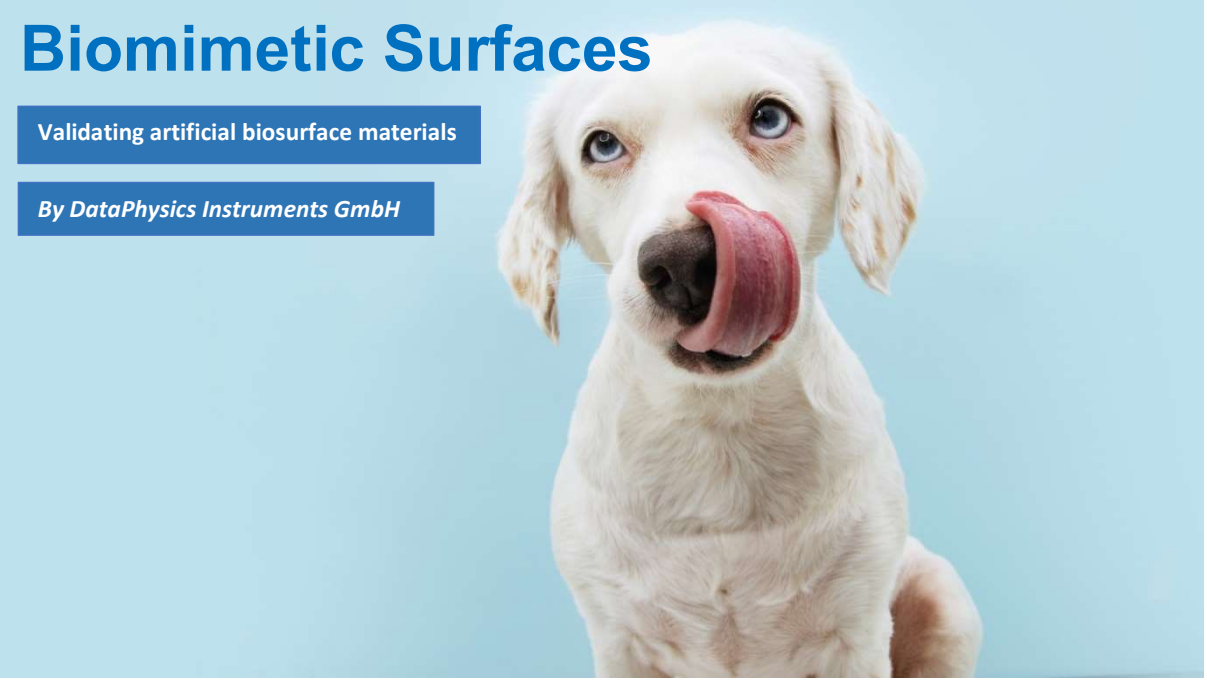
How contact angle measurements help to design artificial tongue surface.



Artificial tongues have attracted the attention of scientists as a way to better understand the tongue-food/fluid interaction and to replace time-consuming/expensive human sensory studies. In particular, since the COVID-19 pandemic, conducting human sensory tests or specialist tasters' tests is almost impossible. Hence, tongue mimicking surfaces with three features—topography, wettability and deformability —of a real tongue are highly needed to help reduce the reliance on human trials to some extent. A special structure called papillae on the tongue surface is of significance for providing the proper mechanical friction to process food or fluid. These complicated microstructures are quite hard to replicate; in addition, no artificial tribological surfaces could so far emulated the wettability behavior of the real tongue. Recently, Efren et al. have shown the first example of the highly sophisticated artificial architecture of a human tongue, which was created by 3D-printing and soft lithography technologies, which demonstrated an excellent topology, elasticity and wettability of the artificial tongue.

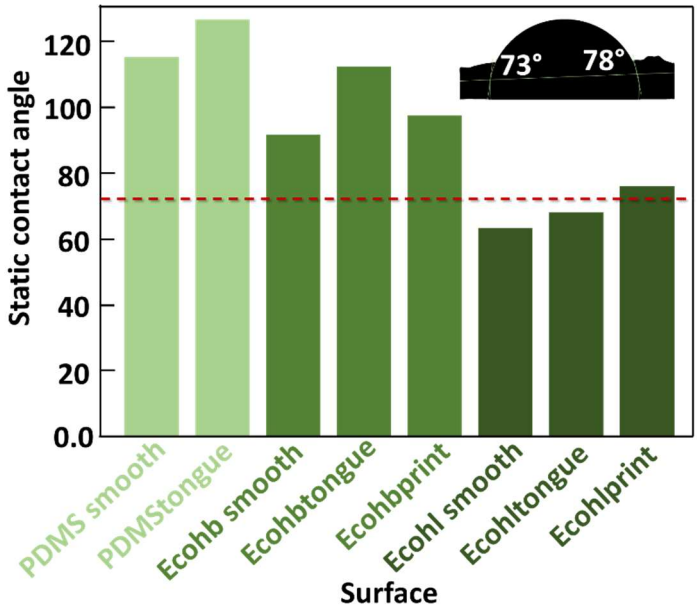
In this work, the authors conducted wettability tests and tribological tests with a real tongue mask and a smooth steel surface as controls to study the performance of the artificial tongue surface. Three types of masks were cast in three different materials: polydimethylsiloxane (PDMS), Ecoflex 00-30 and Ecoflex 00-30 containing Span 80. Herein, surfactant Span 80 was added to modify the wettability. 3D optical scanning results show that the negative tongue mask displayed the papillae as circular holes, accordingly, positive polymeric masks showed dome-shaped fungiform papillae surrounded by filiform papillae as clusters of pillars. In comparison, the artificial tongue surface (Ecohbprint) presented a random distribution of

papillae with higher density of filiform papillae than that of fungiform papillae, indicating remarkably similar features with the real tongue.

