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EFFECT OF THE AGING PROCESS ON THE PERFORMANCE OF *ALOE VERA* AS DRAG REDUCER

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Abstract. The search for natural additives capable of reducing the friction factor is growing, due to their advantages in industrial, environmental and medical applications. The biopolymer extracted from Aloe vera is one of the additives that present good results in drag reduction. However, the plant aging process can affect the chemical composition and, therefore, its capacity to reduce drag. This article analyzes the influences of the ages on the capability to reduce drag in turbulent flows, to determine the best age for harvesting the plant to obtain the best results on drag reduction. The rheological characterization of the materials was done in a rheometer. The tests were also performed in a flow loop apparatus, which is closer to practical conditions. It was noticed that the plant age could influence the drag reduction, because the ages of intermediate and adult leaves presented higher efficiency than the young leaves.

Keywords: turbulence, drag reduction, biopolymer, Aloe vera, age.

1. INTRODUCTION

The studies on drag reduction have started from the pioneering works of Forrest and Grierson (1931), Toms (1948) and Mysels (1949), which shows that the addition of small quantities of certain substances in turbulent flows reduces the resistance to the transport of a fluid. This area became of interest to the scientific community, as it made systems cheaper and more efficient.

Polymer additives are well known in industrial applications and engineering systems like, for instance, the increase of the speed of ships (Larson, 2003) and the transport of crude oil in the pipeline system (Burger *et al*., 2013). However, the polymers used are usually synthetic and toxic and its application is inconvenient for medical and environmental areas.

In the specific case of *Aloe vera* as a polymer, according to experiments carried out by Barbosa (2017), the mucilage present in the leaves of this plant can reduce by up to 71% the friction. So, because it has a low-cost, it is natural and non-toxic, the *Aloe vera* is a product of great potential for the area of drag reduction. However, according to Silva *et al.* (2005), the different ages of the plants can change their chemical composition. The studies conducted with *Aloe* did not yet verify the age of the leaves. Thus, the objective of this work is to analyze the influence of the age of the plant on drag reduction capability in turbulent flows.

2. METODOLOGY

2.1 Polymer extraction and storage

The leaves of *Aloe vera* were obtained in the region of Linhares, Espírito Santo. The leaves were grouped into three categories (young, intermediate and mature) and were separated by parameters such as: length, width and thickness, as done by Silva, Dos Santos and De Paiva (1998), Monteiro *et al*. (2005) and Lima *et al*. (2011). The Table 1 indicates the parameters used in the separation of *Aloe vera* leaves by age.

Table 1. Parameters used to separate the *Aloe Vera* leaves by age.

Category	Length (cm)	Maximum thickness (cm)	Maximum width (cm)
Young	25.6	1,1	2,9
Intermediate	36.8	1.6	4.3
Mature	52.2	1.9	5.5

For the experiments, it was necessary to have concentrated mucilage extracted from the leaves of the plants as the final product. Therefore, the methodology used by Barbosa (2017) was adopted as illustrated in Fig. 1. First, the leaves of the plant were washed and dried. Then, the outer leaves were removed. As a result of this step, a mucilage and fiber composite gel was produced, then the next steps were to grind the material and obtain the concentrated mucilage by a filtering procedure. Thus, 100 % polyester tulle was used at first. Subsequently, the material passed through a 1.80 mm sieve and then in another sieve with 106 μm aperture. These sieves followed the NBR NM-ISO 3310/1. Finally, the product was homogenized, stored in recipients and transferred to a freezer.

