Saturation process of ozone and effect on quality in common beans

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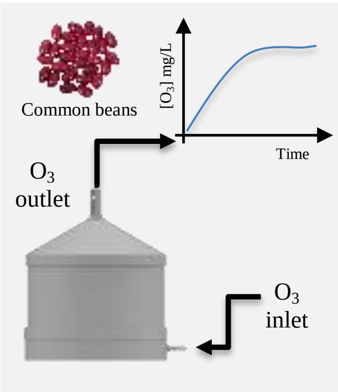

The objective of this work was to characterize the saturation process of ozone at different specific rates for common beans and to evaluate the quality of the grains. The inlet concentration was 10 mg L^{-1}, for specific flow rates of 0.3 and 1.0 m^3 min^{-1} t^{-1}. The time and concentration of saturation were determined. The water content and electrical conductivity of the grains were determined. For the specific flow rate of 0.3 m^3 min^{-1} t^{-1}, the time and concentration of saturation were 19.43 min and 7.10 mg L^{-1}, respectively. For the specific flow of 1.0 m^3 min^{-1} t^{-1}, values equal to 16.79 min and 7.14 mg L^{-1} were obtained for time and concentration of saturation, respectively. The saturation process of ozone for common beans was not influenced by the specific flow rate. The ozonation did not affect the quality of the grains, considering the water content and the electrical conductivity.

Introduction

Common kidney beans (*Phaseolus vulgaris* L.) are one of the most cultivated and consumed legumes worldwide [1]. However, the availability of beans for human consumption is limited due to losses during storage, especially due to pest attacks such as microorganisms and insects [2].

In this scenario, it is essential to adopt techniques for pest control during the storage of bean grains. Ozonation has been studied for pest control in stored grains. Some authors demonstrated that ozone is effective in inactivating fungi and controlling insects in grains [3,4].

However, the saturation process of ozone and changes in quality must be studied for the different grains, considering the influence of chemical composition and physical properties. Thus, the objective of this study was to describe the saturation process of ozone in common beans and to determine the effects on the quality of the grains.

Material and Methods

In the experiment, grains of common beans (*Phaseolus vulgaris* L.) were used. Ozone was produced in an ozone generator model M10 (myOZONE, Jaguariúna, Brazil), using oxygen, obtained from an oxygen concentrator model EverFlo (Philips Respironics, Murrysville, USA). Ozone concentration was measured by the iodometric method [5].

In the ozonation of the grains, samples of 3.0 kg previously placed in PVC prototype (0.20 m in diameter and 0.20 m in height) were used. The inlet concentration (C_0) was 10 mg L^{-1}, with specific flow rates of 0.3 and 1.0 m^3 min^{-1} t^{-1} for 30 h. In the control treatment, oxygen was used. In the evaluation of the saturation process, the time and concentration of saturation were determined [6]. For quality evaluation of the grains, water content and electrical conductivity were evaluated, and the exposure periods were 0, 5, 10, 20 and 30 h.

Results and Discussion

The residual concentration of ozone as a function of time for common beans followed a trend similar to that observed by other authors for peanuts and common corn [4,6].

As for the time and concentration of saturation (Table 1), no effect of the specific flow rate was observed for common bean. These results may be associated with the low reactivity of ozone in the porous medium formed by this type of grain. Saturation time of 19.46 and 16.79 min were obtained for the specific flows of 0.3 and 1.0 m^3 min t^{-1}, respectively. Regarding the saturation concentration (C_{sat}), the estimated values were equivalent to 7.10 and 7.15 mg L^{-1}, for the specific flows of 0.3 and 1.0 m^3 min^{-1} t^{-1}, respectively. It is also obtained that C_{sat}/C_0 values equal to 0.71 and 0.69 were obtained for the specific flows of 0.3 and 1.0 m^3 min^{-1} t^{-1}, respectively. These values are lower than those obtained by Abreu et al. who found a C_{sat}/C_0 ratio for cowpea grains in the range of 0.47 to 0.64 for of 0.5 to 3.5 mg L^{-1} of ozone, respectively [7]. These results showed that the grains used in this study are less reactive than cowpea grains.

