v. 2, n. 2, 2022

Journal of
Engineering
Research

STUDY OF OPERATIONAL PRESSURE EFFECT ON PORE BLOCKING MECHANISM

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Abstract: The particulate removal is crucial in filtration studies to guarantee the product quality. In this work, classical pore blocking mechanisms found in dead-end microfiltration are studied in wine processing, whose tests were evaluated using a commercial filter medium subjected to two different operational pressures. The predominance of intermediate pore blocking was identified using 15 psi, while the predominant mechanism at 30 psi was cake formation.
Keywords: Pressure, Microfiltration, Wine, Mechanism, Fouling.

INTRODUCTION

Wine transcends time and the search for aroma and flavor promotes human emotions, which engineering cannot to ignore. The wine final attributes, such as taste, color, and smell are determined not only due to grapes characteristic, but also by their processing. In the preparation of final product, the fermentation turns the grape sugar into alcohol, which changes the balance of medium's physical-chemical. As result, the crude wine may show, over time, a series of precipitations or colloidal formations that to provoke visual and taste unpleasant. In this case, the microfiltration process is essential, because it removes, from the crude wine, solid or colloidal particles (Dias, 2007). There are other factors that must be considered which are decisive for efficiency and operation cost, as the process flow and filter medium blocking phenomena (Ribéreau-Gayon et al., 2006).

The microfiltration efficiency, therefore, can be verified by measuring of permeate quality as turbidity and total number of particles in the suspension (Wendriner and Cremasco, 2015). The relationship between the number of particles contained in the permeate (or filtered) and in the crude wine establishes the rejection degree or microfiltration efficiency. This efficiency is governed by several factors, basically by equipment, microfiltration operation (dead-end or cross flow), operational temperature and pressure conditions, as well as the filter medium characteristics. In this case, the affinity between the material from solution to be micro filtered and filter medium material, particularly the pore nature, influences the resistance to microfiltration and, consequently, the operation efficiency. This resistance includes intrinsic membrane resistance; resistance due to fouling, that can be defined as irreversible deposition of retained particles, colloids, emulsions, suspensions, macromolecules on the membrane surface (Cremasco, 2018); resistance from polarization because of solute concentration.

As observed, it is essential to know the pore blocking mechanism that occurs in dead-end microfiltration, identified mainly by fouling occurrence in addition to the cake formation on the filter medium surface. Classically, the mechanisms identified for dead-end microfiltration are standard blocking, complete blocking, intermediate pore blocking, and cake formation as illustrated in Figure 1. The models related with the mechanisms illustrated in this figure are in Table 1. In this table, J is the filtration velocity; J_0 filtration velocity considering no blocking effects; A, microfiltration area; k is the kinetic constant associated to respective model.

Therefore, this work aims to evaluate the operational pressure effect on pore blocking mechanism found in wine microfiltration. For this purpose, it used a commercial wine, which was subjected to dead-end microfiltration using filtering medium at two different operational pressures.

MATERIALS AND METHODS

This article is based on Wenderiner´s work (Wenderiner, 2014), that presented the

