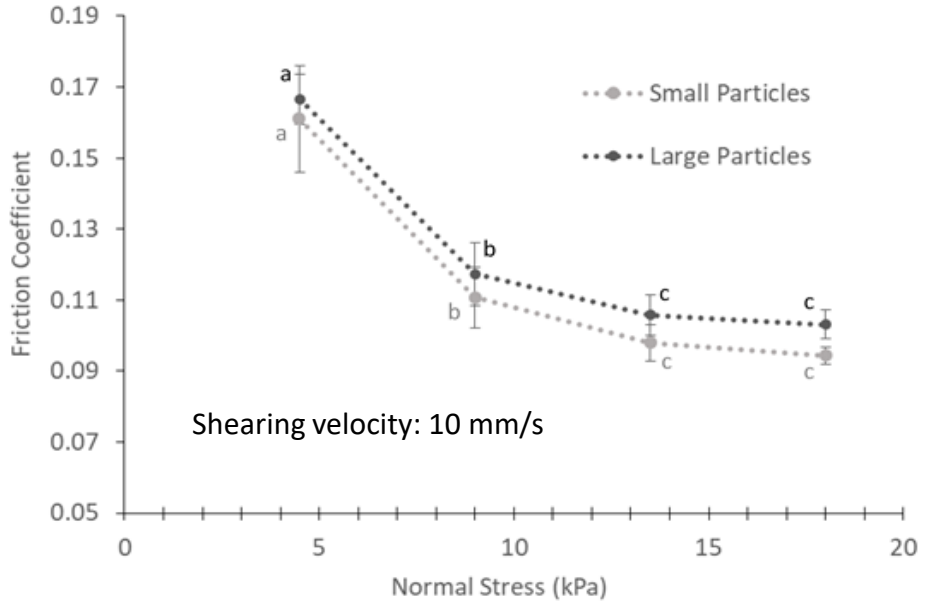
(Effective spreading of cheese on the rough surface under applied normal stress)

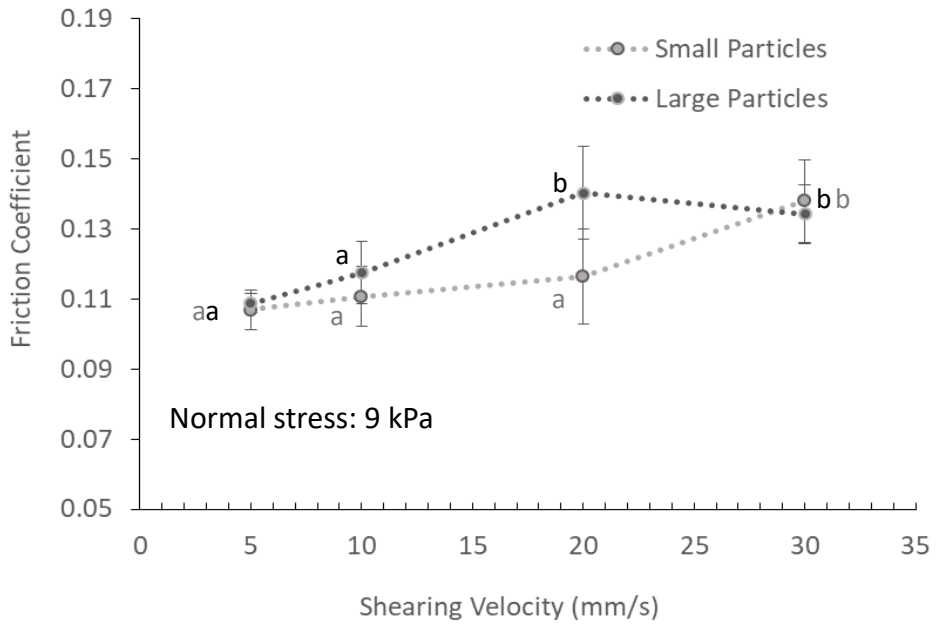
Could there be are certain combinations of operational parameters and tongue properties that could better segregate the particle size ?

