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The Oil Cage: Arduino, Biosurfactant, and CCRD

Pedro P. F. Brasileiro[a,b,c], Bruno A. C. Roque[a], Juliana M. de Luna[a,c], Raquel D. Rufino[a], Valdemir A. dos Santos[a,b,c], Leonie A. Sarubbo[a,b,c]

[a]Centre of Science and Technology, Catholic University of Pernambuco, Rua do Príncipe, n. 526, Boa Vista, Postal Code: 50050-900, Recife, Pernambuco, Brazil
[b]Chemical Engineering Department, Federal University of Pernambuco, Avenida dos Economistas, n. 24-52, Cidade Universitária, Postal Code: 50670-901, Recife, Pernambuco, Brazil
[c]Inovation and Technology Advanced Institute, Rua Silveira Lobo, n. 32, Poço da Panela, Recife, Pernambuco, Brazil
ppfbrasileiro@hotmail.com

Since the Exxon Valdez Oil Spill, the world has been started to be careful in the construction and security of the oil platforms, althought the mechanisms to contain the oil are not prepared to avoid an oil spill as demonstrated in the Gulf of Mexico Accident. The absence of effective methods to control the oil plus the higher toxicity of remediative agents permited that 780 million liters of petroleum were spilled into ocean. A potential alternative to control this spot is to apply a mechanism that induces the oil to flow in the direction of a contention tubulation added with a biochemical compound, the biosurfactant produced by *Candida guilliermondii* (UCP 0992). According with a Central Composed Rotate Design (CCRD), this mechanism, that was denominated "The Oil Cage", was built in different sizes of the diameter of cage and the height of tubes to apply the biosurfactant, as well as the flow of biosurfactant was varied progressively. Therefore, the biosurfactant was produced in a 50.0 L batch bioreactor, during 132 hours; the Oil Cages were constructed by the CCRD with 3 variables; the control logic was developed using an *Arduino UNO* R3 board, and the tubulation was applied using flow sensors and manual valves. Besides, the difference of turbidities was the mainly parameter to be the response surface. As the results, the diameter of 17.5 cm, the height of 13.7 cm, and the ratio between oil and biosurfactant of 0.300 were the best conditions to retrive the oil, and the total cost to build the system was € 368,00. Finally, the experiment should be scaled up to verify conditions more realistics, including other variables in the CCRD and foresseeing reasons to maintain the petroleum isolated from the ocean and to save the world.

1. Introduction

According to the history of the oil extraction, one of the considerable challenges has been the building of mechanisms to maintain an entirely platform stable under the strength of winds, waves and other natural phenomena, which are able to ruin a billionaire investment. Besides the expensive cost of an oil platform stability, the environmental security is also related with the platform maintenance. A clear example of this connection was the accident of the Deepwater Horizon Platform in the Gulf of Mexico, where 780 million litters of oil were spilled into the ocean, destroying the marine life. Therefore, the ideal stability and environmental security of an oil platform are essential to produce the oil without devastating any biota (Mascarelli, 2011).

In this sense, mechanisms to prevent and to remediate the spreading of the oil are required. An example of a machine that could avoid the accidents is the Blowout Preventer (BOP), whose function is the blocking of the tubes, when the oil is starting to escape. Unfortunately, in the Deepwater Horizon accident, all the management to buy a semi-millionaire probe was destroyed, when the BOP failed to block the valve which connects the oil spot with the platform, kicking off the biggest oil accident of the world (Tansel, 2014).

Attempts to remediate the oil on the sea are booms, skimmers, sprayed chemical detergents, and incinerations, however these methods did not control the oil flow inside the ocean, only on the surface. Furthermore, chemical dispersants and incinerations cause a higher toxicity on the ocean and on the air.

For this reason, there is a requirement to build a system to control the oil flow with the combined utilization of low-toxic surfactant compounds: the biosurfactants. Biomolecules produced by plants or microorganisms, which can join hydrophobic and hydrophilic compounds, allowing the aggregation of oil droplets with the water. The dispersant compound should not be only sprayed on the water, although it should be applied in the origin of the spill, preventing the dispersion of the oil (Sarubbo et al., 2015).

Therefore, the aim of this work was to construct a system denominated “The Oil Cage”, whose functions were to apply the biosurfactant produced by the microorganism *Candida Guilliermondii* against an oil flow and to remove the emulsification composed by water, oil, and biosurfactant. An *Arduino* board was utilized to measure the volumetric flows, and a Central Composed Rotate Design (CCRD) was applied to investigate the influence of the height and diameter of the cage and the volumetric flow of biosurfactant in the removal of turbidity as the response surface.

