Application of AISI 316 stainless steel in building a alcohol mini distillery and a compact plant for biodiesel production

Aplicação do aço inoxidável AISI 316 na construção de uma mini destilaria de álcool e uma usina compacta para produção de biodiesel

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Abstract

Previous work of the group showed that the stainless steel presents low corrosion, so it is the most suitable material for use in the construction of: container, tanks, vats and other systems to be used for biodiesel storage. The aim of this work is to study the corrosion resistance and efficiency of ethanol production and biodiesel with the use of austenitic stainless steel AISI 316 SS in a mini distillery and a compact plant to produce biodiesel. Were employed as techniques: optical analysis, gravimetric analysis, physical-chemical analysis to compliance of biofuel, the alcohol content of ethanol and biodiesel production yield. The low cost and excellent corrosion resistance of AISI 316 SS suggest to the construction of mini power plants with this metallic material for small farms, allowing the use of biofuels and minimizing the costs thereof.

Keywords: *corrosion, ethanol, environmental, social and biofuel.*

Resumo

Os trabalhos anteriores do grupo mostraram que o aço inoxidável apresenta baixa corrosão, por isso é o material mais adequado para uso na construção de: container, reservatórios, cubas e outros sistemas a serem utilizados para o armazenamento de biodiesel. O objetivo deste trabalho é estudar a resistência à corrosão e a eficiência da produção de etanol e biodiesel com a utilização de aço inoxidável austenítico AISI 316 em uma mini destilaria e uma fábrica compacta para produzir biodiesel. Foram empregadas técnicas como: análise ótica, análise gravimétrica, análise físico-química para o cumprimento de biocombustível, a teor alcoólico do etanol e do rendimento de produção de biodiesel. O baixo custo e excelente resistência à corrosão do AISI 316 sugerem a construção de miniusinas com este material metálico para as pequenas explorações, permitindo a utilização de biocombustíveis e minimizando os custos da mesma.

Palavras-chave: *etanol, corrosão, ambientais, sociais e de biocombustíveis*

Introduction

Biodiesel is an alternative fuel for diesel engines made from renewable biological sources such as vegetable oils and animal fats, in addition to being biodegradable, nontoxic and has low emission of toxic gases. (RODRIGUES, 2006; NETO, 1999).

Biodiesel is naturally cleaner by reducing greenhouse gas emissions compared to petroleum derivatives, and have high ability to lubricate the engine or engines reducing possible damage, it is safe to transport because it is biodegradable, nontoxic and non-explosive or flammable at room temperature, do not contribute to acid rain by not showing sulfur in its composition (RODRIGUES, 2006; RAMALHO, 2006; NICODEM, 1997).

Due to the increase in the amount of biodiesel produced and consequently stored in metal tanks, one should take some precautions with regard to quality control of biodiesel, as this not in an appropriate pH standards but can oxidize the tanks, causing problems for fuel distributors (GALLINA *et.al.,* 2010; HERNANDEZ, 2008; MITTELBACH and GANGL, 2001).

Another biofuel that care should be taken with respect to corrosion is ethanol, which must pass a rigorous quality control process so that you can not cause any technical problem the distributors and distillation plants and ethanol production (ANP, 2010 COSTA NET., 2000*;* FARIA, 2002).

In this study we evaluated various situations, was first tested when the corrosion of biodiesel were immersed in 316 stainless steel plates and carbon steel. For the tests with ethanol were immersed plates of 316 stainless steel at different temperatures in order to assess the power of corrosion ethanol.

Materials and Methods

For the production of biodiesel, we used the method of transesterification, converting the vegetable oil into an ester fuel when it is placed in the presence of alcohol and a catalyst. The reagents used were refined soybean oil, ethanol and potassium hydroxide. Glycerin was separated in biodiesel by decanting. After this separation biodiesel was washed with a solution of ascorbic acid $1x10^{-2}$ mol L^{-1}, the acid was chosen because in previous work this was the acid that contributed least to the corrosion of stainless steel biodiesel. After washing the biodiesel was separated by decantation. The flowchart of this process is shown in Figure 1 *(GALLINA,* 2010; SCHUCHARDT, 1998; ENCINAR, 2002).

