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Improving the performances of mixing operation with 3D controlled movements of a Delta robot

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BACKGROUND

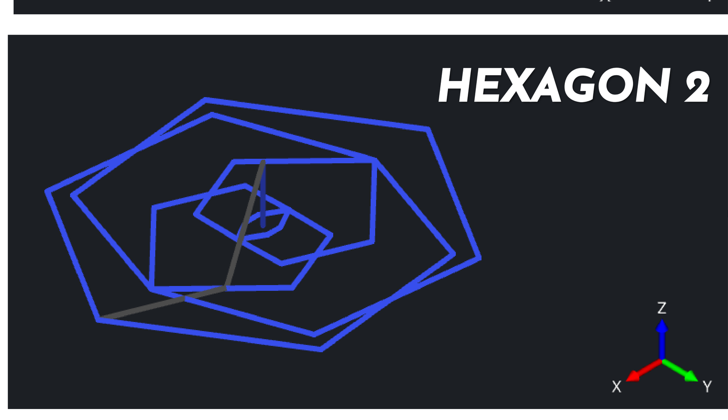
In the current scenario, robotic applications are gaining ground in various fields (aerospace, automotive, etc.), including the food industry, as many food processes are now automated, thanks to the opportunities and benefits that automation can bring to food operations. Unfortunately, in recent years, the phase that has progressively adapted to what will be the future of industrial systems has mainly focused on pick-and-place or, more generally, handling operations [1]. To extend the scope of robots to other food operations, this study explored robotic technologies in the mixing of food ingredients, aiming to improve performance through controlled 3D movements.

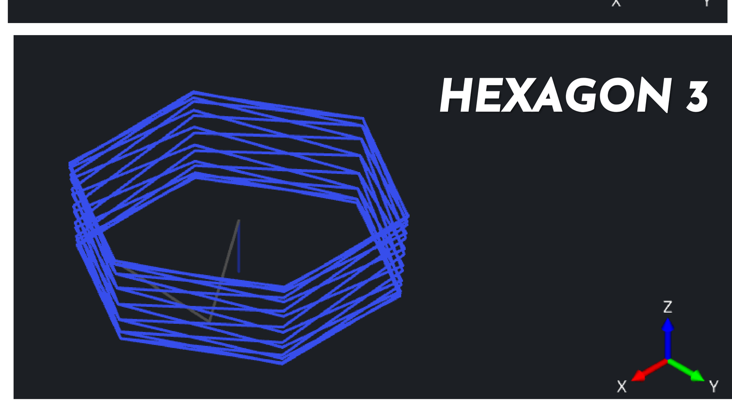
MATERIALS AND METODS

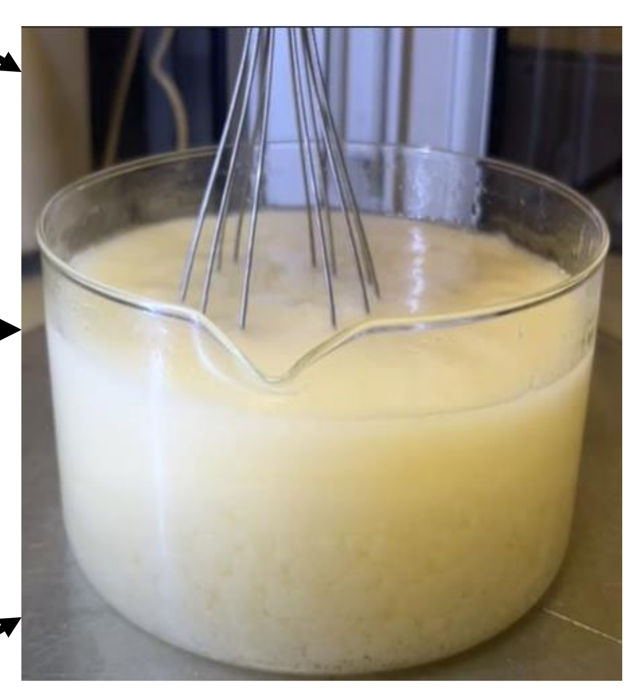
FullControl GCode Designer

Digitally designed path [2]

