Corrosion resistance of orthodontic wires made of thermo active alloy and SS 18/8 alloy in a beverage (hard drink) decreases on dilution with water

Article *in* International Journal of Corrosion and Scale Inhibition · March 2021

DOI: 10.17675/2305-6894-2020-10-1-22

CITATION
1

READS
101

7 authors, including:

N.Karthiga Karthiga
St.Antony's College of Arts and Sciences for Women
9 PUBLICATIONS **30** CITATIONS
SEE PROFILE

Susai Rajendran
St Antony's College of Arts and Sciences for Women, Amala Annai Nagar, Thamaraip…
581 PUBLICATIONS **3,530** CITATIONS
SEE PROFILE

Joseph Angelin Thangakani
The American College, Madurai
8 PUBLICATIONS **24** CITATIONS
SEE PROFILE

Corrosion resistance of orthodontic wires made of thermo active alloy and SS 18/8 alloy in a beverage (hard drink) decreases on dilution with water

G. Geetha,[1] J.C. Angelin,[1] S. Krishnaveni,[1] N. Karthiga,[1] J.M. Praveena,[1] S. Rajendran[1]* and J.A. Thangakani[2]

[1]Corrosion Research Centre, PG Department of Chemistry, St Antony's College of Arts and Sciences for Women, Amala Annai Nagar, Tamaraipadi, Dindigul, Tamilnadu, India
[2]Department of Chemistry, The American College, Madurai, Tamil Nadu, India
**E-mail: susairajendran@gmail.com*

Abstract

Corrosion resistance of SS 18/8 alloy and Thermo active alloy in various systems are compared. The various systems are (i) beverage alone, (ii) beverage + water and (iii) beverage + soda water system. Electrochemical study such as polarization study has been employed for this purpose. When Thermo active alloy is immersed in undiluted as such beverage, the corrosion potential is –319 mV *vs* SCE. The LPR value is $5.749 \cdot 10^7$ Ohm·cm^2. The corrosion current is $0.7607 \cdot 10^{-9}$ A/cm^2. When beverage is diluted with water, the LPR value decreases from $5.749 \cdot 10^7$ Ohm·cm^2 to $6.495 \cdot 10^6$ Ohm·cm^2. It is inferred that when the beverage is diluted with water, the corrosion resistance of Thermo active alloy decreases. This is further supported by the fact, when water is added to the beverage, the corrosion current increases from $0.7607 \cdot 10^{-9}$ A/cm^2 to $6.533 \cdot 10^{-9}$ A/cm^2. Similarly when soda water is added to the beverage, the LPR value decreases from $5.749 \cdot 10^7$ Ohm·cm^2 to $9.028 \cdot 10^6$ Ohm·cm^2; the corrosion current increases from $0.7607 \cdot 10^{-9}$ A/cm^2 to $4.077 \cdot 10^{-9}$ A/cm^2. Hence it is inferred that when Thermo active alloy is immersed in the diluted beverage, the corrosion resistance of Thermo active alloy decreases. When SS 18/8 alloy is immersed in undiluted as such beverage, the corrosion potential is –249 mV *vs* SCE. The LPR value is $3.609 \cdot 10^6$ Ohm·cm^2. The corrosion current is $1.124 \cdot 10^{-8}$ A/cm^2. When beverage is diluted with water, the LPR value decreases from $3.609 \cdot 10^6$ Ohm·cm^2 to $1.314 \cdot 10^6$ Ohm·cm^2. It is inferred that when the beverage is diluted with water, the corrosion resistance of SS 18/8 alloy decreases. This is further supported by the fact, when water is added to the beverage, the corrosion current increases from $1.124 \cdot 10^{-8}$ A/cm^2 to $3.235 \cdot 10^{-8}$ A/cm^2. Similarly when soda water is added to the beverage, the LPR value decreases from $3.609 \cdot 10^6$ Ohm·cm^2 to $1.098 \cdot 10^6$ Ohm·cm^2; the corrosion current increases from $1.124 \cdot 10^{-8}$ A/cm^2 to $4.189 \cdot 10^{-8}$ A/cm^2. Hence it is inferred that when soda water is added to the beverage, the corrosion resistance of SS 18/8 alloy decreases. Thermo active alloy is found to be more corrosion resistant in as such beverage than in beverage + water system or beverage + soda water system. SS 18/8 alloy is more corrosion resistant in as such beverage than in beverage + water system or beverage + soda water system. In as such beverage system, Thermo active alloy is more corrosion resistant than SS 18/8 system. In beverage + water system, Thermo active alloy

is more corrosion resistant than SS 18/8 system. In beverage + soda water system, Thermo active alloy is more corrosion resistant than SS 18/8 system.

