World Conference on Timber Engineering
Oslo 2023

CORROSION INHIBITOR POTENCIAL WITH BOLDO BRASILEIRO COMPARED TO COMMERCIAL INHIBITOR OI WOOD CONNECTIONS

Letícia Costa[1], Ana Farias[2], Antonio da Silva[3], Francisco Lahr[4]

ABSTRACT: The corrosion caused in metallic elements in connection with wood is a relevant fact for scientific research, since this problem directly affects the strength and service life of structures. When metal alloys are subjected to wood, exposure to corrosion is noticeable, due to the presence of water and oxygen in the cellular structure of wood, as well as chemical reactions between its constituents. Although metals have definite and advantageous mechanical properties, they are still not sufficient to contain the oxidation content. It is observed that these connecting pieces embedded in wood present easy degradation, bringing high economic, environmental and technological costs in their maintenance or replacement. Through analysis, a comparison was made between the corrosion rates and protection efficiency of different corrosion inhibitors that are often marketed, replacing them with green inhibitors, also known as natural inhibitors, used to prevent the corrosion process in metals. In the tests, several specimens were tested, with and without the presence of the natural additive, thus being able to evaluate satisfactory results in which the extract plectranthus barbatus Andrews, also known as Brazilian boldo, formed a protective layer on the metals. In summary, it is notorious that these natural inhibitors do not harm the environment, as well as economic advantages when compared to the commercial inhibitor, which is harmful and toxic to the environment.

KEYWORDS: **Corrosion, natural inhibitors, plectranthus barbatus Andrews.**

1. INTRODUCTION

Wood is a precursor material, widely used in civil construction. It has several applicability because it is a massive and versatile element, used in structures, especially in roofs or finishes (MATIELLO and NESPOLO, 2015). According to Nagaoka (2014), wood has been a material that is not very resistant, but with a high market value, generally used in craft techniques. In countries in the northern hemisphere, it is also used as a structural material, due to its technological devices. Its geometry, areas and proportions allow the creation of different parts, and allows the realization of amendments and/or connections with metallic elements that make up the structure. On the other hand, it is observed in several conventional constructions the use of nails, pegs and screws, which are interconnection components for elements that have the same material or different materials. For large industries, a good example of this, which has the possibility of quick assembly and standardization in the connections, are the Gang Nail connectors, an element made of hot-dip galvanized steel. In general, steels are widely sold in several industrial sectors due to their other properties and resistance to the effects of corrosion and oxidation. In theory, they are alloys composed of iron and carbon, which respond positively to the way they are exposed to weather and stress, as a result of their composition, microstructure, morphology, electrical resistivity, heat treatments, among other factors. The metallic elements are fundamental pieces that strongly contribute to the wood-metal junction, making it a technological and comprehensive innovation. In the constructive system, the combination of these materials can cause a series of damages in the structures, due to a phenomenon called corrosion (NAPPI, Manuela Marques Lalane et al, 2012)3It is known that despite the high resistance of metals, corrosion is a redox process that occurs in the

[1]Letícia do Nascimento Costa, Graduate Student, Federal Institute of Maranhão (IFMA), São Luís – Maranhão, Brazil, c.leticia@acad.ifma.edu.br

[2]Ana Patrícia Pinto Farias, Master in Analytical Chemistry (PPGQUIM) at the Federal University of Maranhão (UFMA), São Luís- Maranhão, Brazil, ana004397@ceuma.com.br

[3]Antonio Jorge Parga da Silva, Ph.D. Federal Institute of Maranhão (IFMA), São Luís – Maranhão, Brazil, parga@ifma.edu.br

[4]Francisco Antonio Rocco Lahr, Ph.D. USP-SC, São Carlos – São Paulo. frocco@sc.usp.br

https://doi.org/10.52202/069179-0126

midst of natural agents, and thus compromises the performance and functionality of the material. Therefore, the present work aimed to study corrosion in marine environments, since seawater has a high concentration of sodium chloride (NaCl), magnesium chloride (MgCl2), magnesium sulfate (MgSo4), calcium sulfate (CaSo4), potassium chloride (KCL) and other dissolved and particulate gases. It is noteworthy that the atmospheric environment also influences the high percentage of relative humidity, solar radiation and tidal effects. According to De Melo, Grazielma Ferreira; et al (2021, p.68) are "factors that act as propellants and catalysts in the corrosion process". Therefore, the following research has investigative data sources for the plectranthus barbatus Andrews extract, also known as Brazilian Boldo, against corrosive media to inhibit the corrosion process in metals, acting as a protective layer. Among the metals, galvanized steel was studied, which served as studies for testing specimens together with the natural extract, serving as a main additive in the concentration that will be mentioned in topic 3 of the methodology. But before, it will be presented in topic 2, the materials that were made to obtain the specimens.