Srivastava et al., 2021

Variation of operational parameters

Rough tongue mimic (50.17 ± 1.46 kPa)





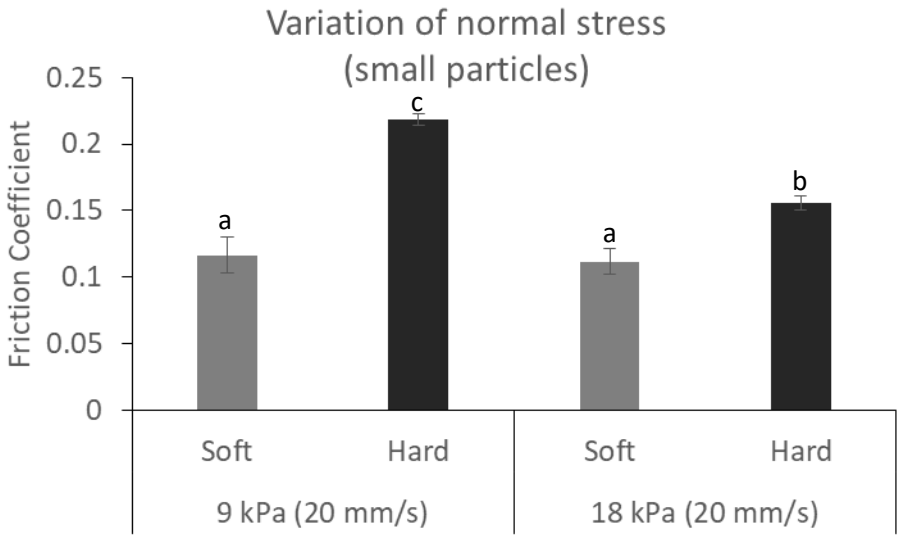
The friction coefficient shows dependency on the operating parameters like normal stress and shearing velocity.

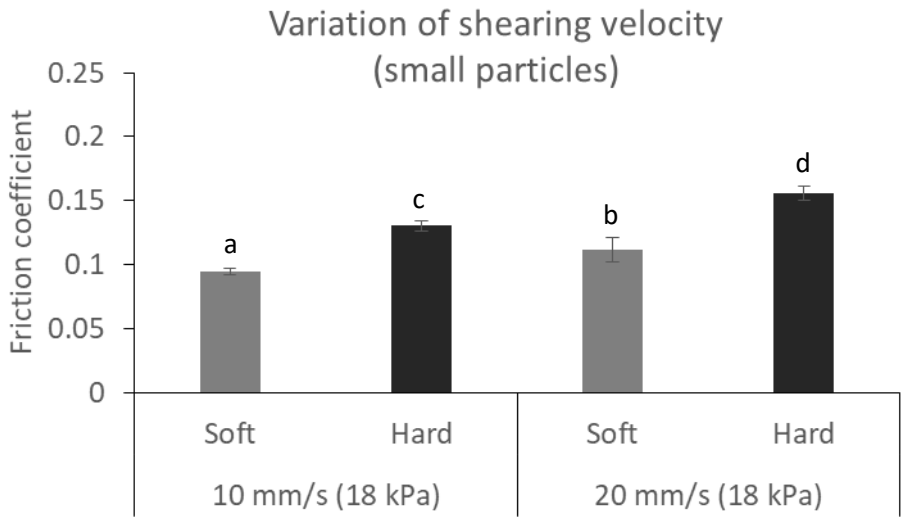
However, to concretely identify the tribological phenomenon a complete Stribeck curve is required, and which will need testing more varied conditions.

Srivastava et al., 2021

Variation of tongue rigidity

Rough tongue mimics (soft: 50.17 ± 1.46 kPa; hard: 100.78 ± 2.12 kPa)





An evident impact of tongue rigidity on friction coefficient values: higher for hard tongue mimic

- *Decrease in friction coefficient with increase in normal stress*
- *Increase in friction coefficient with increase in shearing velocity*

Srivastava et al., 2021

In conclusion

- **This oral tribological set-up was successfully developed to achieve more realistic oral conditions for investigating friction mechanisms**

- **Connections between friction coefficient and Tongue properties (surface roughness and rigidity)**
  - Friction coefficient values were higher on the rough surface
  - Friction values were higher on hard tongue mimic; variation of normal load and shearing velocities were also prominent.

- **Future developments**
  - Building complete Stribeck curve
  - Looking into the relaxation part of the motion
  - Set-up itself can be modified to perform more realistic motions (e.g., oscillatory, translational) and to allow more robust control and automation

Thank you for your attention

Vincent Mathieu
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Paul Menut
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David Forest
Johana Guyader
Bertille Dormoy
Clara Ajamian