| a) *Aloe* leaves | b) inner leaves | c) grinding process |

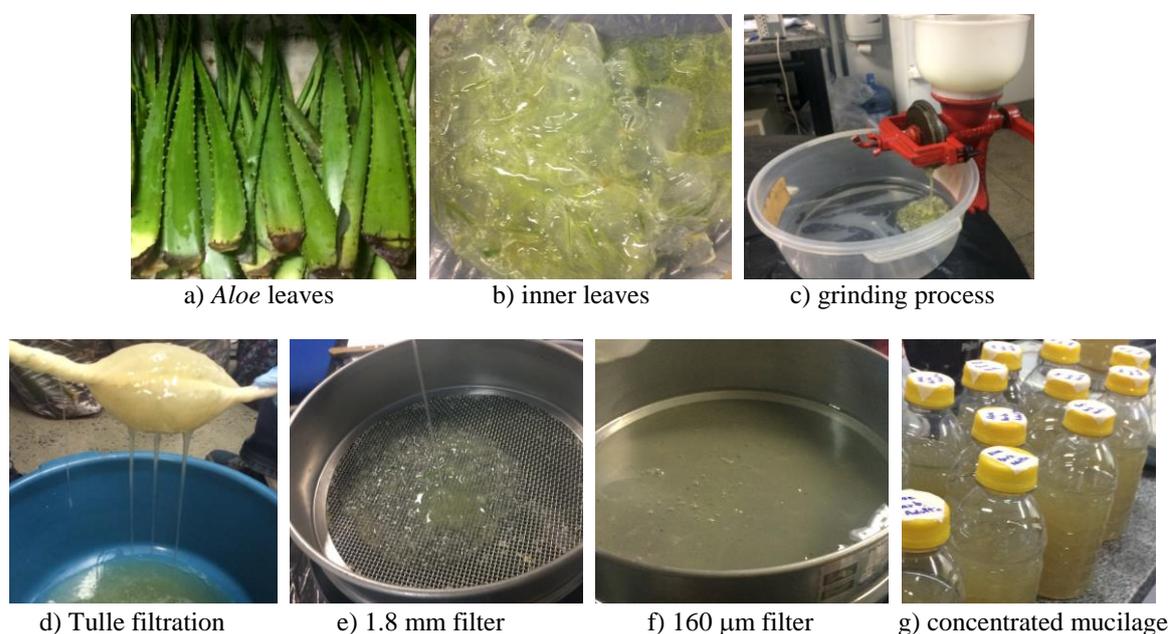| d) Tulle filtration | e) 1.8 mm filter | f) 160 μm filter | g) concentrated mucilage |

Figure 1. Steps of the *Aloe vera* mucilage extraction.

For the drag reduction tests, the concentration of the solution must be determined. Thus, a small part of the mucilage before being taken to the freezer was separated for mass measurement. This sample was put in a glass recipient and it mass was measured. After that, the recipient was transferred to an oven at 55 ºC and remained there for a period of 24 hours, so that the constant mass condition was achieved, and the measurement of the mass occurred again. Knowing the mass before and after the drying process, it is possible to determine the concentration. The concentrations obtained were: 6814 ppm (part per million) for young, 7314 ppm for intermediate and 7951 ppm for mature leaves mucilage.

2.2 Flow loop apparatus

The drag reduction results in the flow loop apparatus are more consistent with that found in practical applications. Therefore, the tests were done in a flow loop, which consisted of straight pipes of circular section. The solution passed through these pipes and was driven by a centrifugal pump, model CAM-W6C, manufactured by Dancor. The bench was also composed by a magnetic flow meter, a storage tank, static pressure transducers, a pressure vessel and a frequency inverter.
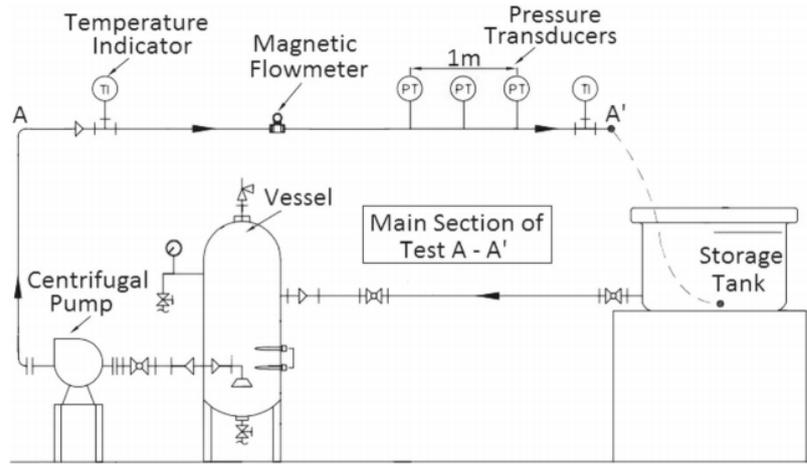
Figure 2. Schematic representation of the flow loop apparatus.
Source: Coelho *et al*. (2016).