2. MATERIALS

2.1 PLECTRANTHUS BARBATUS ANDREWS

The Plectranthus barbatus Andrews also known as Brazilian Boldo, from the lamiaceae family, originating in Africa is widely used in Brazilian territory. Because it is a bushy, aromatic, perennial plant with erect branches, it can reach a height of up to 1.5 meters, has oval, hairy and thick leaves, its flowers have a bluish color and grow like spikes in rainy seasons. Plectranthus barbatus Andrews is an herb recognized in Brazil as a medicine for the treatment of liver diseases, infections, liver problems and food digestion. Due to the presence of flavonoids, tannins and alkaloids in their composition, these substances have antioxidant actions, making the natural extract an excellent inhibitor in combating corrosion, which justifies and makes it important to study this plant, since it has a good inhibition efficiency shown in previous researches.

2.2 GALVANIZED STEEL

Galvanized steel is a material that undergoes several processes, one of which is the galvanizing process where it is coated with a very thin layer of zinc, which provides resistance against corrosion. Steel itself is a material that is widely marketed and used in building structures. It is worth remembering that its initial material, which is iron or zinc, is not yet as resistant and ends up being corroded by rust, over time, bringing expenses and maintenance to companies.

2.3 HDF- HIGH DENSITY FIBERBOARD

HDF is its abbreviation for High Density Fiberboard or Industrialized Wood Panel. HDF is a material derived from wood, produced with fibers from selected Pine or Eucalyptus woods from reforestation, introduced by thermosetting resins by pressure and high temperature. In the quality certificate and in its technical reports, it offers great resistance, homogeneity and dimensional stability. of furniture, side and bottom of drawers. It offers excellent cutting and machining capacity, not to mention that it has a great cost benefit. However, when this wooden panel is subjected with pins, screws, or any type of metal exposed to room temperature, it is subject to oxidation, corrosion and other types of degradation, leading to the useful life of wooden structures.

3. METHODS

3.1 PRODUCTION OF EXTRACTS

In the production of extracts, it was first necessary to analyze the leaves of the Brazilian Boldo. They were removed from the herbarium at Ceuma University, and selected for the drying process. The research continued in the laboratory of the Federal Institute of Maranhão (IFMA), where a new plantation of Brazilian boldo was made with the same species of leaves that were cultivated at the Ceuma university. Then, the leaves were placed in an oven at a temperature of 100° degrees celsius for 24 hours to carry out a new drying, after this procedure, the leaves were sent to the materials laboratory, then they were removed from the oven and part of them were introduced on a precision balance to obtain its original mass. Therefore, the leaves were transferred to a mortar to carry out the maceration process, previously grinding the leaves for the preparation of tea in order to reduce the size of the particles and facilitate dissolution in an aqueous medium. Then, in a closed glass container, 500 grams of macerated leaves, as weighed by the volumetric balance, and 500 ml of H2O were added, subject to room temperature for a few hours. The following figures show the procedures for making the extracts.