The exposure period to ozone did not significantly affect the water content of the grains when the gas was injected at the specific flow rate of 0.15 m^3 min^{-1} t^{-1} (Table 2). When the specific flow rate of 1.0

m^3 min^{-1} t^{-1} was used, there was a reduction in water content as a function of the exposure period in the treatment with ozone and oxygen (control). The electrical conductivity increased in both ozone treatment conditions (0.3 and 1.0 m^3 min^{-1} t^{-1}) (Table 2). The grains treated with ozone at the specific flow rate of 0.3 m^3 min^{-1} t^{-1} showed higher conductivity values compared to the samples treated with ozone gas at the specific flow rate of 1.0 m^3 min^{-1} t^{-1}, as the exposure period increased.

Table 1. Adjusted regression equations and respective coefficients of determination (R^2) for residual ozone concentration (mg L^{-1}) as a function of time (min) of exposure in common beans, for different specific flow rates at the inlet concentration of 10 mg L^{-1}

Specific flow rate m^3 min^{-1} t^{-1}	Adjusted equations	R^2	P	SEE	t_{Sat} (min)	C_{Sat} (mg L^{-1})	C_{Sat}/ C_0
0.3	$\hat{y} = \frac{8.06}{\left(1 + e^{-\left(\frac{t-10.51}{4.46}\right)}\right)}$	0.90	<0.0001	0.57	19.46	7.10	0.71
1.0	$\hat{y} = \frac{8.12}{\left(1 + e^{-\left(\frac{t-1.66}{7.57}\right)}\right)}$	0.90	<0.0001	0.56	16.79	7.15	0.69

t_{Sat} - saturation time; C_{sat} – Saturation concentration; C_0 - Inlet concentration; SEE – Standard Error of the Estimate; P – p value; R^2 - Coefficient of determination.

Table 2. Regression equations adjusted for water content and electrical conductivity of grains as a function of ozone exposure period at a concentration of 10 mg L^{-1} and specific flow rates of 0.3 and 1.0 m^3 min^{-1} t^{-1}

Specific flow rate (m^3 min^{-1} t^{-1})	Treatments	Adjusted equations	R^2	P	SEE
		Water content (%)			
0.3	Oxygen	$\hat{y} = 14.23 - 0.40 \cdot 10^{-3ns}x$	0.87	0.0500	0.17
	Ozone	$\hat{y} = 14.27 - 0.20 \cdot 10^{-3ns}x$	0.64	0.2416	0.18
1.0	Oxygen	$\hat{y} = 14.30 - 0.70 \cdot 10^{-3*}x$	0.97	0.0189	0.19
	Ozone	$\hat{y} = 14.45 - 1.10 \cdot 10^{-3*}x$	0.98	0.0035	0.18
		Electrical conductivity (µS cm^{-1} g^{-1})			
0.3	Oxygen	$\hat{y} = 65.25 - 2.70 \cdot 10^{-3\,ns}\,x$	0.47	0.4142	4.12
	Ozone	$\hat{y} = 63.90 + 8.50 \cdot 10^{-3**}x$	0.98	0.0024	1.27
1.0	Oxygen	$\hat{y} = 61.80 - 1.90 \cdot 10^{-3\,ns}\,x$	0.59	0.2864	2.13
	Ozone	$\hat{y} = 63.55 + 5.50 \cdot 10^{-3**}\,x$	0.96	0.0094	0.96

* Significant at 5% probability by t-test ($P < 0.05$);** Significant at 1% probability by t-test ($P < 0.01$); ns Not significant at 5% probability by t-test ($P > 0.05$); R^2 - Coefficient of determination; SEE – Standard Error of the Estimate; P – p value.

Conclusions

The saturation process of ozone in common beans was not influenced by the specific flow rate. The ozonation did not affect the quality of the grains, considering the water content and the electrical conductivity.

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