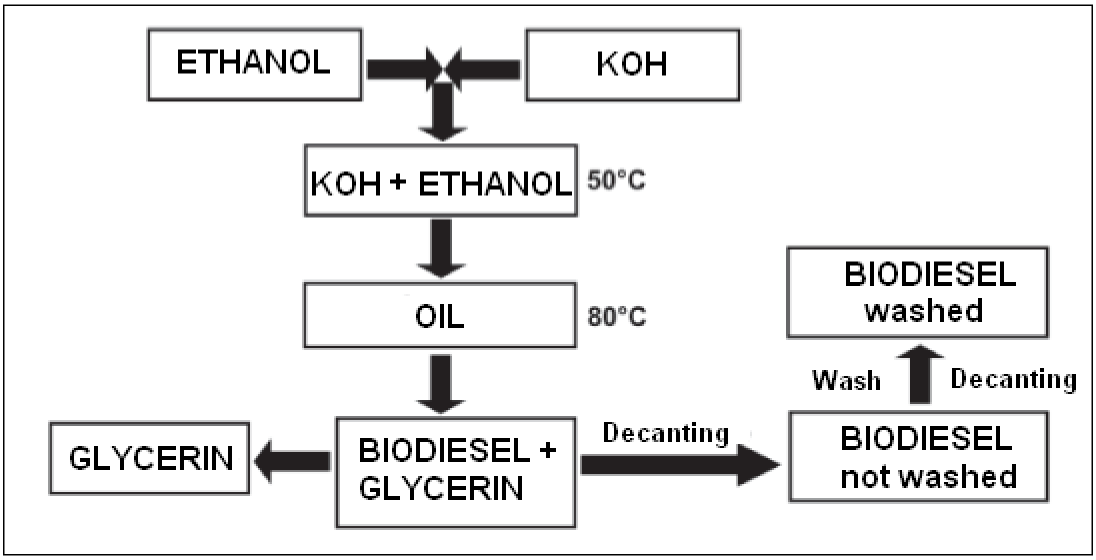

Figure 1 - Flowchart for obtaining washed biodiesel (GALLINA, 2010).

The ethanol samples were obtained from the mini distillery, which was developed in steel AISI 316 SS and is being used at the State University of the Midwest, UNICENTRO, Guarapuava - PR, in partnership with the Federal Government, the distillation of alcoholic beverages unlawful and seized, which were previously destroyed and transformed into biofuel for the University.

The test used for the corrosion of biodiesel and ethanol, followed the ABNT NBR 14 359, but the testing time was extended from 3h to 72h for all samples.

Gravimetric analysis and were subsequently optically (100-fold increase), were also taken pictures of biodiesel before and after immersion to determine the color of it. We used the visual method to characterize the color of the biodiesel samples before and after immersion. The areas of the stainless steel plates were on average 5.03 cm^{-2} and carbon steel plate 2.77 cm^{-2}.

For samples of alcohol were performing the same procedures, but in three distinct temperature ranges: 100 ° C ± 2 º C, 70 ° C ± 2 º C and 25 ° C ± 2 º C. Due to the problem of evaporation of ethanol at temperatures higher than 70 ° C was constantly measured the volume of the experimental cell.

Results

In the table 1 are shown the results of gravity tests.

Table 1 - Data and gravimetric corrosion rate for samples immersed in different samples and temperatures.

Sample	Biofuel	Temperature (ºC)	*V_{corr} ($g.cm^{-2}.min^{-1}$)
SS	Biodiesel	100	1.67 $x10^{-6}$
Carbon Steel	Biodiesel	100	9.78 $x10^{-6}$
SS	Ethanol	100	8.57 $x10^{-7}$
SS	Ethanol	70	4.70 $x10^{-7}$
SS	Ethanol	25	3.23 x10 -7

*V_{corr} = corrosion rate, calculated as the ratio between the difference in mass and area of the part multiplied by the time the samples were immersed.

Figure 2 and 3 show the optical analysis performed for the metal parts studied.