Keywords: *corrosion resistance, hard drink, beverage, polarization study, Thermo active Ni-Ti super elastic shape memory alloy, SS 18/8 alloy.*

Received: December 23, 2020. Published: March 14, 2021 doi: 10.17675/2305-6894-2020-10-1-22

Introduction

Storing of food materials in good containers is a social problem. Several studies have been carried out on storing of food materials, soft drinks, hot drinks and beverages [1–8]. Tinplate is a thin steel sheet coated by tin. Tinplate is used for making all types of containers such as food cans and beverage cans. Social development and green food requirements necessitate a high standard to the anticorrosion and protective performance for metal packaging materials. Nonetheless, there are always important problems related to the use of metal packaging materials with corrosive food products, such as corrosion failure, loss of seal integrity, or discoloration that cause product rejection by consumers The studies of Catala *et al*. [1] and Blunden and Wallace [2] have indicated that a high concentrations of tin in food annoy the gastrointestinal tract and may cause stomach upsets in some individuals, with symptoms which include nausea, vomiting, diarrhoea, abdominal cramps, abdominal bloating, fever and headache.

Ismail *et al*. have investigated the corrosion performance of aluminum and stannum as beverage packaging [3]. The corrosion resistance has been evaluated by polarization study. The study revealed that aluminum can have more anti-corrosion properties than tinplate can. Peralta-Lopez *et al*. have studied the corrosion resistance of three stainless steel alloys and titanium metal in cola soft drinks. They have employed polarization study for this purpose. The corrosion resistance of the stainless-steel alloys and titanium in the cola soft drinks was provided by the formation of a stable passive film formed by metal oxides. Scanning electron microscopy reveals the formation of a protective film on the alloys. This increased the corrosion resistance of these alloys [4]. Corrosion behavior of aluminum for beverage packaging in acidic media containing chlorides and copper ions has been investigated by Soares *et al*. [5]. Electrochemical studies have been employed in this study. Mareci *et al*. have employed electrochemical studies on the stability and corrosion resistance of two austenitic stainless steels for soft drinks containers. Three carbonated soft drinks were investigated as for their effect on the stability of FeCrNi and FeCrNiMo alloys. The high corrosion resistance of the austenitic stainless steel alloys in the soft drinks was provided by the formation of a rather stable passive film produced by metal oxides. The electrochemical behaviour was related to an inhibitory action by caffeine as evidenced using potentiodynamic polarization and electrochemical impedance spectroscopy methods [6]. Corrosion resistance of orthodontic wires made of SS 316 L alloy in artificial saliva in the absence and presence of a soft drink namely sprite has been evaluated by polarisation study. This study reveals

that, the corrosion resistance of SS 316 L alloy decreases in the following order: sprite only > sprite + artificial saliva > artificial saliva. It is concluded that people who have been implanted with orthodontic wires made of SS 316 L alloy need not dither to take the soft drink sprite orally [7]. Corrosion behaviour of a dental alloy in some beverages and drinks has been investigated by Duffó and Farina [8]. The effect of several beverages (alcoholic drinks, natural and artificial fruit juices, vinegar, soft drinks, milk) on the corrosion behaviour of an aluminum-bronze dental alloy has been investigated. Results have been compared to those obtained in artificial saliva and in a solution of sodium chloride. The style of taking beverages by people is varying and quite interesting. Some people take after dilution with water or mixing with soda water. Some people go for taking beverage without dilution. The present work is undertaken to investigate the corrosion resistance of two dental alloys namely, thermoactive Ni-Ti super elastic shape memory alloy and SS 18/8 in various test solutions namely, (i) a beverage as such (Copper Barrel deluxe XXX Rum) (hard drink) without dilution, (ii) beverage diluted with water and (iii) beverage mixed with soda water. Polarization study was employed to evaluate the corrosion resistance of various materials used.