https://doi.org/10.52202/069179-0126

Figure 1. *Brazilian Boldo Plantation (Source: Author, 2023)*

Figure 2. *Leaves inserted in the oven- Drying Process (Source: Author, 2023)*

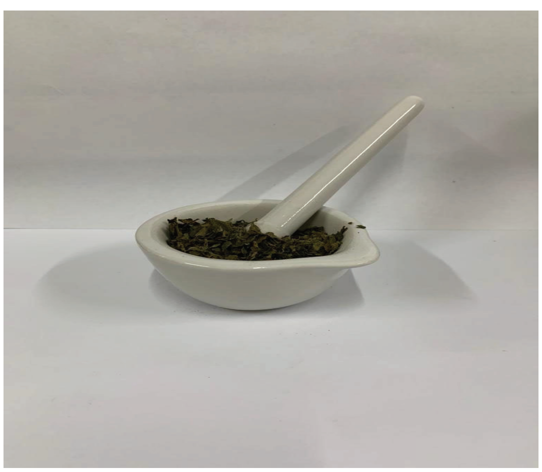


Figure 3. *Maceration process (Source: Author, 2023)*

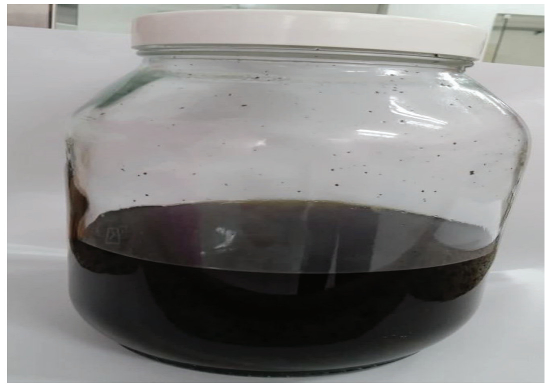


Figure 4. *Brazilian Boldo Extract (Source: Author, 2023)*

3.2 MANUFACTURE OF TEST SPECIMENS

In this research, galvanized steel screws and pins were used fixed in 4 sheets of laminated flooring composed of HDF, wood fibers in its structure, specifically mentioned in the materials in topic 2. Before being submitted to their sheets, the materials were weighed to obtain their referred initial masses, then they were bathed each in their respective beakers. Each container having a mixture and concentration of different extracts. The first CP (Proof body) having only H2O, the second CP only with natural extract (additive) and H2O, the third CP with H2O and NaCl (sodium chloride) popularly known as table salt, and the fourth and last CP, was obtained from all mixtures previously formed (H2O + Nacl + natural extract). In the research, 4 divergent CPS were used, precisely to compare the efficiency of inhibition in each test requested. The figures below show the respective samples that were prepared to bathe the 4 HDF sheets which were tested in the gravimetric tests.

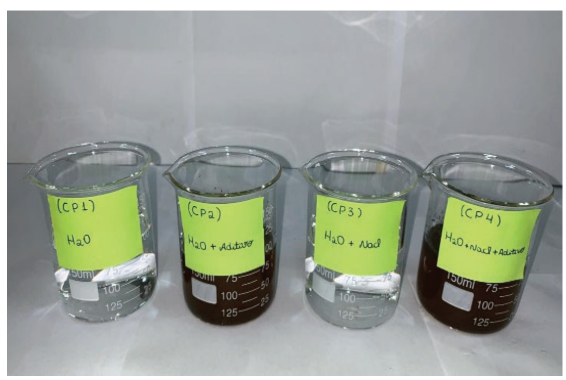


Figure 5. *Samples (Source: Author, 2023)*

.

Figure 6. *Representation of inserted pins and screws on the HDFsheet (Source: Author, 2023)*

3.3 MANUFACTURE OF SPECIMENS WITH COMMERCIAL INHIBITOR

As the research was intended to compare the natural inhibitor with the commercial inhibitor, it was necessary to carry out new tests by bathing other HDF sheets made using TF7 (industrial inhibitor), an excellent rust converter sold in Brazil to eliminate rust in surfaces, forming films that eliminate and prevent corrosion. Therefore, 3 beakers were prepared to carry out new tests and serve as a comparison for the other specimens. Figure 7 shows the CPs with TF7 and HCL (hydrochloric acid). In this test, 90 ml of TF7 and 10 ml of HCL were used in concentration.