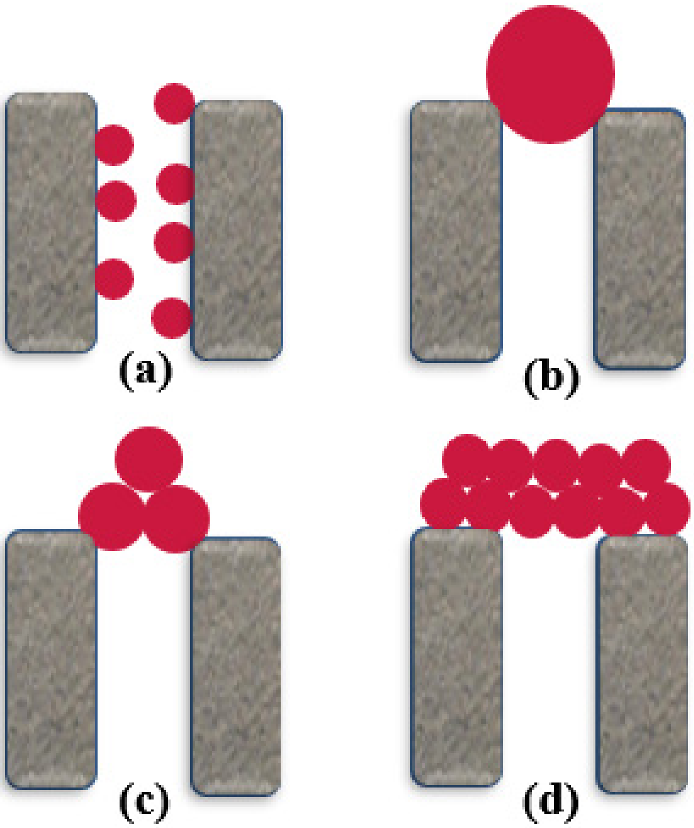

Figure 1. Pore blocking mechanisms: (a) standard blocking; (b) complete blocking; (c) intermediate blocking; (d) cake formation (Koonani and Amirinejad, 2019).

Mechanism	Model	Eq.
Standard blocking	$J = J_0\left[1+\frac{1}{2}k_s(AJ_0)^{1/2}t\right]^{-2}$	(1)
Complete blocking	$J = J_0\exp(-k_b t)$	(2)
Intermediate blocking	$J = J_0[1+k_i(AJ_0)t]^{-1}$	(3)
Cake formation	$J = J_0\left[1+2k_c(AJ_0)^2 t\right]^{-1/2}$	(4)

Table 1. Mechanisms related to pore blocking.

microfiltration results from experimental runs obtained at 3M do Brazil. Wendriner used red wine, brand Zago, 2014. The filter medium was membrane type 90 S, with 17.34 cm^2 filtration area and pore diameter range between 0.05 to 0.3 µm, subjected at 21 °C and feed pressure (P) equal 15 and 30 psi, in the experimental system illustrated in Figure 2.

The crude wine sample was placed in a pressure vessel. After pressurizing the system and opening the valve, the crude wine passed through the filter medium, whose permeate was collected in a beaker. The instant the first drop of filtrate fell into the beaker, the stopwatch was started, and the filtration time was recorded for each permeate volume (Wendriner and Cremasco, 2015).

RESULTS AND DISCUSSION

The results of crude wine microfiltration at 21 °C and operational pressures equal 15 psi and 30 psi are shown in Figures 3 and 4. In both figures, J refers to the filtration velocity (Q/A), with Q permeate volumetric flow rate and A, the filtration area.

The evaluation of the models presented in Table 1 occurs by linearization of the equations present there according to

$$y = ax + b \tag{5}$$

whose y, x, a, and b parameters for each model are presented in Table 2. From the data that generated Figures 3 and 4 as well as considering the linearization according to Equation 5, the respective representations were constructed as shown in Figures 5 to 12. Due to the lines associated with such figures, were verified the determination coefficient, R^2, are shown in Table 3. This table presents the best model to describe, at 15 psi, is the intermediate pore blocking with $R^2 = 0.9926$, $a = 0.0116\ s^{-1}$ and $b = 25.858$ s/cm. For 30 psi pressure, the mechanism is the cake formation