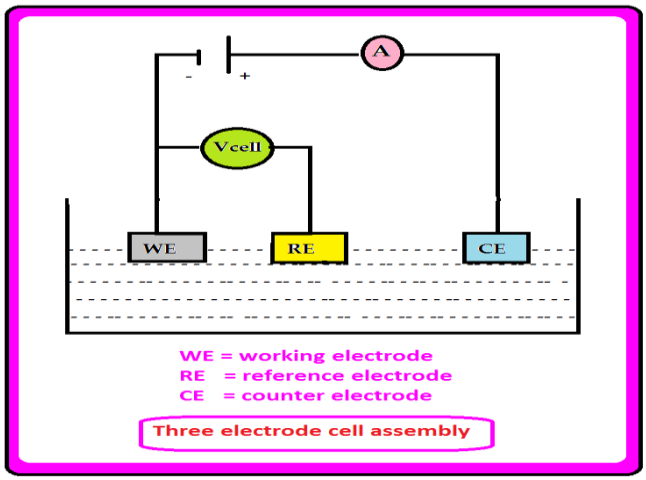
Experimental

Electrochemical study

In the present work corrosion resistance of dental alloys, namely, SS 18/8 alloy and Thermo active alloy immersed in various test solutions were measured by Polarization study.

Polarization study

Polarization studies were carried out in a CHI Electrochemical work station/analyzer, model 660A. It was provided with automatic *iR* compensation facility. A three electrode cell assembly was used (Scheme A).



Scheme A. Three electrode cell assembly.

The working electrode was SS 18/8 alloy / Thermo active alloy. A SCE was the reference electrode. Platinum was the counter electrode. A time interval of 5 to 10 min was given for the system to attain a steady state open circuit potential. From polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic = b_a and cathodic = b_c and LPR (linear polarisation resistance) value were measured.

Dental alloys

Thermoactive Ni-Ti super elastic shape memory alloy (Thermo active alloy) contains 55.5% Ni and 44.5% Ti. SS 18/8 alloy contains 73.75% Fe, 18% Cr, 8% Ni, and 0.25% C. These two alloys are used as orthodontic wires in dental technology.

Composition of copper barrel deluxe XXX rum (hard drink)

It contains demineralised water, natural spirit, permitted natural color INS 150a. Permitted Natural Colour (INS 150a) is a dark brown food color produced by heat treatment of sucrose. It is a food additive approved by the European Union and is denoted by INS 150a under International Numbering System.

Composition of soda water

It is carbonated water containing salts of magnesium and sodium.

Results and Discussion

Corrosion resistance of orthodontic wires made of thermoactive alloy and SS 18/8 alloy in presence of a beverage (Copper Barrel deluxe XXX Rum) (hard drink) has been investigated by electrochemical study, namely, polarisation study. The experiment has been repeated with beverage + water system and also beverage + soda water system. These experiments were done because people usually drink this beverage as such or mixing with water or mixing with soda water. Interesting results have been obtained. They are presented and discussed in this section. It is a fact that when corrosion resistance of a metal or alloy increases, the linear polarization resistance (LPR) value increases and corrosion current (I_{corr}) value decreases [9–13]. This is due to the fact that when a protective film is formed on the metal surface the flow of corrosive ions on to the metal surface is prevented. Further, the loss of electrons from the metal surface is also prevented.

Corrosion resistance of Thermoactive alloy in beverage system, beverage + water system and beverage + soda water system

Corrosion resistance of Thermoactive alloy in beverage (B) system, beverage + water system and beverage + soda water system, has been investigated by polarization study. The polarization curves of Thermoactive alloy immersed in various test solutions are shown in Figure 1. The corrosion parameters such as linear polarization resistance (LPR), corrosion potential E_{corr}, corrosion current I_{corr} and Tafel slopes (b_a and b_c) are given in Table 1.