The magnetic flow meter contained in the bench had uncertainty of 0,5%. The pressure transducers had a measurement range from 0 to 500 kPa (4 to 20 mA) and uncertainty of 0,0057 mA. The internal diameter of the pipe was 16.35 mm. The main test section (section A-A ') was 9.7 m long. Regarding the tests in the experimental apparatus, the drag reduction was evaluated as a function of the number of passes (cycles), and the analysis of the effect of the concentration was done only with adult *Aloe vera*. For the workbench validation, 100 liters of water was used and the flow of the centrifugal pump was varied, that is, it consisted in changing the Reynolds between a range of 67000 to 101000. For the drag reduction tests, water and the *Aloe vera*'s solution were added to a storage tank. After a time of 2 hours for homogenization, the mixture was directed to the pressure vessel by the action of gravity. A centrifugal pump worked for boosting the fluid from the pressure vessel to the test circuit hydraulic. When the entire solution returns to the storage tank, a pass was counted. The drag reduction was calculated by Eq. (1).

$$DR = 1 - \frac{f_p}{f_0} \tag{1}$$

On Eq. (1), f_p is the friction factor of the mucilage solution and f_0 is the friction factor of the solvent. The friction factor of the solution is obtained by the Eq. (2).

$$f_p = \frac{2D}{\rho \bar{u}^2} \left(\frac{\Delta P}{L} \right) \tag{2}$$

On Eq. (2), D is the diameter of tube, ρ is the density of the mixture of solution, $\bar{u}$ is the mean velocity of the flow, ΔP is the pressure drop measure from pressure transducers and L is the distance of transducers.

2.3 Rheological characterization of solutions

For viscosity measurements it was used a rheometer HaakeMars II ThermoScientific. Coupled to the rheometer, there was a ThermoHaake Phoenix II type thermostatic bath, model P1-C50P, which was responsible for temperature control. The rheological characterization was done for leaves classified as young, intermediate and mature. The test uses rotational geometry with double-gap cylinders. The temperature was maintained at 25 ºC and the rotor angular velocity was varied from 0 to 2400 rpm (revolutions per minute) for 480 seconds, rotation at which flow was still termed as laminar.

3.   RESULTS AND DISCUSSION

Fig.3 shows the validation test of the flow loop bench, which relates the Darcy friction factor to the Reynolds number. The friction factor obtained from the experiment (blue circles) is compared with the Blasius correlation (red line), which represents the friction factor for turbulent water flow through smooth tubes. The results are very close to the Blasius correlation, with a maximum error of approximately 3%, which proves a good accuracy of the bench.
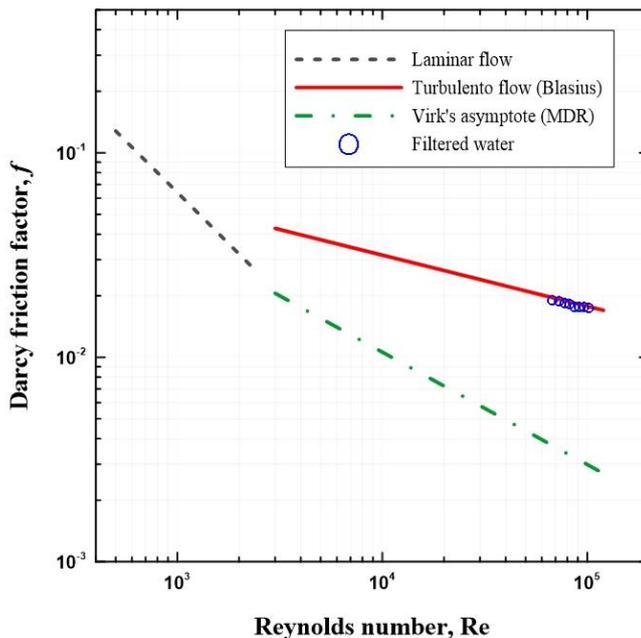
Figure 3. Validation of the flow loop bench.