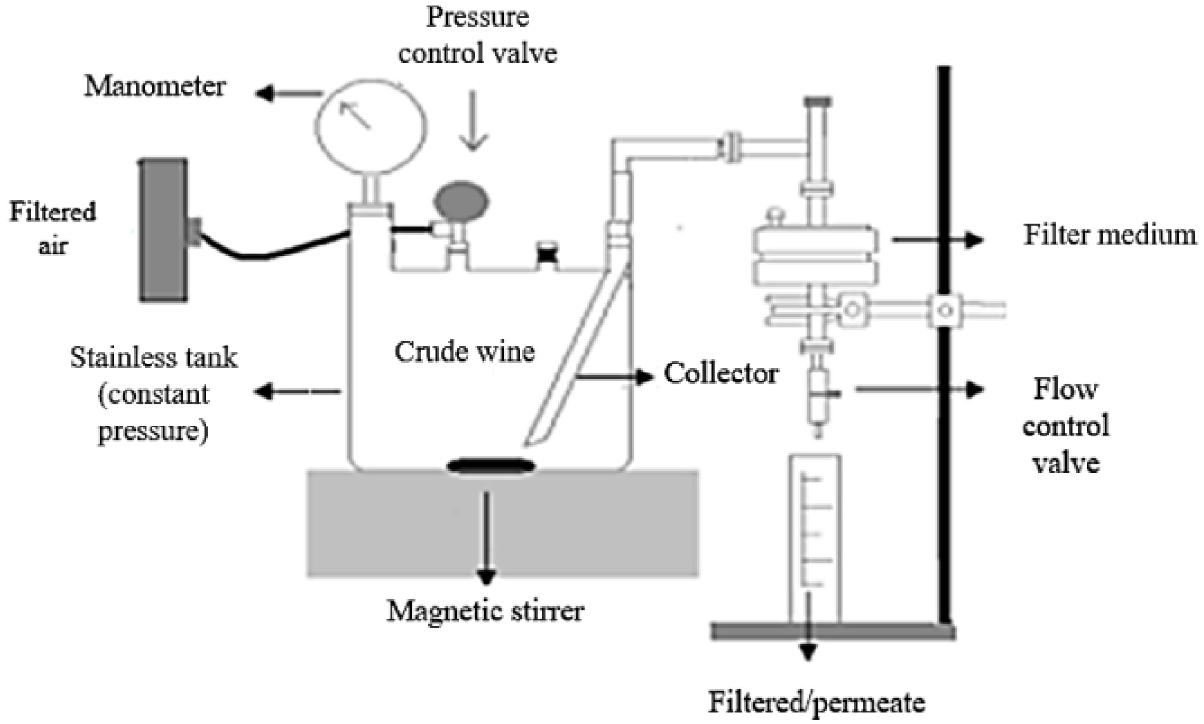

Figure 2. Filtration system.

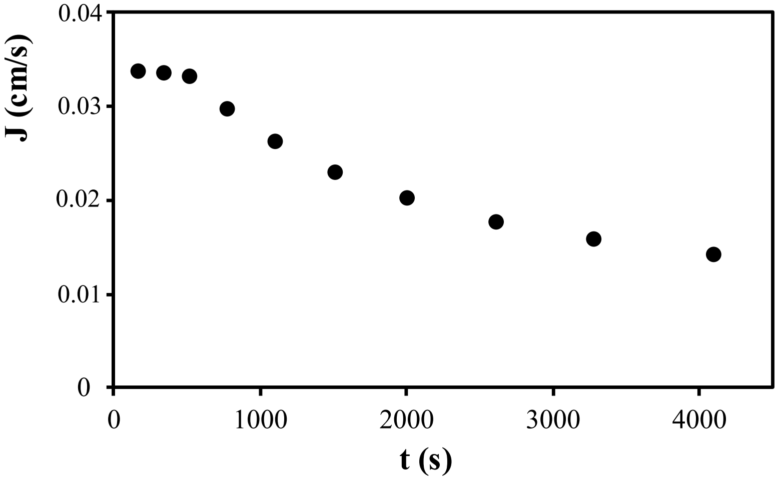

Figure 3. Crude wine microfiltration: P = 15 psi.

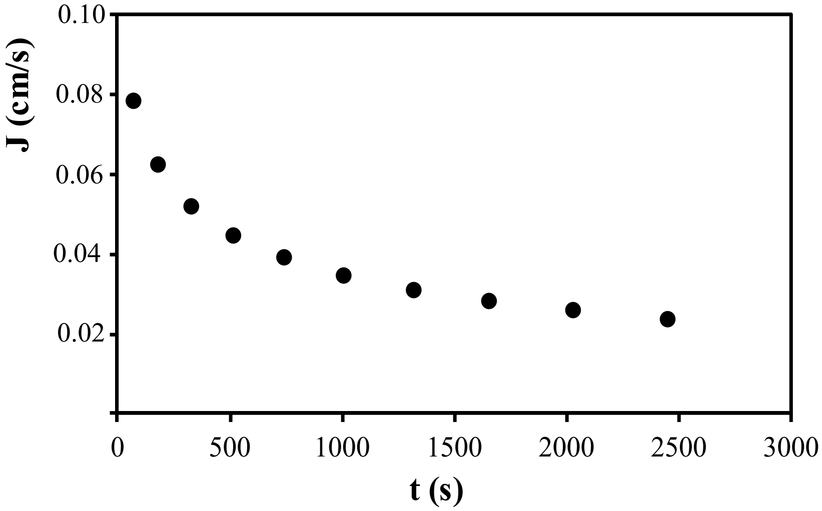

Figure 4. Crude wine microfiltration: P = 30 psi.