2. Material and Methods

2.1 Microorganism and Fermentation Medium

The yeast *Candida guilliermondii* (UCP 0992) stored by the *Banco de Culturas do Núcleo de Pesquisas Ambientais* in the Catholic University of Pernambuco was utilized as the biosurfactant producer and was maintained on slants of Yeast Mold Agar (YMA) composed by (w/v) yeast extract (0.3 %), malt extract (0.3 %), tryptone (0.5 %), D-glucose (1.0 %), and agar (5.0 %). In the absence of agar, the medium was called Yeast Mold Broth (YMB) (Brasileiro et al., 2015).

The production of the biosurfactant occurred by the inoculum of 4.0 % from the YMB into a 20 l batch bioreactor, reaching a concentration of 10^4 cells by ml of the yeast *C. guilliermondii*. This reactor was submitted to an agitation under 250 rpm, an aeration of 16.7 L/min, and a temperature of 28 °C, during 132 h. After the production, the metabolic medium was centrifuged at 4000 rpm and vacuum filtered (Brasileiro et al., 2016).

2.2 The Oil Cage

There were built structures (Figure 1) that could insert the biosurfactant (Biosurfactant Inlet) trough capillaries (Biosurfactant Outlets) for the purposes of the biosurfactant spreading all over the center of The Oil Cage cylindrical shape and of mixture recovering (Mixture Outlet).

The Oil Cage was introduced into a system that measured the biosurfactant (inlet), the oil (inlet), and the mixture (outlet) flows (Figure 2) by an *Arduino Uno* board, utilizing the pumps A, B and C respectively during 15 s. The oil was also set trough a capillary to give speed below The Oil Cage.

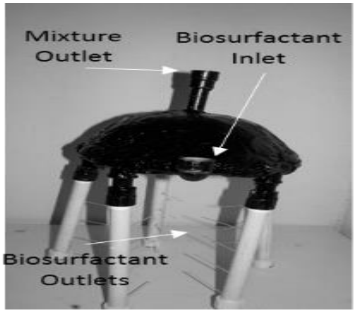

Figure 1: The Oil Cage

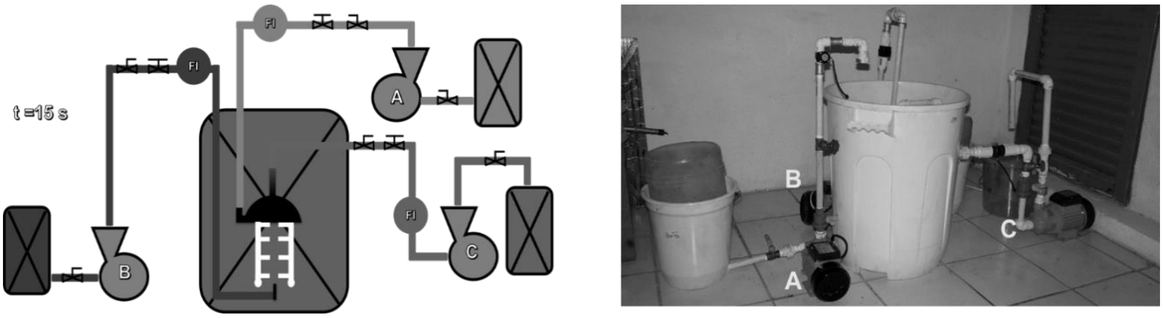

Figure 2: Comparison between the illustrative and real systems from The Oil Cage with the biosurfactant (A), oil, and mixture (C) pumps

2.3 Central Composed Rotate Design for The Oil Cage System

In order to measure the factors of The Oil Cage with the better results, there was built a Central Composed Rotate Design with three independent variables, which can be seen in the Table 1: the ratio between oil and biosurfactant, the cage diameter and the cage height. Therefore, it was possible to see the antagonisms and the synergisms between these three parameters by the variation of the Table 2 with the results in the software STATISCA 10. The response surface was the Difference between the Turbidities (DBT) Final and Initial (Rodrigues and Iemma, 2009).

