

BIOMIMETIC SURFACES FOR DAIRY FOULING MANAGEMENT

S. Zouaghi^a, J. Frémiot^a, N.-E. Chihib^{a,d}, Y. Coffinier^b, V. Thomy^b, C. André^c, M. A. Grunlan^d, G. Delaplace^{a,e}, M. Jimenez^a

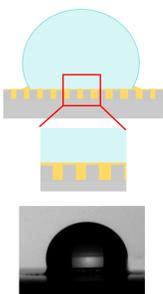
^aUMET, CNRS-UMR 8207, Villeneuve d'Ascq, France / ^bIEMN, CNRS-UMR 8520, Villeneuve d'Ascq, France / ^cHautes Etudes d'Ingénieur (HEI) Lille France / ^dBiomedical Engineering, Materials Science & Engineering, Texas A&M University, College Station, Texas, USA / ^eInstitut National de la Recherche Agronomique (INRA) Villeneuve d'Ascq, France

Introduction – Fouling is a complex phenomenon which burdens the cost and environmental footprint of milk and dairy thermal processing by shortening production time and increasing cleaning expenses. Thus, fouling control is a major challenge which can be achieved through the modification of the equipment surface. This work proposes to study three biomimetic surfaces considered for fouling management applications.

Biomimetic surfaces for fouling control

Slippery liquid infused surfaces

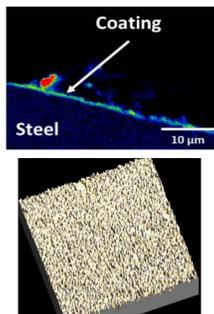
Smooth and hydrophobic



- Inspired from Nepenthes pitcher plants
- Laser textured stainless steel impregnated with fluorinated oil
- High WCA (112°) and very low CAH (0,6°)
- Expected antiadhesive properties

Silane-based plasma coatings

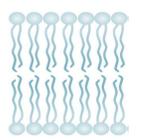
Nanorough and hydrophobic



- Inspired from Lotus leaves
- Atmospheric plasma spraying of a siloxane precursor in N₂
- Thin coating with relative hydrophobicity (WCA = 94°) and nano-roughness
- Expected good cleanability and fouling-release properties

Amphiphilic PEG-silicon coatings

Hydrophilic

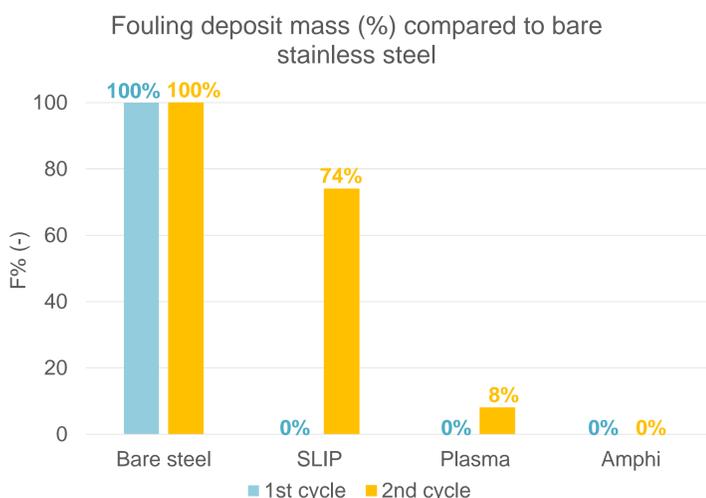


- Inspired from natural amphiphiles
- Hydrophilic PEG connected to hydrophobic silicon by a siloxane tether to ensure mobility
- Environment-responsive coating with antifouling properties

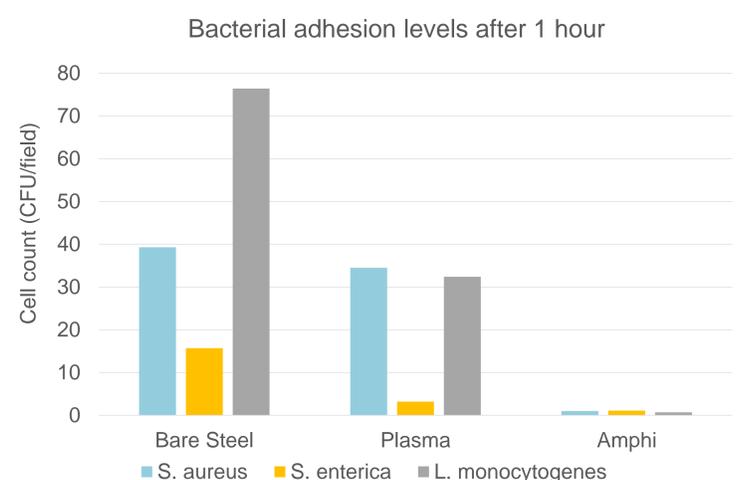


The three biomimetic surfaces were submitted to **fouling tests** performed in a pilot-scale pasteuriser fed with a dairy fluid and to **static bacterial adhesion tests** with three pathogenic strains (*Staphylococcus aureus*, *Salmonella enterica* and *Listeria monocytogenes*).

Pilot fouling test and bacterial adhesion test



- All biomimetic surfaces exhibit interesting fouling performances
- SLIP surfaces lose their antifouling properties after one fouling cycle
- Amphiphilic coatings maintain their excellent results for two consecutive cycles
- Bacterial adhesion is significantly impacted by surface modifications and amphiphilic coatings show good antibacterial properties



Amphiphilic coatings show the best results for both fouling and bacterial adhesion

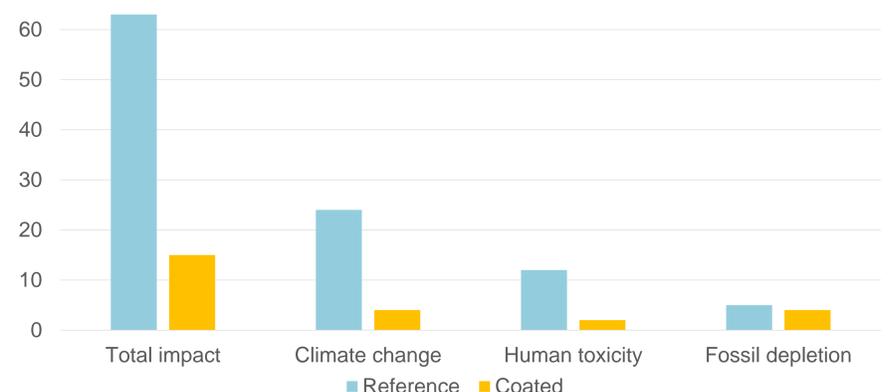
Environmental impact of fouling mitigation (LCA study)

Life Cycle Assessment "From cradle to grave"

- Amphiphilic coatings can lead to significant softening of the industrial cleaning procedures
- Compare the environmental impact of a reference pasteuriser and a pasteuriser coated with amphiphilic coating according to different impact categories (climate change, fossil depletion...)
- Functional unit: 1kg of pasteurized dairy fluid treated in a pilot installation.

Coating the pasteurizer with the amphiphilic coating allows to decrease the environmental impact of pasteurised dairy fluid by more than 70%

Environmental impact of a 1.5h pasteurisation cycle



Conclusions – The biomimetic approach proved to be interesting for the design of functional surfaces for fouling management applications. Particularly, amphiphilic environment-responsive surfaces showed not only excellent antifouling and antibacterial properties, but also a beneficial effect on the process environmental impact. Further research should focus on the coating's durability and on its effect on heat transfer.