Delta printer





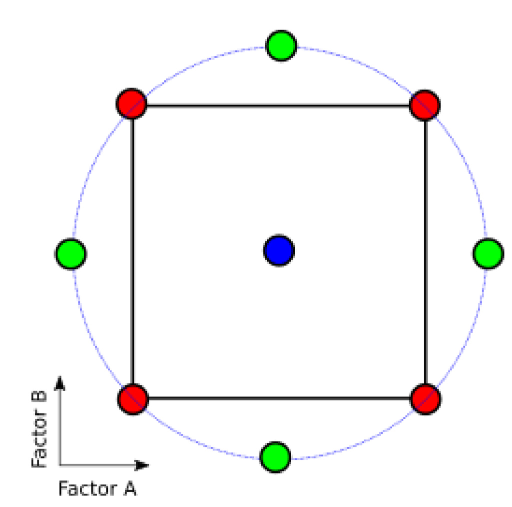


Variable 1: *MIXING TIME*

HEXAGON 1 (10, 20, 30 min)
HEXAGON 2 (10, 25, 40 min)
HEXAGON 3 (10, 35, 60 min)

Variable 2: *MIXING SPEED*

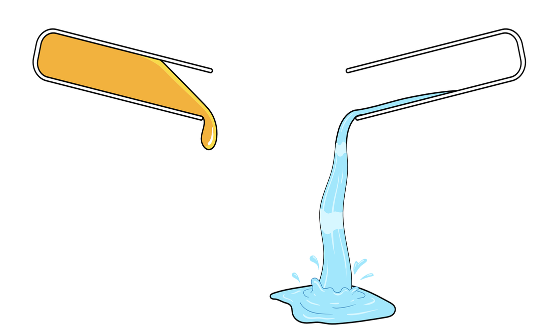
170 mm/s
220 mm/s
270 mm/s



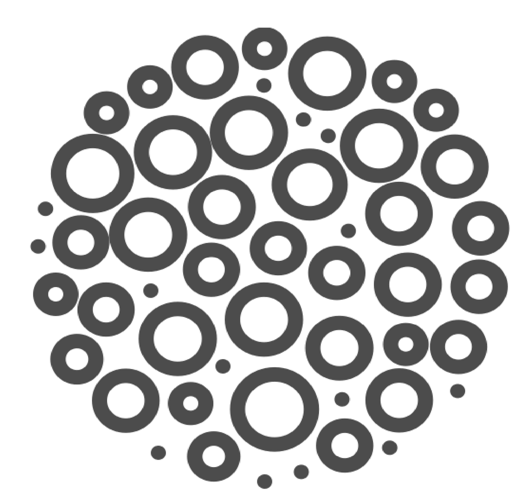
$$\alpha = [2^k]^{\frac{1}{4}} = 1.414, k = 2$$