Table 1: The Oil Cage variables: ratio between oil and biosurfactant, cage diameter, and cage height

Level	Ratio between Oil and Biosurfactant	Cage Diameter (cm)	Cage Height (cm)
-1.68	0.216	13.3	13.3
-1.00	0.250	15.0	15.0
0.00	0.300	17.5	17.5
1.00	0.450	20.0	20.0
1.68	0.552	21.7	21.7

Table 2: The Oil Cage assays

Assays	Ratio between Oil and Biosurfactant	Cage Diameter (cm)	Cage Height (cm)
1	0.250	15.0	15.0
2	0.250	15.0	20.0
3	0.250	20.0	15.0
4	0.250	20.0	20.0
5	0.450	15.0	15.0
6	0.450	15.0	20.0
7	0.450	20.0	15.0
8	0.450	20.0	20.0
9	0.216	17.5	17.5
10	0.552	17.5	17.5
11	0.300	13.3	17.5
12	0.300	21.7	17.5
13	0.300	17.5	13.3
14	0.300	17.5	21.7
15	0.300	17.5	17.5
16	0.300	17.5	17.5
17	0.300	17.5	17.5
18	0.300	17.5	17.5

3. Results and Discussion

3.1 Central Composed Rotate Design for The Oil Cage System

In order to analyse the three independent parameters: the ratio between oil and biosurfactant (R_{ob}), the cage diameter (D, cm), and the cage height (H, cm), the software STATISCA 10 built the equation 1, correlating to the response surface: the Difference between Turbidities (DBT expressed in NTU).

$$DBT = 882.81 - 2{,}258.47 \cdot R_{ob} + 2{,}339.84 \cdot {R_{ob}}^2 - 48.86 \cdot D + 0.93 \cdot D^2 - 1.62 \cdot H + 0.07 \cdot H^2 + 28.66 \cdot R_{ob} \cdot D - 8.91 \cdot R_{ob} \cdot H + 0.24 \cdot D \cdot H \quad (1)$$

The cost of € 368.00 to build The Oil Cage System had the purpose to plot the surface graphs. While each independent variable was standardized in the level 0, according to the Table 1, the other two independent variables were alternated with the results of the equation 1.

In this sense, the Figure 3 could show the lowest results of the comparison between R_{ob} and D, when the R_{ob} was in a range of 0.300 - 0.400, and D was in a range of 12.0 – 16.0 cm.

In the Figure 4, it was possible to observe that the same range of 0.300 – 0.400 of R_{ob} was the main reducer of the DBT, while H was decreasing.

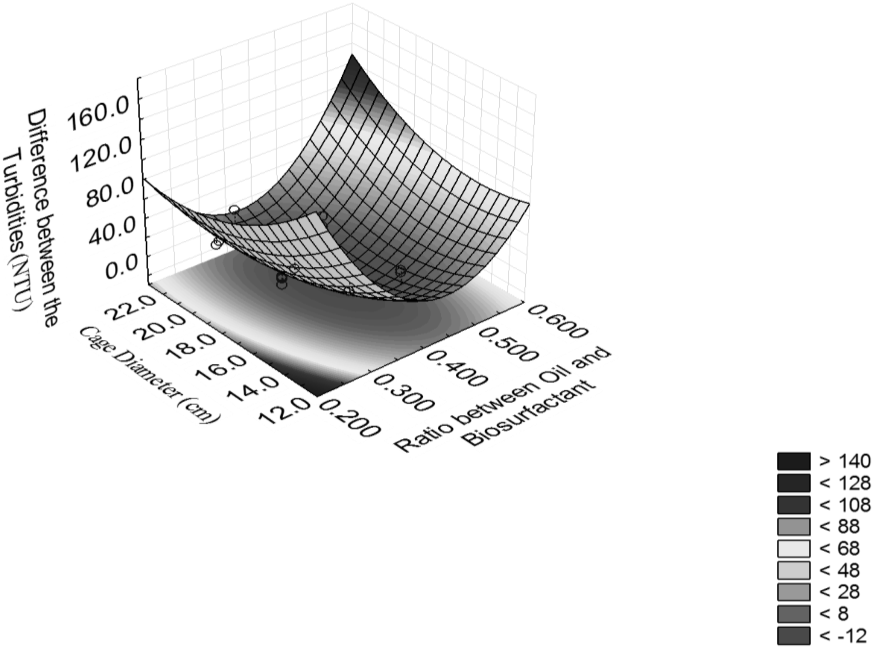

Figure 3: Surface Graph of Difference between Turbidities, cage diameter, and ratio between oil and biosurfactant

