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# Quantitative ultrasound to explore tactile perceptions of food elicited by tongue-palate friction: a biomimetic approach

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## > Unravelling the mechanisms of texture perception

Towards the development of innovative methods in physiologically relevant environments

- Tongue has a central role in texture perception of food
- Mechanoreceptors with varied ranges of sensitivity (amplitude & frequency)
- Critical needs :

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- Physiologically relevant testing environments
- Original techniques to monitor the mechanical interactions between the tongue, the food and the palate
- What about the potential of Ultrasound methods ?

Let's see what we can get from them on a tongue-palate biomimicking testing bench...



#### > Tongue palate biomimicking system



- Contact area : 45 x 25 mm<sup>2</sup>
- Imposed initial normal load : 10 N (around 9kPa)
- 5 cycles of shearing motions : Amplitude 10 mm; Velocity 10 mm.s<sup>-1</sup>





#### > Tongue palate biomimicking system



🔁 STLO

#### > Tongue mimicking surfaces

Design and characterization of 6 tongue mimicking surfaces (TMSs)

- 10% w/w Polyvinyle Alcohol cryogels
- Young's modulus : ~30 kPa
- US speed of sound : 1540 m.s<sup>-1</sup>
- Varied roughness

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#### > Lubricants

Preparation of 6 mixtures of water and glycerol

- Newtonian fluids
- Covering a wide range of viscosity

Solutions labels	G <sub>0</sub>	G <sub>50</sub>	G <sub>85</sub>	G <sub>93</sub>	G <sub>97</sub>	<b>G</b> <sub>100</sub>
Concentration (% w/w)	0	50	85	93	97	100
G <sub>0</sub> G <sub>100</sub>						

Pure water

Pure glycerol









#### Signal processing of ultrasound signals >

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Detecting & monitoring the time-of-flight of tongue-palate interface.



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## > US time-of-flight as a marker of lubrication regime

Two contrasting cases

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- Mixed regime :
  - longer static friction phase
  - higher friction amplitude
  - higher variations in normal force

## > US time-of-flight as a marker of lubrication regime

Two contrasting cases

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- Mixed regime :
  - longer static friction phase
  - higher friction amplitude
  - higher variations in normal force
- US ToF in mixed regime reflects deformations induced by bulk deformations of the TMS
- US ToF in hydrodynamic regime reflects the evolution of fluid film thickness

## > US time-of-flight as a marker of lubrication regime

#### **Overall analysis**

- Pearson's linear correlation tests performed between normal force and time-of-flight signals
- G<sub>0</sub> and G<sub>50</sub> in mixed regime : strong correlations reflecting the deformations induced by TMS bulk deformations
- G<sub>85</sub>, G<sub>93</sub>, G<sub>97</sub>, G<sub>100</sub> getting closer to hydrodynamic regime : loss of correlation due to fluid film thickness at the interface.

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## > US time-of-flight as a marker of stick-slip

Two contrasting cases

- Fast Fourier Transform analysis performed on all acceleration and ultrasound ToF signals
- Passband filters (40-120Hz)
- Observation of synchronized events between both signals
- Filtered US ToF as a marker of vertical induced by vibrations at the micrometer scale.

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## > US time-of-flight as a marker of stick-slip

Overall analysis

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- Calculation of root-mean-square on acceleration and US time-of-flight signals
- Consistent trends of variations through TMS roughness and lubricant
- Smoothest TMSs (form T<sub>20</sub> and T<sub>40</sub>) : low levels of vibrations and low variations across lubrication conditions
- Roughest TMSs (from T<sub>70</sub> to T<sub>140</sub>) : high fluctuations across lubrication conditions, complementary with friction coefficients



#### > Conclusions

- Signal processing of US time-of-flight proved to be efficient to capture :
  - Fluid film thickness evolution in the case of contrasting speeds of sound
  - Palate displacements induced by to tongue deformation (static friction) and palate vibrations (stick-slip)
- Both the roughness of the artificial tongues and the viscosity of the lubricant were shown to influence friction mechanisms
- The work opens perspectives for the development of food for people with specific physiology (tongue roughness, rigidity, lubrication)
- Potential applications a little further during digestion

## Thank you for your attention !

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