Physical properties evaluation

VISCOSITY



GRANULOMETRY



RESULTS

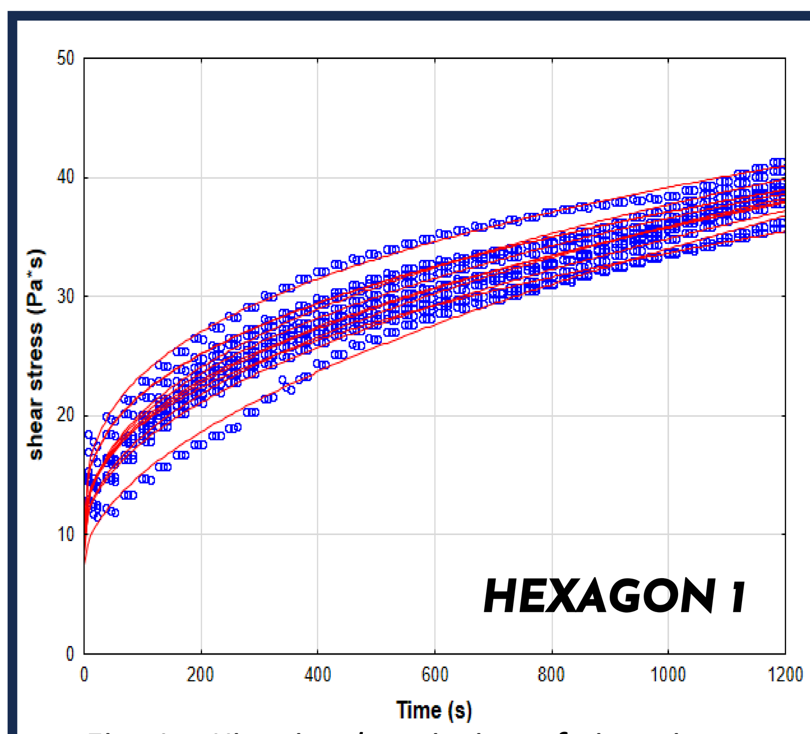


Fig. 1 – Kinetics description of viscosity

The viscosity of the samples were analyzed through viscometer RM 100 (Lamy Rheology). The Hershel-Bulkley model was used to describe the viscosity kinetics of the samples under different experimental conditions. The mathematical model provided a high level of accuracy ($R^2 > 0.90$).

	HEXAGON 1	HEXAGON 2	HEXAGON 3
A	3.817	16.545	2.386
k	8.029	1.40631	3.729
n	0.276	0.558	0.258
R^2	0.994	0.981	0.913

Fig. 2 – Estimated shear stress of emulsions obtained with the three mixing paths at the same time and speed (10 min – 270 mm/s)

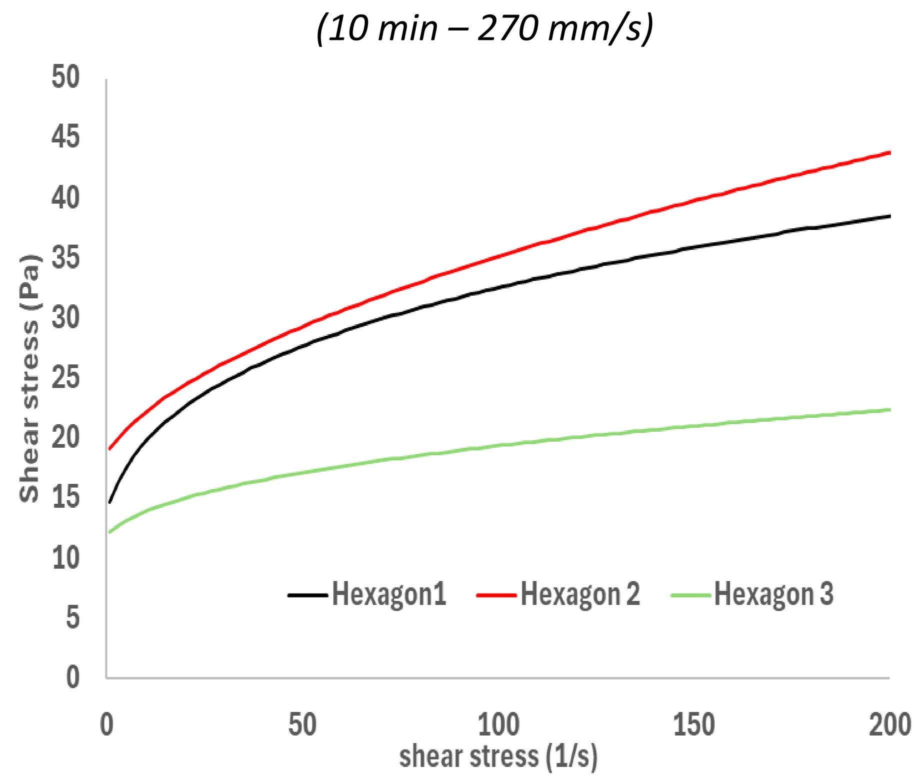


Fig. 3 – Kinetics shear stress comparison of the three mixing paths at the same time and speed (10 min – 270 mm/s)