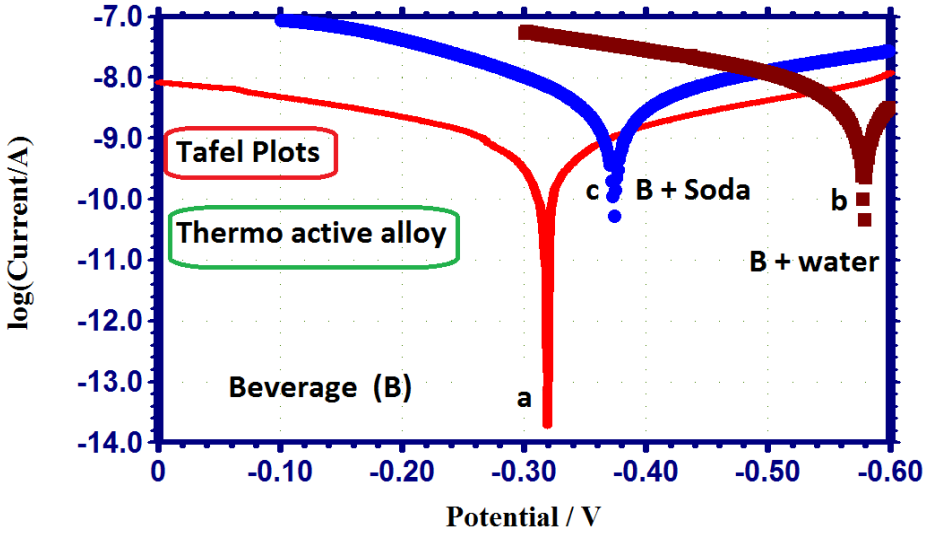


Figure 1. Polarisation curves of Thermo active alloy immersed in various test solutions.

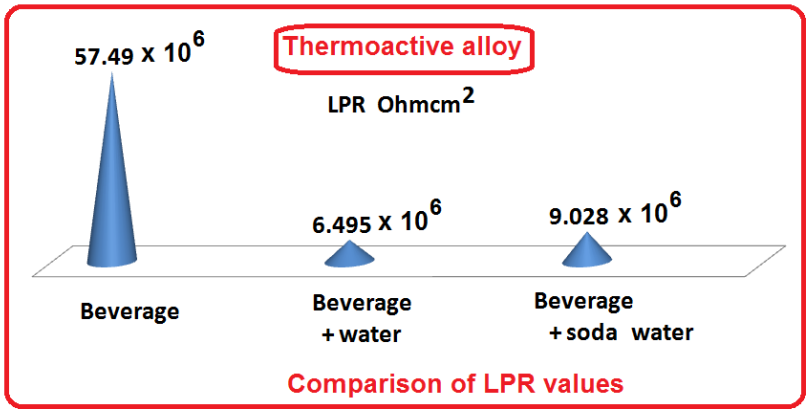
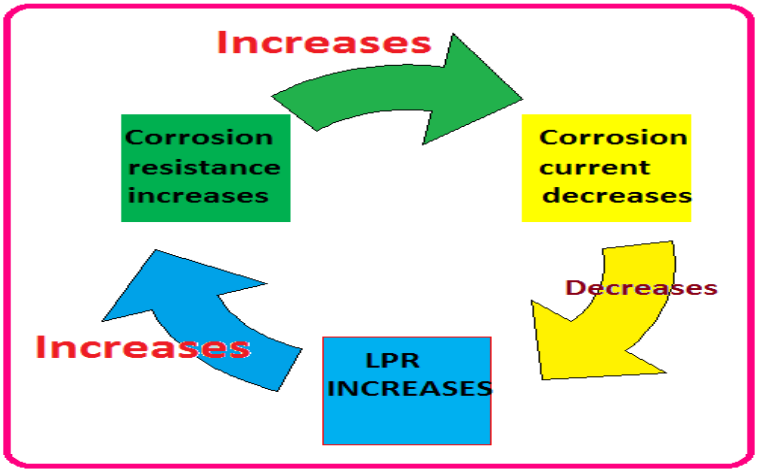


Figure 2. Comparison of LPR values of Thermo active alloy immersed in various test solutions.



Scheme B. Relation among corrosion resistance and polarisation parameters.

Table 1. Corrosion parameters of thermo active alloy immersed in various test solutions obtained by polarization study.