Figure 7. *CP1, CP2 e CP3 (Source: Author, 2023)*

3.4 CORROSION RATE AND INHIBITION EFFICIENCY CALCULATIONS

The fraction from the extraction of plectranthus barbatus Andrews, with the presence of H_2O and Nacl acid, was evaluated as a potential corrosion inhibitor for galvanized steel, using gravimetric tests for mass loss. The intensity of corrosive processing was determined by calculating the corrosion rate (TC), which, according to ASTM G1-03 (2011), is represented by the following formula:

TC = (K.W) / A t p (equation 1)

$$TC = (K.W) / A\,t\,p$$

Where:
K=Specific Constant (8.76×10^4)
W= mass loss (in grams)
A= area (in cm^2)
t= time (in hours)
p= specific mass (in $g.cm^{-3}$)

As a final result, the average corrosion rates were applied to the first 4 specimens of each test. The inhibition efficiency (EI) of the extract as a corrosion inhibitor was calculated from the corrosion rates (TC) by the following formula: (OLIVEIRA, T.M.de; CARDOSO, S.P., 2014).

EI = (T0 – T1) / T0 (equation 2)

$$EI = (T_0 - T_1) / T_0$$

Where:
T0= corrosion rate without the presence of the inhibitor;
T1= corrosion rate with the presence of the inhibitor.

4. DISCUSSION AND RESULTS

Mass loss tests were carried out according to the proposed methodology, in figure 8 shows the CP1, specimen that was submitted in a container containing only H_2O. Note some corrosion spots on screws and pins. Figure 9 shows CP2, a specimen that was inserted into a container containing H_2O along with the natural extract. A yellowish coloration is observed, due to some antioxidant substances contained in its composition, which implies and makes the research even more investigative. It is likely that this coloration presented in metals is a protective layer in the fight against corrosion.

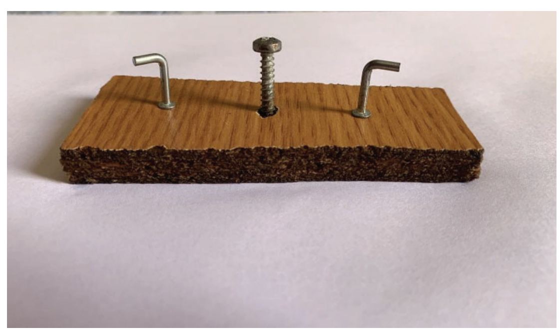


Figure 8. *CP1 (H_2O) (Source: Author, 2023)*

https://doi.org/10.52202/069179-0126

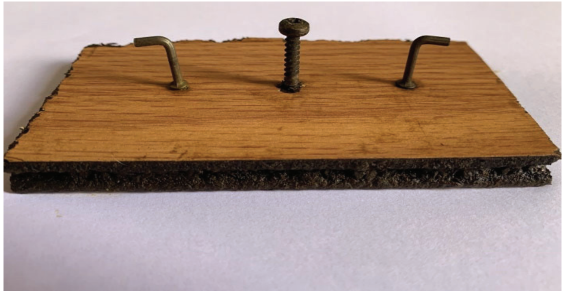


Figure 9. *CP2 (H2O+ Natural Extract (Source: Author, 2023)*

In view of this analysis, two more CPS were tested to obtain results. CP3, a specimen containing H2O + Nacl without the presence of the natural natural extract, was tested precisely to compare its corrosion rates. With this, it was possible to observe how much metals corrode, especially when they are close to saline areas. Finally, CP4 was performed, a specimen containing H2O + Nacl + natural extract (Brazilian boldo additive). In this CP, it presented a behavior equivalent to CP3, and also similar to CP2. It is observed that the compounds of this mixture act against and in favor of corrosion, a factor that provokes and induces researchers to look for results. Image 10 and 11 show the behavior of the CP tested at 14 days, which were soaked with their respective extracts.