Concerning the rheological characterization, Fig. 4 illustrates the flow curves for the young, intermediate and mature samples. The same behavior was observed for all curves. At lower rotations, it was noticed that the viscosity decreases as the rotation increases, region characterized by laminar flow of a shear-thinning fluid. After approximately 500 rpm, it was noticed that the viscosity increases as the rotation increases due to the turbulent regime. The values that are used for the drag reduction test were the minimum point of the curves, being these values very similar.
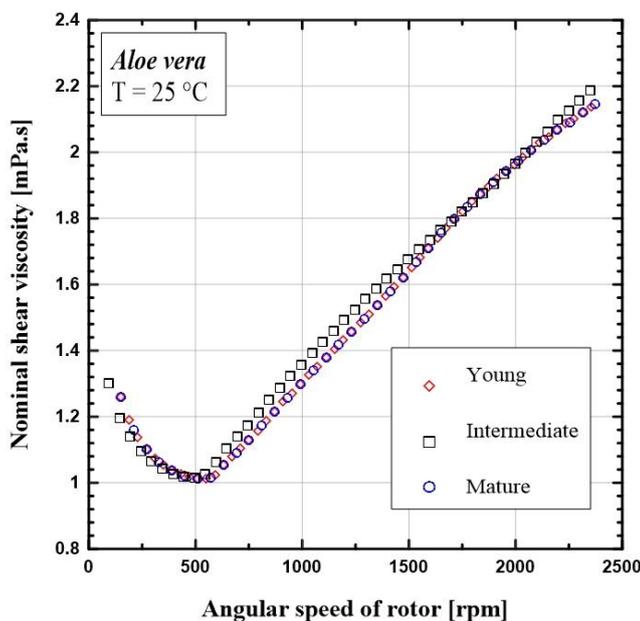

Figure 4. Flow curves for mucilage samples of *Aloe vera* with different ages.

The effect of concentration on drag reduction were investigated for the mature leaves and are displayed in Fig. 5. It was observed that the maximum drag reduction value occurs at the beginning of the test and the DR decays as the number of passes increases, until reaching a constant value. This behavior occurs due to the desagregation of the polymer, as reported by Soares *et al.* (2015) for polymers that are classified as rigid, like *Aloe vera*. It can also be seen that the higher the concentration the larger the reduction of the friction factor. Comparing the asymptotic values with those obtained by Barbosa (2017), which obtained this same curve behavior, presented differences of approximately 5% for 100 ppm and 16% for 200 ppm. At 50 ppm, the value obtained was practically the same.
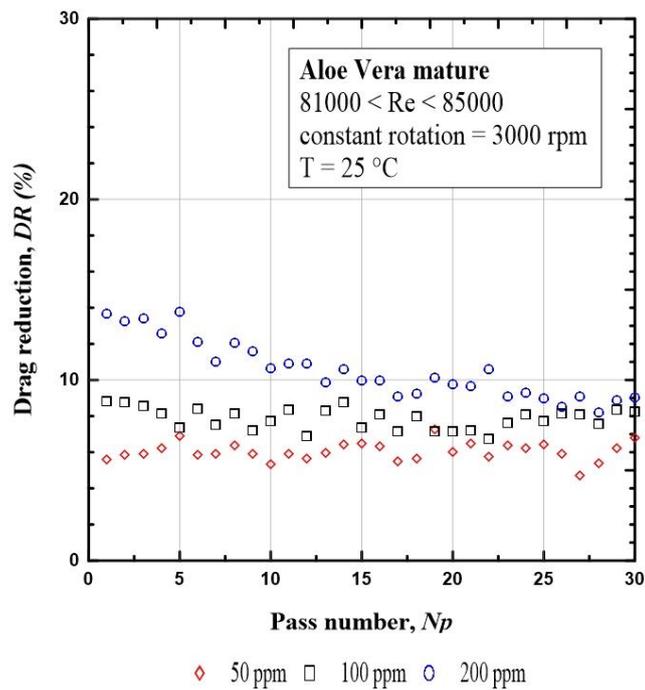
Figure 5. Influence of concentration on drag reduction.