System	E_{corr} mV *vs* SCE	b_c mV/decade	b_a mV/decade	LPR Ohm·cm^2	I_{corr} A/cm^2
Beverage	–319	207	216	$5.749 \cdot 10^7$	$0.7607 \cdot 10^{-9}$
beverage + water	–579	190	206	$6.495 \cdot 10^6$	$6.533 \cdot 10^{-9}$
beverage + soda water	–374	204	146	$9.028 \cdot 10^6$	$4.077 \cdot 10^{-9}$

It is observed from Table 1 that when Thermo active alloy is immersed in undiluted as such beverage, the corrosion potential is –319 mV *vs* SCE. The LPR value is $5.749 \cdot 10^7$ Ohm·cm^2. The corrosion current is $0.7607 \cdot 10^{-9}$ A/cm^2. When beverage is diluted with water, the LPR value decreases from $5.749 \cdot 10^7$ Ohm·cm^2 to $6.495 \cdot 10^6$ Ohm·cm^2. It is inferred that when the beverage is diluted with water, the corrosion resistance of Thermo active alloy decreases. This is further supported by the fact, when water is added to the beverage, the corrosion current increases from $0.7607 \cdot 10^{-9}$ A/cm^2 to $6.533 \cdot 10^{-9}$ A/cm^2. Similarly when soda water is added to the beverage, the LPR value decreases from $5.749 \cdot 10^7$ Ohm·cm^2 to $9.028 \cdot 10^6$ Ohm·cm^2; the corrosion current increases from $0.7607 \cdot 10^{-9}$ A/cm^2 to $4.077 \cdot 10^{-9}$ A/cm^2 (Figure 2). Hence it is inferred that when soda water is added to the beverage, the corrosion resistance of thermo active alloy decreases [9–13].

Implication

Corrosion resistance of thermo active alloy is higher in as such beverage than in beverage mixed with water or with soda water.

Corrosion resistance of SS 18/8 alloy in beverage system, beverage + water system and beverage + soda water system

Corrosion resistance of SS 18/8 alloy in beverage (B) system, beverage + water system and also beverage + soda water system, has been investigated by polarization study. The polarization curves of SS 18/8 alloy immersed in various test solutions are shown in Figure 3. The corrosion parameters such as linear polarization resistance (LPR), corrosion potential E_{corr}, corrosion current I_{corr} and Tafel slopes (b_a and b_c) are given in Table 2.

Table 2. Corrosion parameters of SS18/8 alloy immersed in various test solution obtained by polarization study.

System	E_{corr} mV *vs* SCE	b_c mV/decade	b_a mV/decade	LPR Ohm·cm^2	I_{corr} A/cm^2
Beverage	–249	134	310	$3.609 \cdot 10^6$	$1.124 \cdot 10^{-8}$
beverage + water	–307	145	299	$1.314 \cdot 10^6$	$3.235 \cdot 10^{-8}$
beverage + soda water	–323	175	268	$1.098 \cdot 10^6$	$4.189 \cdot 10^{-8}$