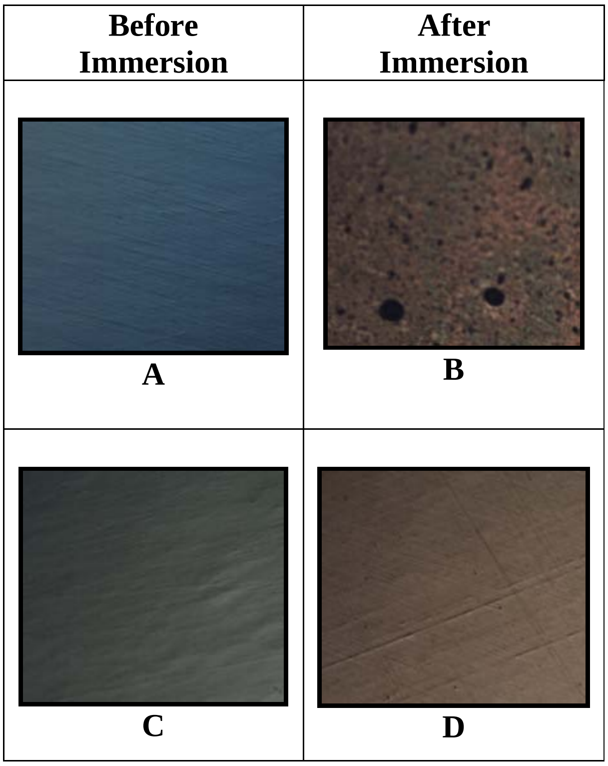

Figure 2 - Analysis optical plates of stainless steel and carbon steel immersed in biodiesel. (A) Carbon steel, (B) Carbon steel, into biodiesel at 100 º C, (C) 316 stainless steel, (D) 316 stainless steel in biodiesel to 100 º C. All with an increase of 100 times.

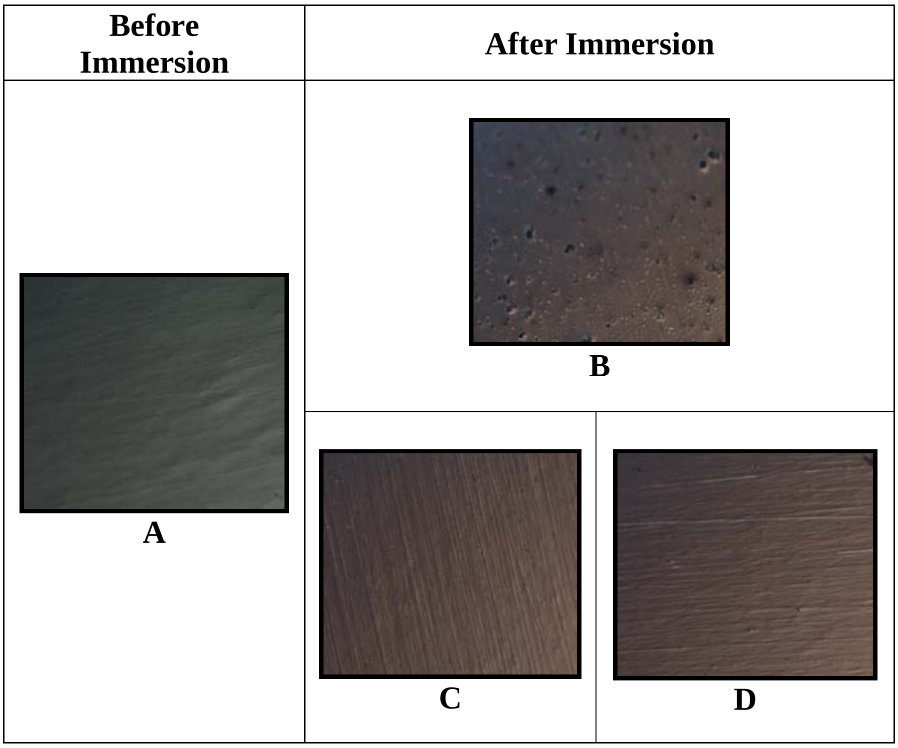

Figure 3 - Analysis optical plates of stainless steel and carbon steel immersed in ethanol. (A) Stainless steel 316, (B) 316 stainless steel at 100 º C, (C) 316 stainless steel at 70 º C, (D) Stainless steel 316 at 25 º C. All with an increase of 100 times.

Figure 4 represents the relationship between the rates of corrosion of carbon steel stainless steel compared with 316 ss in biodiesel.