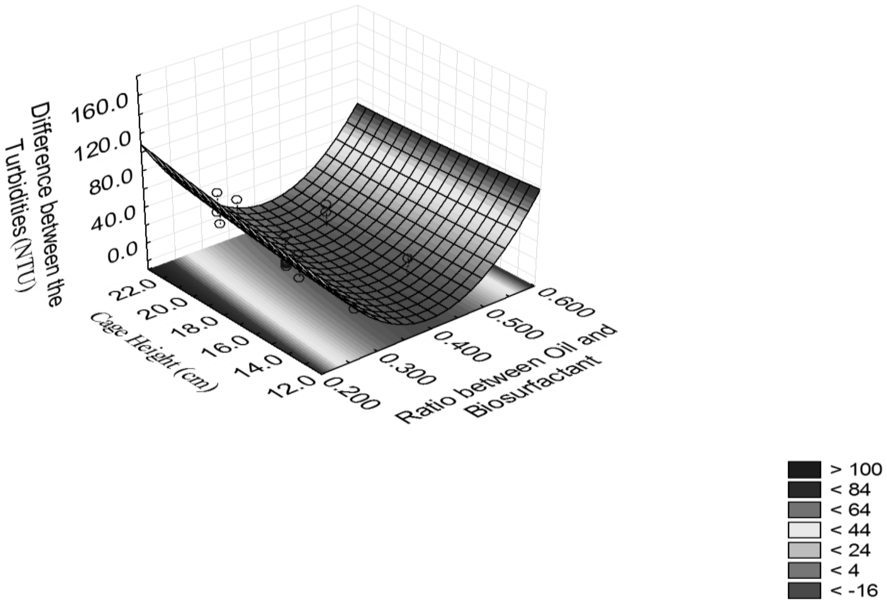

Figure 4: Surface Graph of Difference between Turbidities, cage height, and ratio between oil and biosurfactant

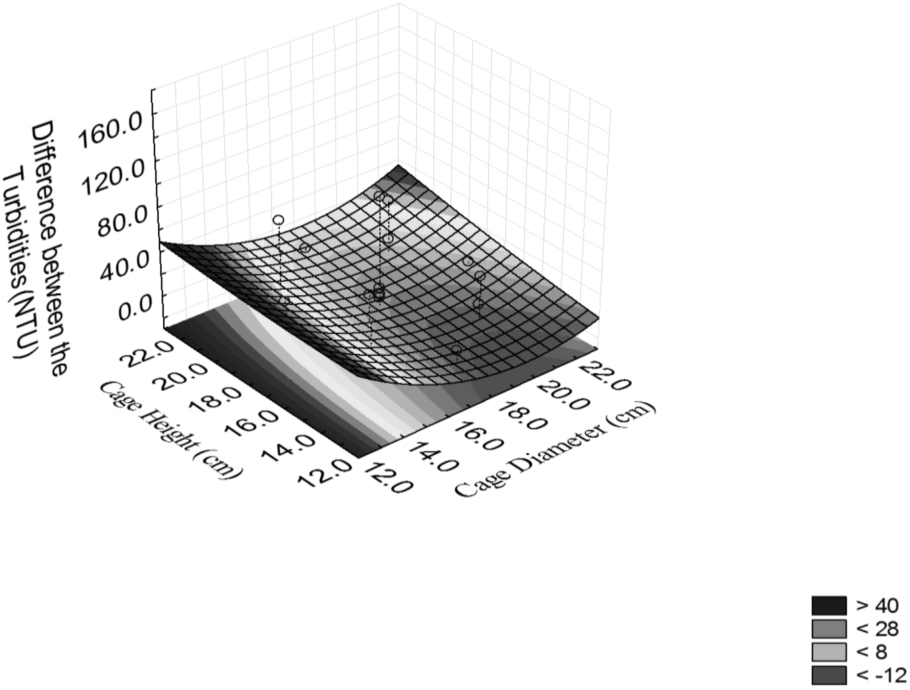

Figure 5: Surface Graph of Difference between Turbidities, cage height, and cage diameter

In the Figure 5, the comparison between H and D demonstrated that the lowest height with a range between 17.5 and 21.7 cm of diameter was able to recover most of the oil.