Figure 6 shows the results obtained of drag reduction for the three ages of *Aloe vera* studied. The same behavior discussed above was noticed. In the first pass, the drag reduction is larger and then, with the increase of the number of passes, it decreases until reaching an asymptotic value. It was verified that the intermediate and mature *Aloe vera* solutions presented values of DR very close to each other and, in this case, they are superior to the DR values obtained by the young *Aloe vera* solutions.
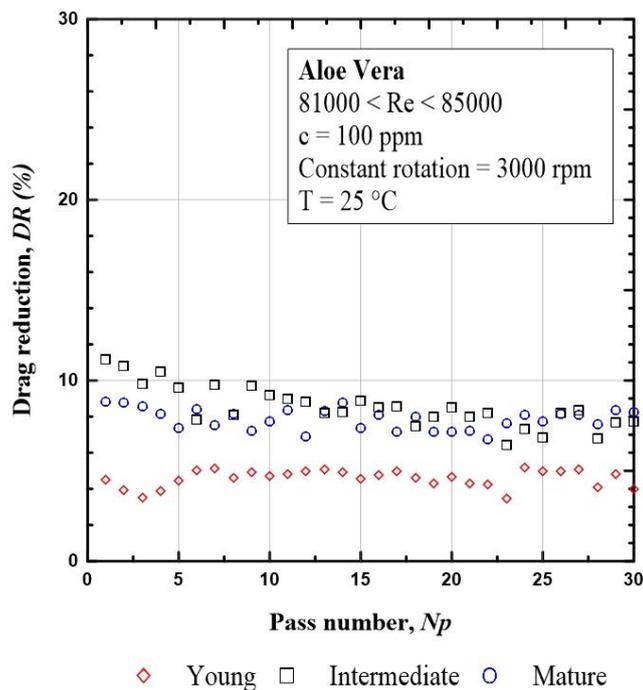

Figure 6. Influence of the ages of *Aloe vera* in the drag reduction capacity.

This result has to be correlated with the chemical characterization, to verify if the composition of the samples are different, which may corroborates that the efficiencies in reducing friction for the different *Aloe vera* plant ages are different.