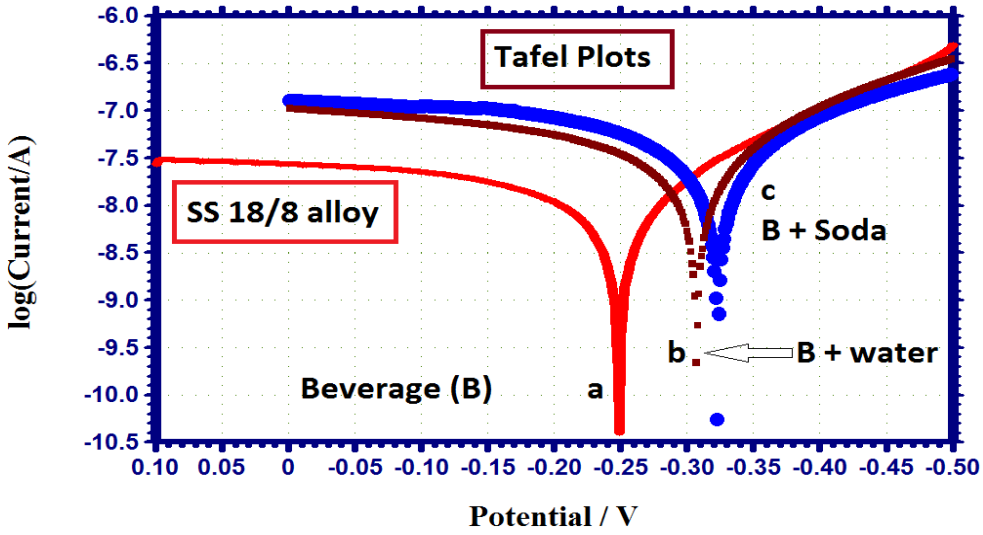


Figure 3. Polarisation curves of SS 18/8 alloy immersed in various test solutions.

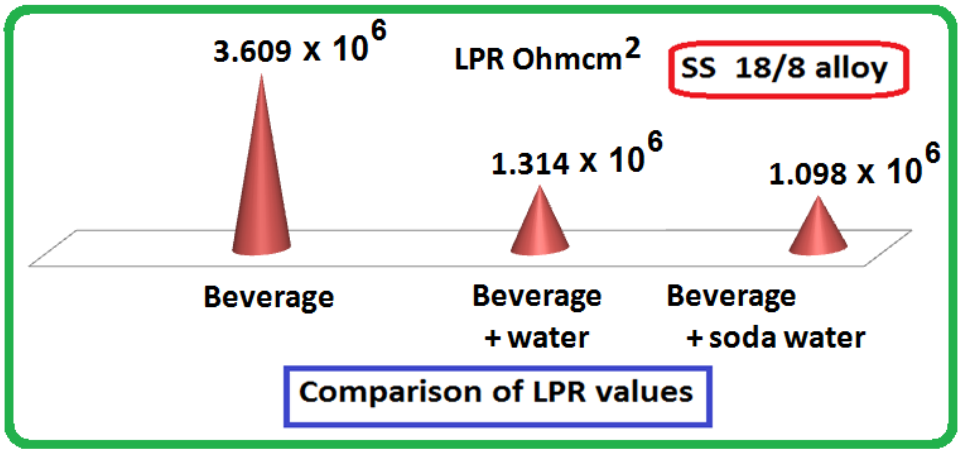


Figure 4. Comparison of LPR values of SS 18/8 alloy immersed in various test solutions.

It is observed from Table 2 that when SS 18/8 alloy is immersed in undiluted as such beverage, the corrosion potential is –249 mV *vs* SCE. The LPR value is $3.609 \cdot 10^6$ Ohm·cm^2. The corrosion current is $1.124 \cdot 10^{-8}$ A/cm^2. When beverage is diluted with water, the LPR value decreases from $3.609 \cdot 10^6$ Ohm·cm^2 to $1.314 \cdot 10^6$ Ohm·cm^2. It is inferred that when the beverage is diluted with water, the corrosion resistance of SS 18/8 alloy decreases. This is further supported by the fact, when water is added to the beverage, the corrosion current increases from $1.124 \cdot 10^{-8}$ A/cm^2 to $3.235 \cdot 10^{-8}$ A/cm^2. Similarly when soda water is added to the beverage, the LPR value decreases from $3.609 \cdot 10^6$ Ohm·cm^2 to $1.098 \cdot 10^6$ Ohm·cm^2; the corrosion current increases from $1.124 \cdot 10^{-8}$ A/cm^2 to $4.189 \cdot 10^{-8}$ A/cm^2 (Figure 4). Hence it is inferred that when soda water is added to the beverage, the corrosion resistance of SS 18/8 alloy decreases.

Implication

Corrosion resistance of SS 18/8 alloy is higher in as such beverage than in beverage mixed with water or with soda water.

Comparison of corrosion resistance of SS 18/8 alloy and Thermo active alloy

Corrosion resistance of SS 18/8 alloy and Thermo active alloy in various systems are compared. The various systems are (i) beverage alone, (ii) beverage + water and (iii) beverage +soda water system.