Mechanism	y	x	a	b
Standard blocking	$1/J^{0.5}$	t	$0.5k_sA^{0.5}$	$1/J_0^{0.5}$
Complete blocking	$-\ln(J)$	t	k_b	$-\ln(J_0)$
Intermediate blocking	$1/J$	t	k_iA	$1/J_0$
Cake formation	$1/J^2$	t	$2k_cA^2$	$1/J_0^2$

Table 2. Mechanism models parameters.

Mechanism	P = 15 psi	P = 30 psi
Standard blocking	0.9874	0.9347
Complete blocking	0.9744	0.8878
Intermediate blocking	0.9926	0.9713
Cake formation	0.9890	0.9992

Table 3. Determination coefficient, R^2.

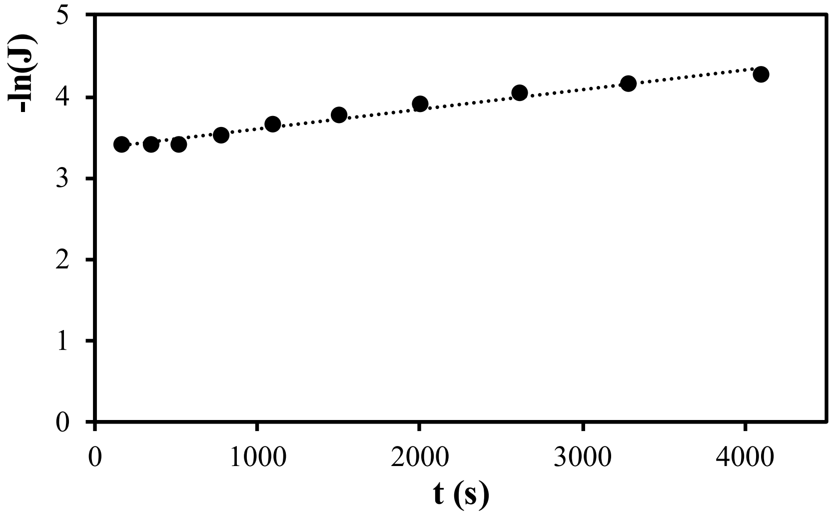

Figure 5. Performance of the complete blocking model: P = 15 psi.

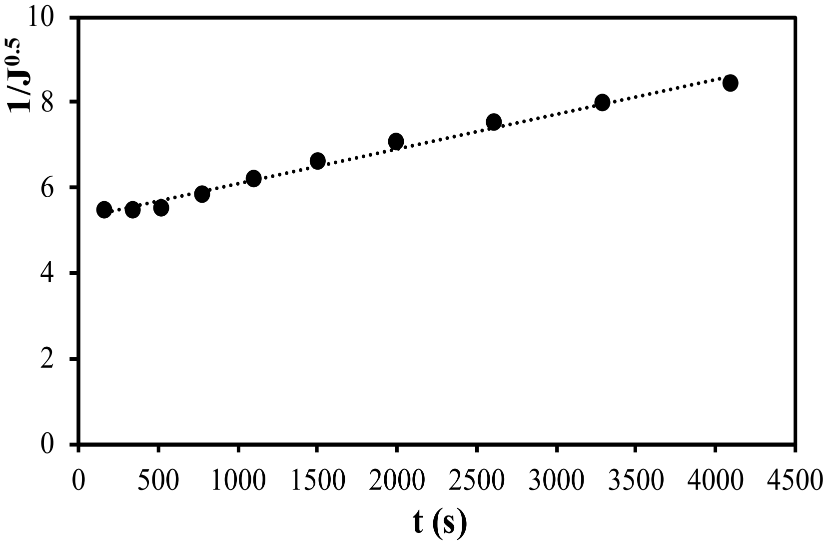

Figure 6. Performance of the standard blocking model: P = 15 psi.