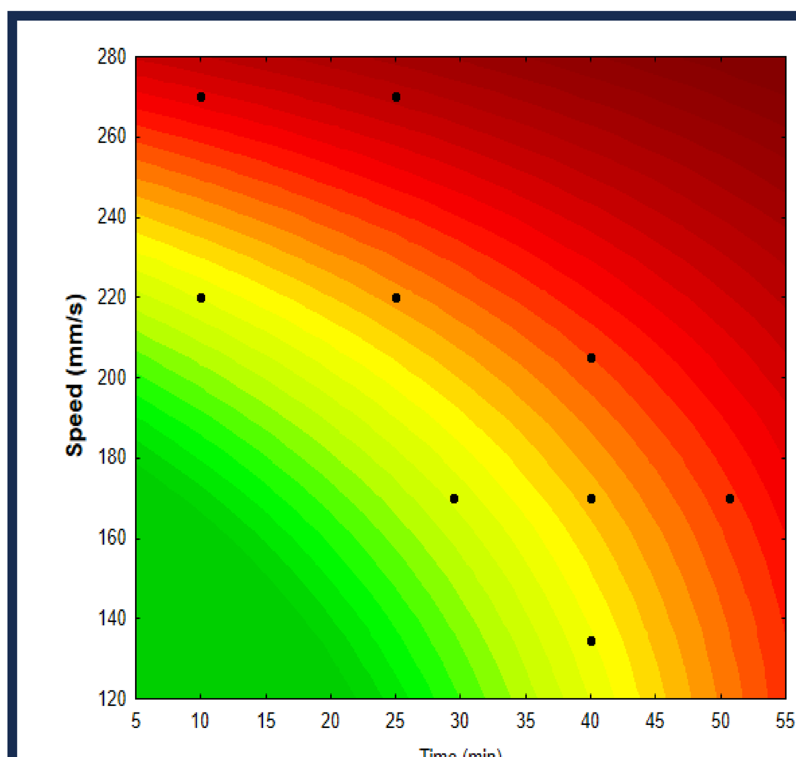


Fig. 4 – Standardized effect of time and speed on volume fraction of oil particle