4. ACKNOWLEDGMENTS

5. REFERENCES

1. Barbosa, K. C. O., 2017. "Estudo da mucilagem e fibra natural da babosa (*Aloe vera*) como redutores de arrasto em escoamentos turbulentos". 2017. 84 f. *Dissertação (Mestrado) - Curso de Engenharia Mecânica*, Universidade Federal do Espírito Santo, Vitória.
2. Bozzi, A., Perrin, C., Austin, S., Vera, F. A. "Quality and authenticity of commercial aloe vera gel powders". *Food Chemistry*, v. 103, p. 22-30, 2007.
3. Burger, E. D. and Chorn, L. G., 1980 "Studies of drag reduction conducted over a broad range of pipeline conditions when flowing prudhoe bay crude oil". *Journal of Rheology*, v. 24, p. 603-626, 1980.
4. Campestrini, L. H., Silveira, J. L. M., Duarte, M. E. R., Koop, H. S., Noseda, M. D. "NMR and rheological study of Aloe barbadensis partially acetylated glucomannan". *Carbohydrate Polymers*, v. 94, p. 511-519, 2013.
5. Coelho, E. C., Barbosa, K. C. O., Soares, E. J., Siqueira, R. N. and Freitas, J. C. C., 2016. "Okra as a drag reducer for high Reynolds numbers water flows". *Rheologica Acta*, v. 55, p. 983-991.
6. Forrest, F. and Grierson, G. A., 1931. "Friction losses in cast iron pipe carrying paper stock". *Paper Trade Journal*, v. 92, n. 22, p. 39-41.
7. Larson, R. G., 2003. "Analysis of polymer turbulent drag reduction in flow past a flat plate". *Journal of non-newtonian fluid mechanics*, v. 111, p. 229-250.
8. Lima, R. L. S., Severino, L. S., Cazetta, J. O., Azevedo, C. A. V., Sofiatti, V. and Arriel, N. H. C., 2011. "Redistribuição de nutrientes em folhas de pinhão-manso entre estágios fenológicos". *Revista Brasileira de Engenharia Agrícola e Ambiental*, v. 15, p. 1175-1179.
9. Monakhova, Y. B., Randel, G., Diehl B. W. K. "Automated Control of the Organic and Inorganic Composition of Aloe vera Extracts Using ^{1}H NMR Spectroscopy". *Journal of AOAC International*, v. 99, p. 1213-1218, 2016.
10. Monteiro, J. E. B. A., Sentelhas, P. C., Chiavegato, E. J., Guiselini, C., Santiago, A. V. and Prela, A., 2005. "Estimação da área foliar do algodoeiro por meio de dimensões e massa das folhas". *Rede de Revistas Científicas da América Latina*, v. 64, p. 15-24.
11. Mysels K. J., 1949. "Flow of thickened fluids". *US Patent 2 492*, 173.
12. Ray, A., Aswatha, S.M., "An analysis of the influence of growth periods on physical appearance, and acemannan and elemental distribution of Aloe vera L. gel". *Industrial Crops and Products*, v. 48, p. 36-42, 2013.
13. Ray, A. and Gupta, S. D. "A panoptic study of antioxidant potential of foliar gel at different harvesting regimens of Aloe vera L". *Industrial Crops and Product*, v. 51, p. 130-137, 2013.
14. Silva, A. C., Dos Santos, A. R. and De Paiva, A. V., 1998. "Translocação de nutrientes em folhas de havea brasiliensis (clone) e em acículas de pinus oocarpa". *R. Un. Alfenas*, v. 4, p. 11-18.
15. Silva, J. C., Matos, J. L. M., Oliveira, J. T. S. and Evangelista, W. V., 2005. "Influência da idade e da posição ao longo do tronco na composição química da madeira de Eucalyptus grandis Hill ex. Maiden". *Rev. Árvore*, Viçosa, v. 29, n. 3, p. 455-460. <http://dx.doi.org/10.1590/S0100-67622005000300013>.
16. Souza, A. M. and Poppi, R. J., 2012. "Experimento didático de quimiometria para análise exploratória de óleos vegetais comestíveis por espectroscopia no infravermelho médio e análise de componentes principais: um tutorial, parte I". *Quím. Nova*, v. 35, p. 223-229. <http://dx.doi.org/10.1590/S0100-40422012000100039>.
17. Toms, B. A., 1948. "Some observations on the flow of linear polymer solutions through straight tubes at large Reynolds numbers". *Proceedings of the International Congress of Rheology*, Amsterdam, Holland, Section II, p. 135-141.

6. RESPONSIBILITY NOTICE