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.317222230013

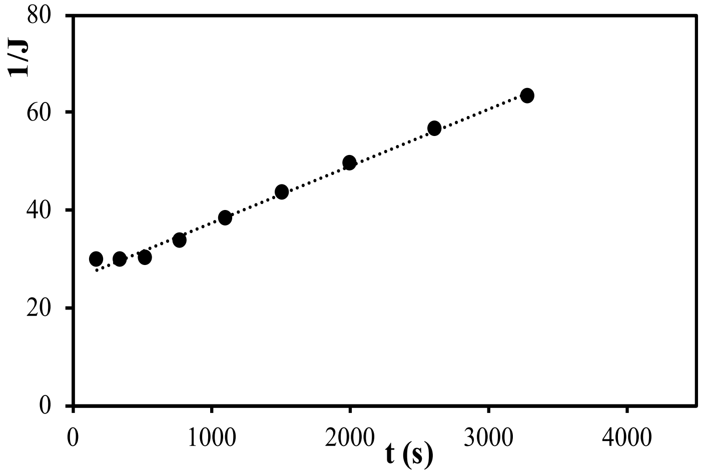

Figure 7. Performance of the intermediate blocking model: P = 15 psi.

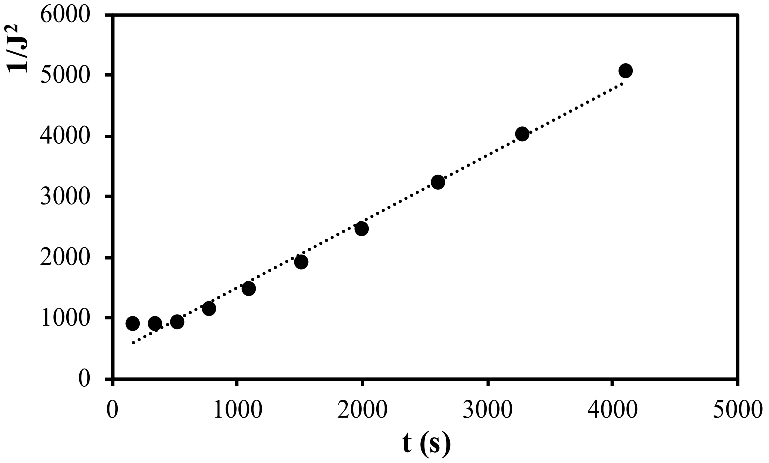

Figure 8. Performance of the cake formation model: P = 15 psi.

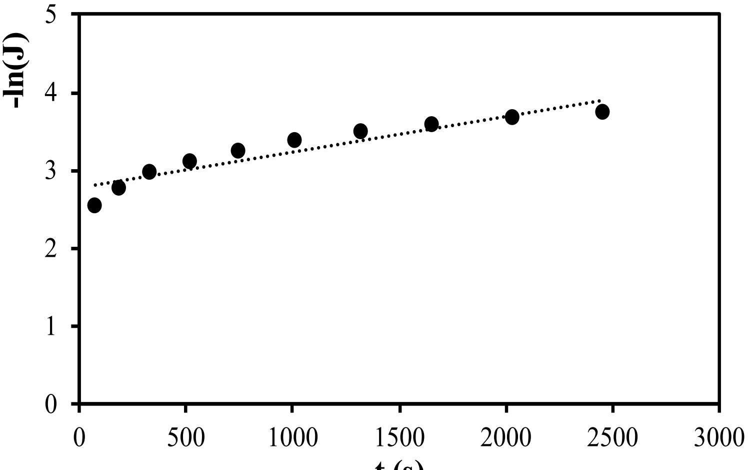

Figure 9. Performance of the complete blocking model: P = 30 psi.