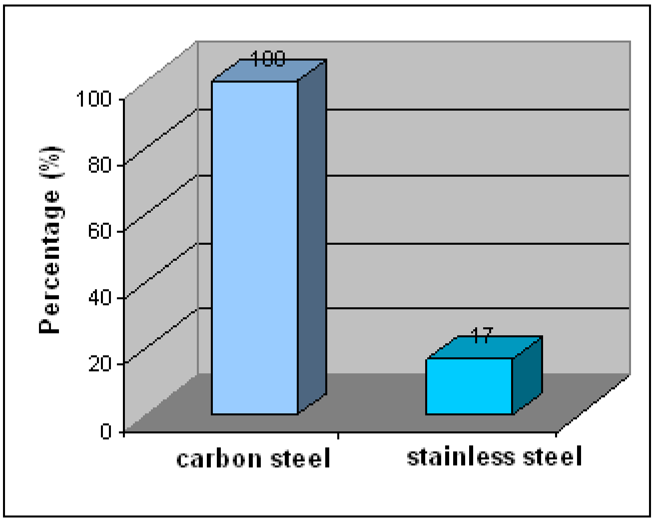

Figure 4 - Comparison between the rates of corrosion of carbon steel and 316 stainless steel, taking into account that the rate of corrosion of carbon steel is 100% by grating the data in table 1.

Figure 5 shows the color differences of biodiesel, after the tests with the metallic plates of 316 stainless steel and carbon steel.

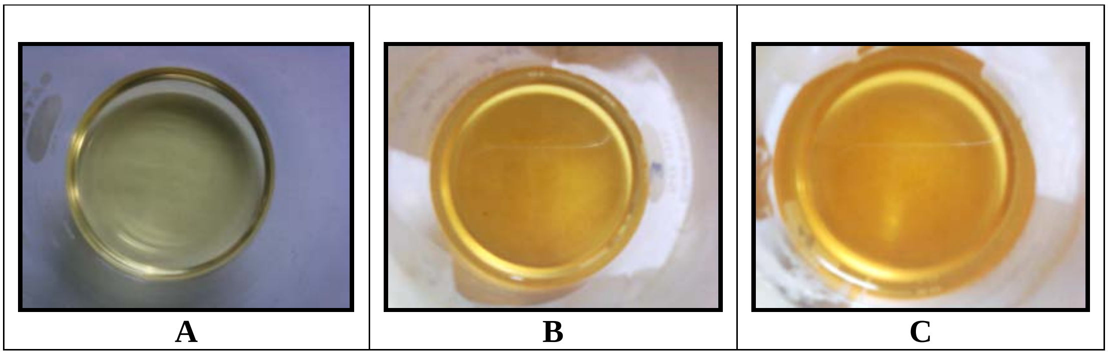

Figure 5 - Stains of biodiesel samples after being immersed the metal plate. (A) Biodiesel before immersion, (B) Biodiesel after immersion of stainless steel, (C) Biodiesel after the immersion of carbon steel.

In Tables 5 and 6 are presented the results of compliance for the fuel ethanol and biodiesel, respectively.

Table 2 - Results of compliance for hydrous ethanol produced by the mini distillery UNICENTRO.

Product: HYDRATED ALCOHOL FUEL				
Feature	**Method**	**Specification**	**Result**	**Unit**
Visual Appearance	Visual	Clear and free of impurities	Clear and free of impurities	- -
Color Visual	Visual	Colorless	Colorless	- -
Specific gravity at 20 ° C	ASTM D 4052	807.6 to 811.0	812.0	$Kg.m^{-3}$
Alcohol content	NBR 5992	92.6 to 93.8	92.1	º INPM
pH	NBR 10891	7.0 ± 1.0	6.2	- -
Electrical conductivity	ASTM D 1125	500 max.	144	mS/m

Table 3 - Results of compliance for B100 biodiesel used in the experiments.

PRODUCT: BIODIESEL B100				
Feature	**Method**	**Specification**	**Result**	**Unit**
Aspect	Visual	Clear and free of impurities	Clear and free of impurities	- -
Color	Visual	Yellowish	Yellowish	- -
Specific gravity at 20 ° C	NBR 7148	820-880	875.4	$Kg.m^{-3}$
Flash point minimum	ASTM D 56	100	102	ºC
pH	NBR 10 891	7.0 ± 1.0	7.0	- -

In Figure 6 presents pictures of the reactor of carbon steel and stainless steel biodiesel plant and the pictures of the mini ethanol distillery in stainless steel.