The best results of the surface graphs can be proven by the visual investigation in the Figure 6-A, when the assay 13 was made with 2.63 NTU of DBT. However, when the properties were not able to maintain the oil inside the hemisphere of The Oil Cage, the results get worsen as can be seen in the Figure 6-B (assay 11).

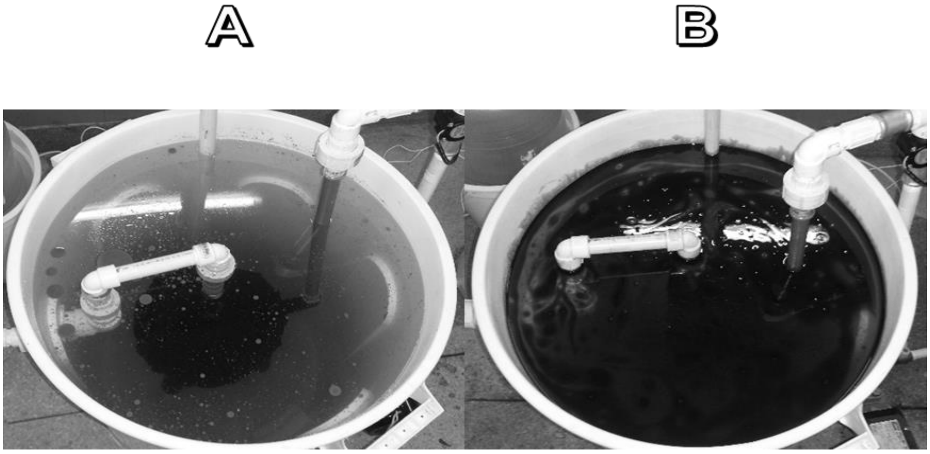

Figure 6: Comparison between the assays 13 (A) with the best removal and 11 (B) with the worst removal

Besides, the Pareto's Chart, in the Figure 7, can finally evidence the parameters observed in the surface graphs, setting the ratio between oil and biosurfactant as the most potential variable to recover the oil from a possible spill.

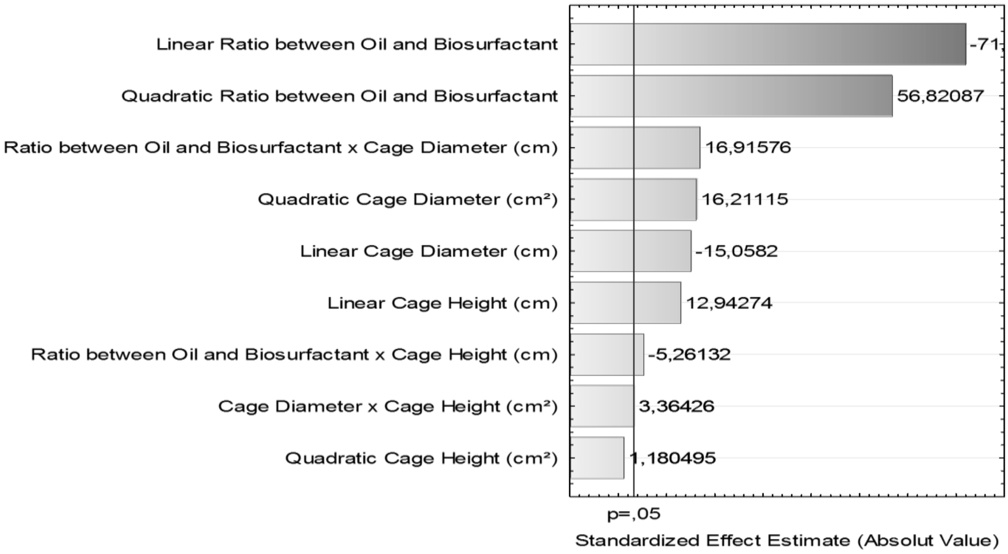

Figure 7: Pareto's Chart of the Central Composed Rotate Design

4. Conclusion

The Oil Cage System with the cost of 368 euros was able to recover the oil until the Difference between Turbidities of 2.63 NTU, according to the assay 13 with the diameter of 17.5 cm, the height of 13.7 cm, and the ratio between oil and biosurfactant of 0.300.

In order to optimize the range of the variables, a new CCRD and a scale-up should be done based on the result of the assay 13.

The use of the biotechnology is important to maintain the equilibrium of the environment, so it is important to apply any others microbial or plant surfactants in this system to verify which biosurfactant is better.

Acknowledgments

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