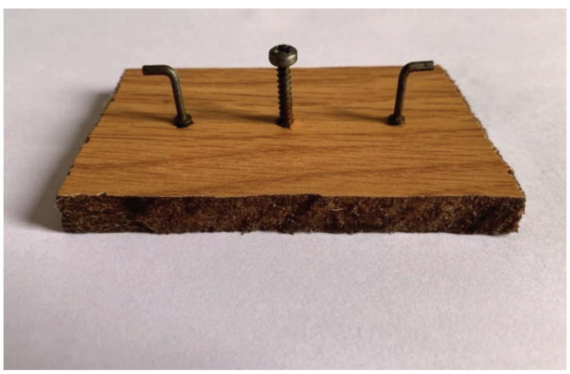


Figure 10. *CP3 (H2O + Nacl)(Source: Author, 2023)*

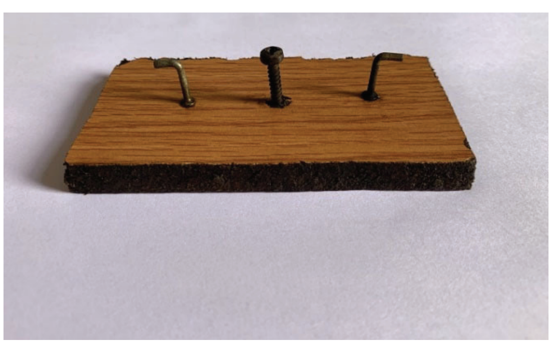


Figure 11. *CP4 (H2O + Natural Extract + Nacl) (Source: Author, 2023)*

Table 1 first shows the initial mass of the specimens referring to all the pins and screws that were embedded in the HDF sheets, before being inserted in their respective extracts.

Table 1. *Initial mass of pins and screws*

MATERIAL	STEEL TYPE	INITIAL MASS
PIN 1	GALVANIZED	0.68 g
PIN 2	GALVANIZED	0.68 g
SCREW	GALVANIZED	1.35g

Source: *Own authorship*

Tables 2 and 3 show the initial mass as well as the final mass of the test specimens of pins and screws. Finally, they present the total mass loss (W), when placed in a mixture after the CPS were wetted and dried at room temperature after 14 days of testing.

Table 2. *Initial mass, final mass and mass loss of pins (W)*

PROOF BODIES	INITIAL MASS	FINAL MASS	WEIGHT LOSS(W)
CP1	0.68 g	0.68 g	0g
CP2	0.68 g	0.67g	0.10g
CP3	0.68 g	0.66 g	0.20g
CP4	0.68 g	0.70 g	0.20g

Source: *Own authorship*

Table 3. *Initial mass, final mass and mass loss of screws (W)*

PROOF BODIES	INITIAL MASS	FINAL MASS	WEIGHT LOSS (W)
CP1	1.35 g	1.35 g	0g
CP2	1.35 g	1.34 g	0.10g
CP3	1.35 g	1.33 g	0.20g
CP4	1.35 g	1.37 g	0.20g

Source: *Own authorship*

Tables 4 and 5 show the aggressiveness in the corrosive medium of all the concentrations that were submitted, which can be proven by gravimetric tests and by equations 1 and 2 mentioned in the methodology, in topic 3.4. With the data provided by Tables 2 and 3, we acquired the initial and final mass of the materials, making it possible to calculate the corrosion rate and inhibition efficiency. (FERNANDES, L.D.; RUAS, L.V.; et al 2019)

Table 4. *Corrosion rate and inhibition efficiency- Pin*

CP	CORROSION RATE	INHIBITION EFFICIENCY (EI)%
CP1	0.66	95%
CP2	0.66	95%
CP3	0.43	74%
CP4	0.61	90%

Source: *Own authorship*

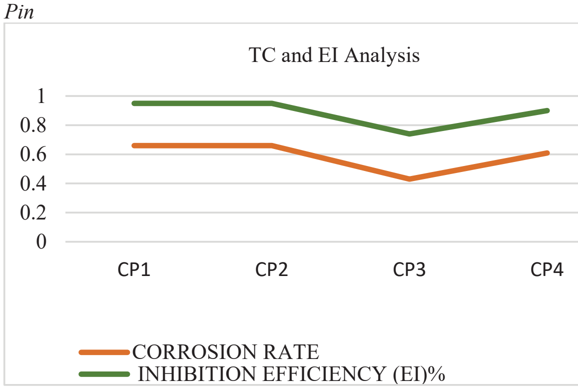
Table 5. *Corrosion rate and inhibition efficiency- Screw*

CP	CORROSION RATE	INHIBITION EFFICIENCY (EI)%
CP1	0.66	95%
CP2	0.66	95%
CP3	0.34	73%
CP4	0.61	90%

Source: Own authorship

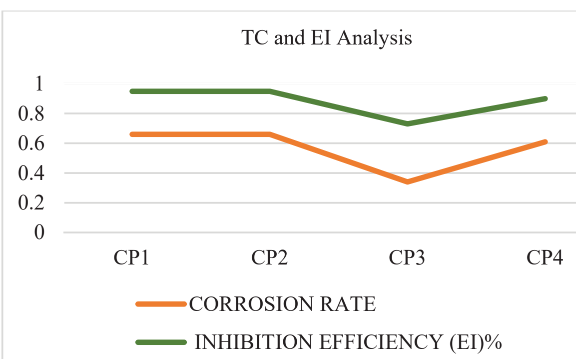
With the information obtained in the tables above, it was observed the growth of the inhibition efficiency, obtained by the corrosion rate. The graphs below show partial results of the specimens.