Table 1. *Surfaces generated by tongue mask, 3D printed master and smooth steel surface*

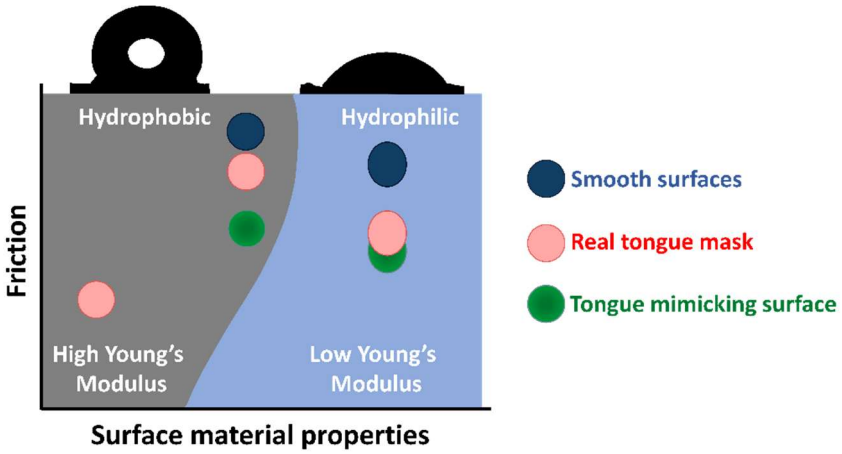
Surface name	Polymer	Span 80 (wt%)	mold
PDMStongue	PDMS	0.0	tongue mask
Ecohbtongue	Ecoflex 00-30	0.0	tongue mask
Ecohltongue	Ecoflex 00-30	0.5	tongue mask
Ecohbprint	Ecoflex 00-30	0.0	3D printed master
Ecohlprint	Ecoflex 00-30	0.5	3D printed master
PDMS smooth	PDMS	0.0	smooth steel surface
Ecohb smooth	Ecoflex 00-30	0.0	smooth steel surface
Ecohl smooth	Ecoflex 00-30	0.5	smooth steel surface

To compare the wettability of the artificial tongue surface (**Table 1**) with the real tongue, water contact angles (CAs) measurements were conducted on various surfaces as shown in (**Picture 1**). The results show smooth PDMS and Ecoflex 00-30 both had hydrophobic nature with CAs of 115.0°± 1.0° and 92.0°± 2.0°, respectively. Upon the introduction of roughness using the tongue mask or 3D-printed master, the CAs increased. As a comparison the CA on a pig's tongue was around 77°. Therefore, the authors tried to make artificial tongue surfaces with similar CAs by introducing the wettability modification. Specifically, upon adding Span 80, the CAs of Ecohl smooth, Ecohltongue and Ecohlprint were 63.0°± 0.2°, 69.0°± 6.05°and 76.0°± 2.0° respectively, which were much closer to that of the real tongue. These results indicate Ecohlprint with the combination of texture and wettability mimicked the real tongue very well.



Picture 1. *The contact angles of different surfaces fabricated using tongue masks and 3D-printed masters (The inset water droplet and the red dashed line represent the wettability of real pig tongue surface)*

Furthermore, as shown in **Picture 2**, the relevant tribological results show that the surface wettability played a vital role in the frictional behaviors. When the surfaces were hydrophobic, the fictional behaviors of surfaces fabricated from the smooth surface, the real tongue mask and the tongue mimicking surface, respectively, were completely different. Upon t wettability modification, the surface derived from the tongue mimicking master presented a similar fictional behavior with the real tongue mask based surface.



Picture 2. *Schematic illustration of the effect of surface material properties on the fictional behaviors*

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Overall, the authors fabricated an artificial tongue surface emulating the real tongue by applying digital designing, 3D-printing and replica-molding techonologies. The wettability of the artificial surface (Ecohlprint) closely resembled the real tongue with CA of 76°. Even though Ecohlprint possessed larger Young's modulus (130 kPa) than the real tongue (< 5 kPa), it was much softer than the current standard PDMS (2.4 MPa). This work sheds light on using artificial tongue materials for testing food safety, controlling food quality, quantifying oral tribological performance with accuracy and other applications.

An optical contour analysis system OCA (DataPhysics Instruments GmbH, Germany) was used in this research.

For more information, please refer to the following article:

3D Biomimetic Tongue-Emulating Surfaces for Tribological Applications; Efren Andablo-Reyes, Michael Bryant, Anne Neville, Paul Hyde, Rik Sarkar, Mathew Francis, and Anwesha Sarkar, *ACS Appl. Mater. Interfaces* ***2020****, 12, 44, 49371-49385*; DOI: 10.1021/acsami.0c12925