DOI 10.22533/at.ed.317222230013

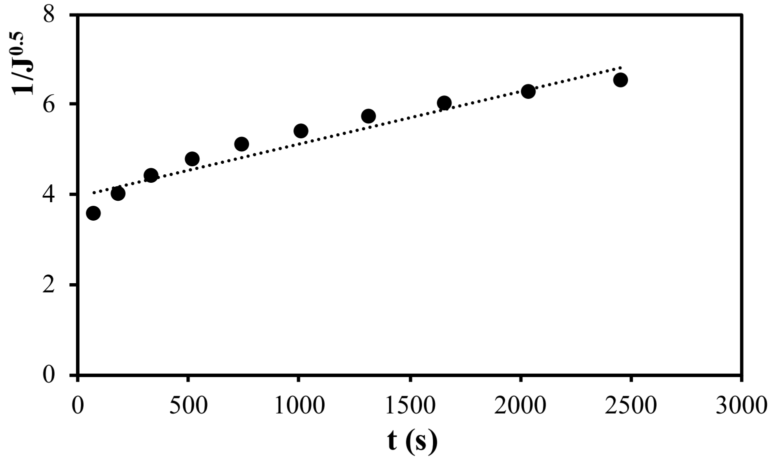

Figure 10. Performance of the standard blocking model: P = 30 psi.

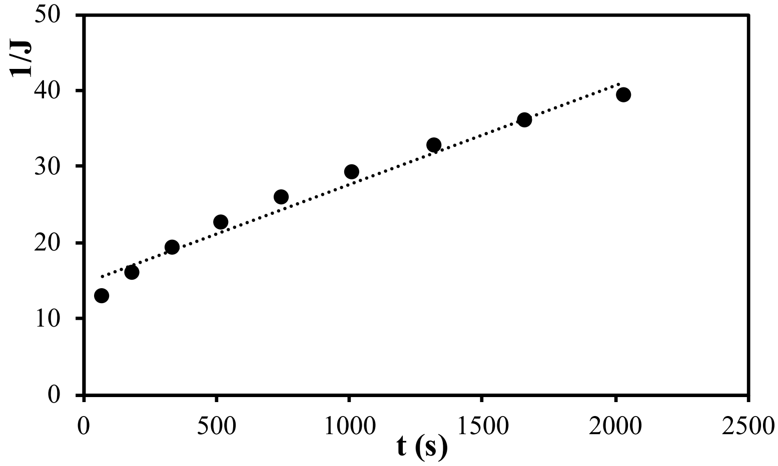

Figure 11. Performance of the intermediate blocking model: P = 30 psi.

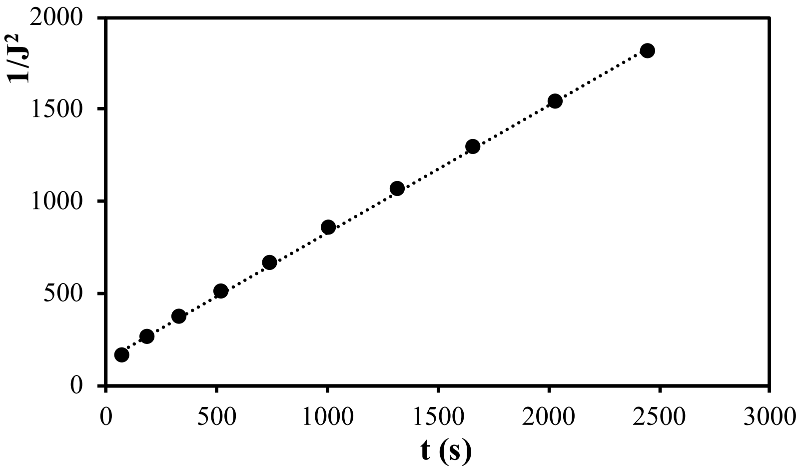

Figure 12. Performance of the cake formation model: P = 30 psi.

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.317222230013

($R^2 = 0.9992$) with a = 0.6888 s^{-1} and b = 141.65 s/cm.

It is necessary to highlight that pressure when increases it compresses the filter medium, altering its structure, even modifying the pore structure, in order to facilitate their depositing on its surface, as verified when operating at 30 psi. By decreasing the operational pressure applied to the filter medium, P = 15 psi, the particles tend to occupy the pores as well the membrane surface, however, not with the same intensity when compared to the action at P = 30 psi.

CONCLUSION

The pore blocking mechanism of filter medium identified in wine processing is fundamental for improving its quality, which depends on the filter medium porous nature. In this work, classical models were analyzed to verify the best mechanism that describes the specific crude wine microfiltration, and it was possible to identify that it depends strongly on the operational pressure, clearly indicating that high pressure leads to cake formation, adding undesirable resistance for its purification by microfiltration and compromising the wine quality.

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