Graph 1. *Corrosion rate analysis and inhibition efficiency-Pin*



Source: Own authorship

Graph 2. *Corrosion rate analysis and inhibition efficiency-Screw*



Source: Own authorship

According to the results provided by the research, there is a satisfactory reduction in the speed of the corrosive process of the CPS, this behavior is satisfactory, since there is use of the natural inhibitor in the concentrations. The data in the table and graph were calculated and compared with CP1, a neutral specimen with H2O only, which was tested without the presence of extract and Nacl in the composition. It is noteworthy that due to the delay in weight loss (w) of metals and the search for a commercial inhibitor for galvanized steel, it has not yet been possible to calculate the weight loss of pins and screws subjected to industrial anticorrosive. However, the specimens are still being tested and after 14 working days it will be possible to compare the efficiency rate with the Brazilian boldo, a natural inhibitor under study.

5. CONCLUSIONS

In the tests carried out, the loss of mass of the galvanized steel in the absence and presence of the inhibitor is verified. Even without the results of mass loss from the commercial inhibitor, it is clear that the Brazilian boldo extract presents a satisfactory inhibitory behavior for research. It can be seen in the specimens presented, a reduction in the speed in the corrosive process, leading to an efficiency of 90% and 95% of inhibition. Studies indicate that this efficiency can provide protection for both steel and wooden structures, which are subject to damage from corrosion. Given this analysis, we can conclude that Plectranthus barbatus Andrews extract becomes an excellent natural extract, as it meets the inhibition requirements. Because it uses a clean, renewable and sustainable technology, minimizing the deterioration of metals and benefiting in economic and environmental aspects when compared to other commercial inhibitors.

ACKNOWLEDGEMENT

First of all, I would like to thank God for allowing me to have health and determination not to lose heart during this work, to my parents and my sisters for all the support and help in my most difficult moments, to my teachers for all the advice and guidance and for all the patience with which they guided my learning. To the IFMA teaching institution, essential in my professional training process, for the dedication and for everything I have been learning over these years in the Civil Engineering course.

https://doi.org/10.52202/069179-0126

REFERENCES

[1] ASTM G1-03. Standard practical for preparing, cleaning, and evaluating corrosion test specimens, 2011.

[2] FERNANDES, L.D.; RUAS, L. V.; SILVA, A. A. da; CASTRO, D.L. in; CARDOSO, S. P. Extracts of leaves and flowers as corrosion inhibitors of plant origin. Research, Society and Development, 2019.

[3] MATIELLO, Nigian; NESPOLO, Samara. Study of the behavior of the connections of wooden pieces with stamped teeth plates, for use in light shears with reforestation wood. 2015. 105 f. Completion of course work (Graduation) - Federal Technological University of Paraná, Pato Branco, 2015.

[4] MELO, G. F.; LAURENTINO, J. V. A.; SANTOS, L. O. Comparative study of the efficiencies of commercial corrosion inhibitors in marine reinforced concrete structures. Engineering Sciences, v.9, n.2, p.66-80, 2021.

[5] NAGAOKA, Rai. K. Mechanical behavior of wooden truss with connections by stamped tooth plates. 2014. 46 f. Completion of course work (Graduation) - Civil Engineering. Federal Technological University of Paraná. Campo Mourao, 2014.

[6] NAPPI, Manuela Marques Lalane et al. Corrosion of metallic elements embedded in different wood species. 2012.

[7] OLIVEIRA, T.M.de; CARDOSO, SP. Camellia sinensis (L.) Kuntze extract (THEACEAE) as a corrosion inhibitor of vegetable origin. Perspectives of science and technology, v .6, n.1/2, 2014.