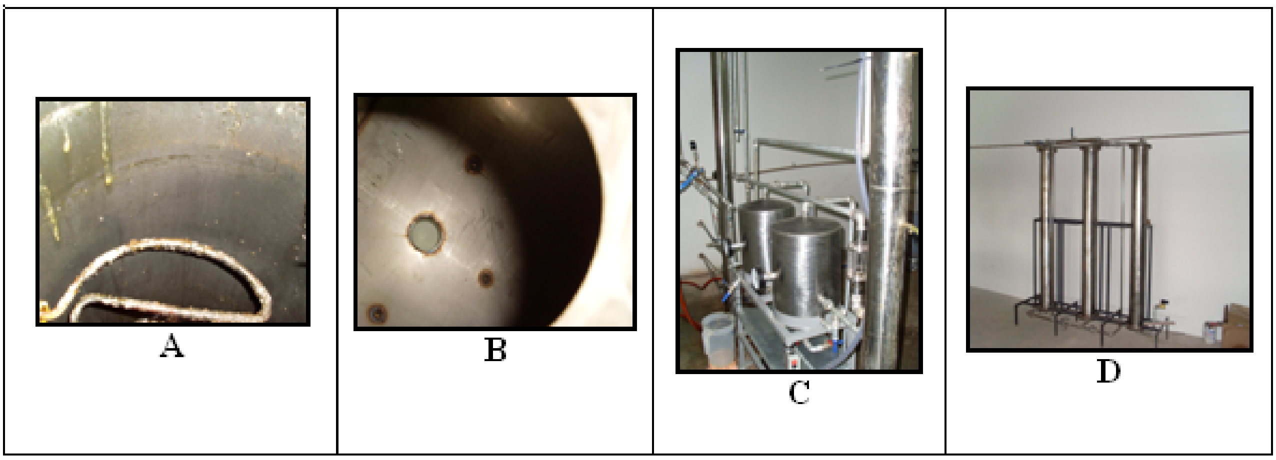

Figure 6 - Photos of equipment used in biodiesel plants and alcohol distilleries. (A) of the reactor biodiesel plant in carbon steel, (B) of the reactor biodiesel plant in stainless steel (C) Mini plant distillation of ethanol; (D) fractionation columns in stainless steel.

Discussion

It can be observed in Figure 5 the change in color of the biodiesel before and immediately after the immersion of pieces of stainless steel and carbon steel, there is a coloration that evolved from a yellow to an orange color due to the presence of ions in solution (GALLINA, 2010). Note also that the color orange is more intense in the biodiesel that was immersed in a piece of carbon steel, suggesting that there was a more pronounced oxidation.

According to the results in Table 1, one can verify that the biodiesel to the corrosion rate is more pronounced for the piece of carbon steel, which is also justified when looking at the photo optics with 100 times magnification, where confirms the larger pieces of steel corrosion in carbon compared to 316 stainless steel parts, see Figure 2.

Should take into account that biodiesel is used within the compliance required by the National Agency of Petroleum, Natural Gas and Biofuels - ANP, presented in table 3. Results of strength and density are therefore outside the specifications of the ANP, as is still being made adjustments in the course of the distillation column so that the alcohol content, which today is around 92% v / v, to increase the range proposed by ANP is between 92.6 to 93.8% v / v, see Table 2.

It appears that for the parts immersed in ethanol by increasing the speed of corrosion according to the temperature increases (Table 1), it is also suggested when analyzing the photos with 100 times magnification in Figure 3. Note that there are points of corrosion more pronounced when ethanol was heated to 100 ° C, possibly due to the presence of water at a rate of approximately 10% (Table 2) in ethanol could be accelerating the oxidation.

The results led to propose that the stainless steel is used for the construction of biodiesel plants is that the rate of corrosion of stainless steel for biodiesel is 17% when compared to carbon steel, this is shown in Figure 4.

All data presented justify the reconstruction of the biodiesel plant and the constructions of mini distillery for ethanol recovery from the UNICENTRO - State University of the Midwest, see Figure 6.

Conclusions

(1) The corrosion of steel 316 is smaller than that observed in carbon steel, storage and production of biodiesel, justifying the use of 316 stainless steel in construction of mini biodiesel plants;

(2) The low corrosion rate recorded for the 316 system in ethanol shows the noble use of this material for construction of mini power plants for distillation and recovery of ethanol.

Acknowledgments

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