Supplementary text

for

Microbial Brazil nut effect

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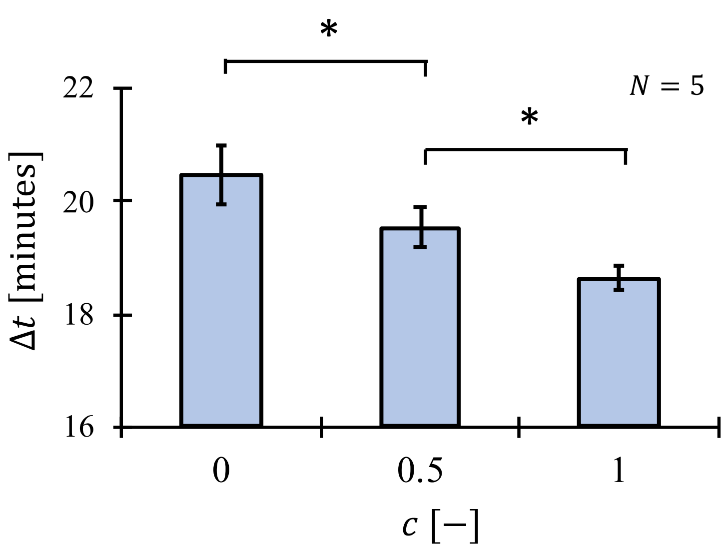
The effect of intruder surface cavities in liquid

The adhesion of bubbles on the surface of a hydrophobic object can reduce its effective density such that it can float upwards against gravity. Since, the adhesion is affected by the presence of surface cavities, we performed the cavity distribution experiment in the liquid alone without any granular medium. We prepared three cuboids with their top surfaces having $c =$ 0, 0.5 and 1 respectively, and introduced them into the YPD broth. Being denser, they sedimented to the floor of the flask. However, after accumulating sufficient number of bubbles, they rose up to the free surface. We measured the time starting from cuboid inoculation into the flask to the time cuboid takes to leave the floor of the flask. We call this time interval Δt. From experiments, we found that Δt was reduced as the cavity distribution ratio c was increased. The results are shown as below. In the graph, the asterisk denote a statistical significance of 95%. The size of the cuboids are {1, 0.6, 1} cm and the cuboid inoculation was done nineteen hours after yeast inoculation.



This confirms if the number of cavities are increased on the surface of the cuboid, it facilitates bubble nucleation and the number of adhering bubbles are increased. Given the cuboids have same volume, the cuboid which overcomes the density offset first will float up first. Since an increase in cavities facilitates bubble nucleation and adhesion, the cuboid with highest c floats up first. This effect was not observed when the same cuboids were kept in the wet granular medium as mentioned in the main document.

The effect of surface tension on microbial BNE

Assuming the bubble production rates by yeasts remain unaffected by a reduction in surface tension of the liquid medium by a surfactant, the mean bubble size within the granular medium should decrease. This is because, under the condition that if the bubble size is very large compared to the grain size, a reduction in surface tension will effectively decrease the surface tension force, say F_γ , which depends on the fluid surface tension γ, the bubble size d_B and the grain size d_G as $F_\gamma \propto \frac{\gamma d_B^2}{d_G}$ [Meier, 2011]. Such surface tension force is balanced by a buoyant force F_B which varies with the volume scale of the bubble i.e., d_B^3. Since, the scale of bubble diameter in the granular medium is governed by a balance of these two forces, assuming all other parameters are unchanged, the mean bubble diameter $d_B \propto \gamma$. This dependence indicates a decrement in the length scale of granular fluctuations due to a decrease in surface tension, thereby, implying a reduction in mean segregation velocity as $\langle v \rangle \propto d_B^2$. That being said, the phenomenon is not as straightforward. The fluid surface tension should also affect the time-scale of granular fluctuations. A smaller bubble with a lower surface tension is expected to grow and collapse much quicker as compared to a larger bubble with a greater surface tension. So, there might be a possibility of reduction in time scale of granular fluctuations (frequency of collapse events) which may then cause an increment in mean segregation velocity. Our studies, however, hinted that for a given surface tension, the frequency of collapse events is not affected by the bubble size.

References

Meier, J.A., Jewell, J.S., Brennen, C.E. and Imberger, J., 2011. Bubbles emerging from a submerged granular bed. Journal of Fluid Mechanics, 666, pp.189-203.