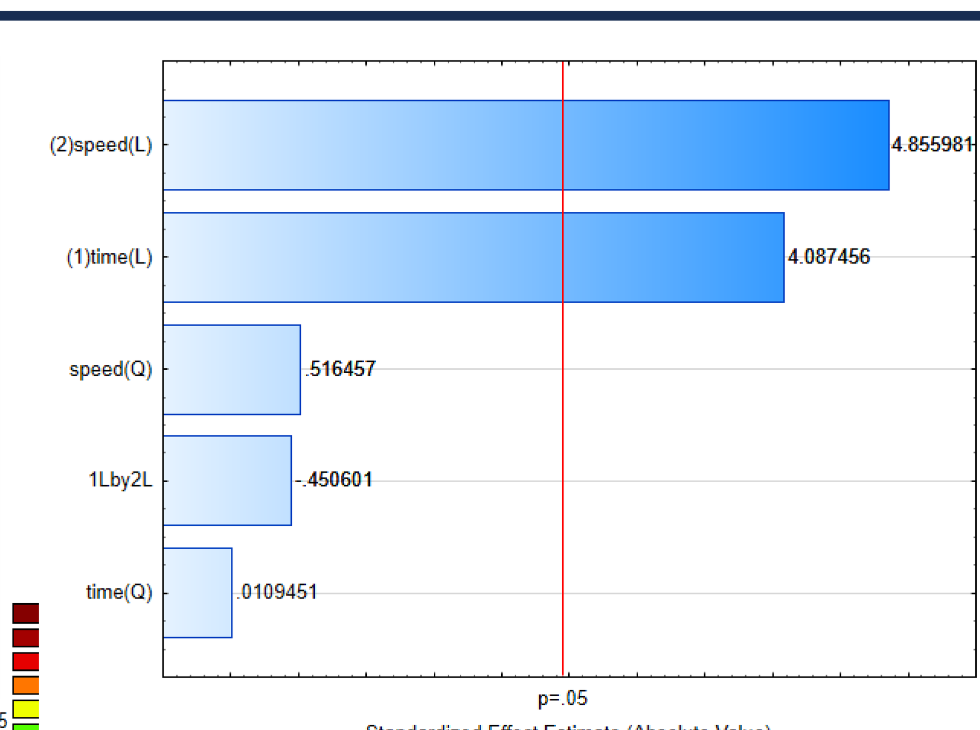


Fig. 5 – Standardized effect of the independent variables

By modulating the refractive index, particle size distribution was evaluated using the Analysette 22 (Fritsch). Time and speed affected the amount of oil droplets less than 200 µm.

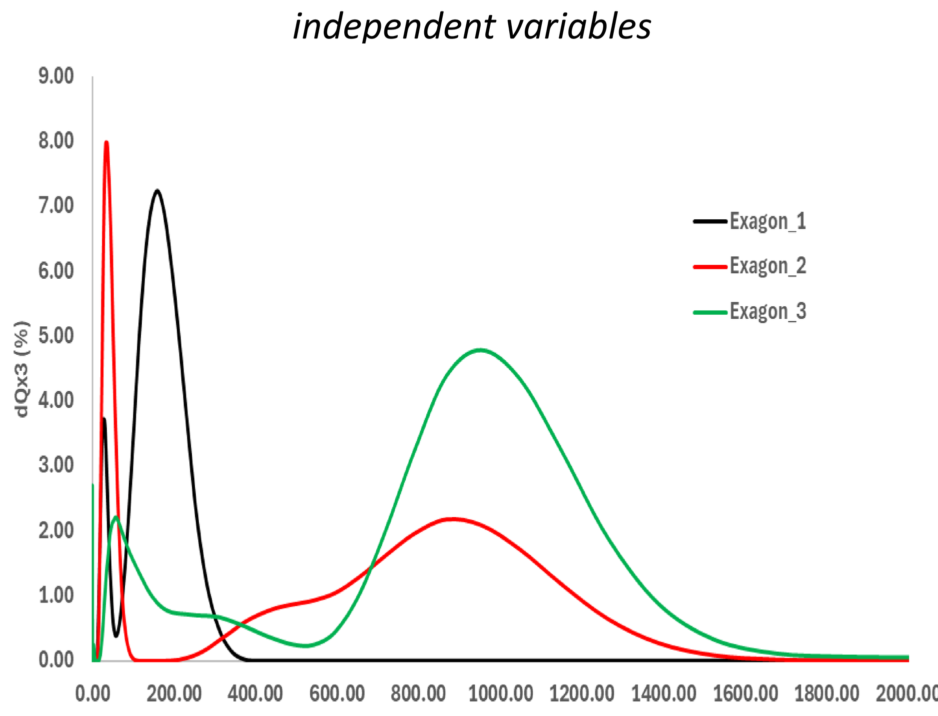


Fig. 6 – Size distribution of oil particles obtained by using three different mixing paths for 10 min at 270 mm/s

[1] Derossi, A., Di Palma, E., Moses., J. A., Santhoshkumar, P., Caporizzi, R., & Severini, C. (2023). Avenues for non-conventional robotics technology applications in the food industry. Food Research International, 173, 11326. [2] Gleadall A. (2021). FullControl GCode Designer: Open-source software for unconstrained design in additive manufacturing, Additive Manufacturing, 46, 102109