(i) Beverage system

Corrosion resistance of SS 18/8 alloy and Thermo active alloy in as such beverage (without dilution) are compared in Figure 5. It is noted that Thermo active alloy is more corrosion resistant than SS 18/8 alloy. This is revealed by the fact that the LPR value of Thermo active alloy is higher than that of SS 18/8 alloy.

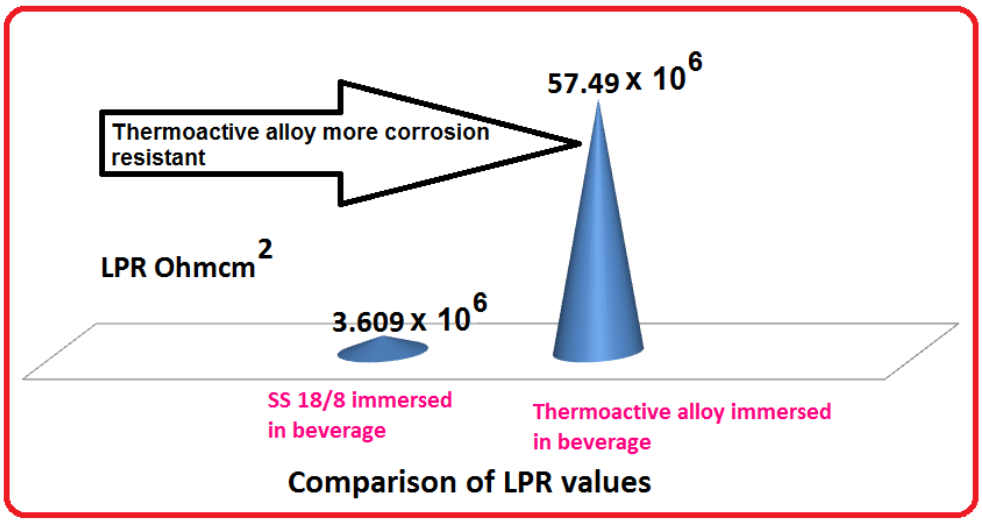


Figure 5. Comparison of corrosion resistance of SS 18/8 alloy and Thermoactive alloy in beverage.

(ii) beverage + water system

Corrosion resistance of SS 18/8 alloy and Thermoactive alloy in beverage + water system are compared in Figure 6. It is noted that Thermo active alloy is more corrosion resistant than SS 18/8 alloy. This is revealed by the fact that the LPR value of Thermoactive alloy is higher than that of SS 18/8 alloy.

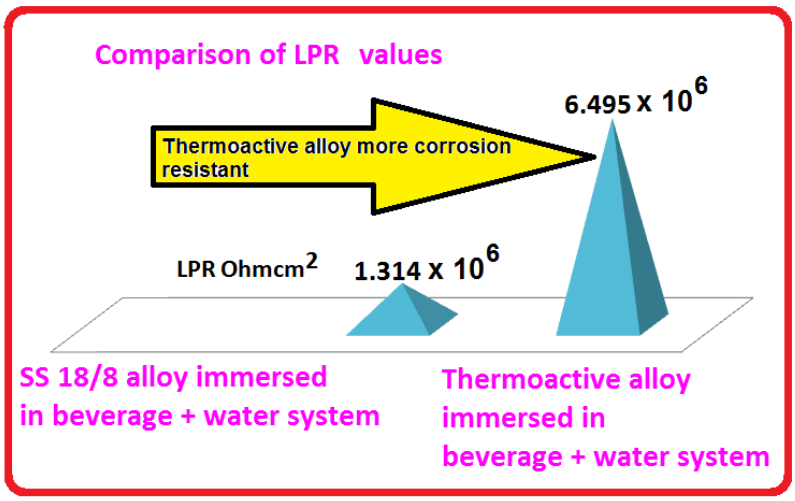


Figure 6. Comparison of corrosion resistance of SS 18/8 alloy and Thermoactive alloy in beverage + water system.

(iii) beverage + soda water system

Corrosion resistance of SS 18/8 alloy and Thermoactive alloy in beverage + soda water system are compared in Figure 7. It is noted that Thermoactive alloy is more corrosion resistant than SS 18/8 alloy. This is revealed by the fact that the LPR value of Thermoactive alloy is higher than that of SS 18/8 alloy.

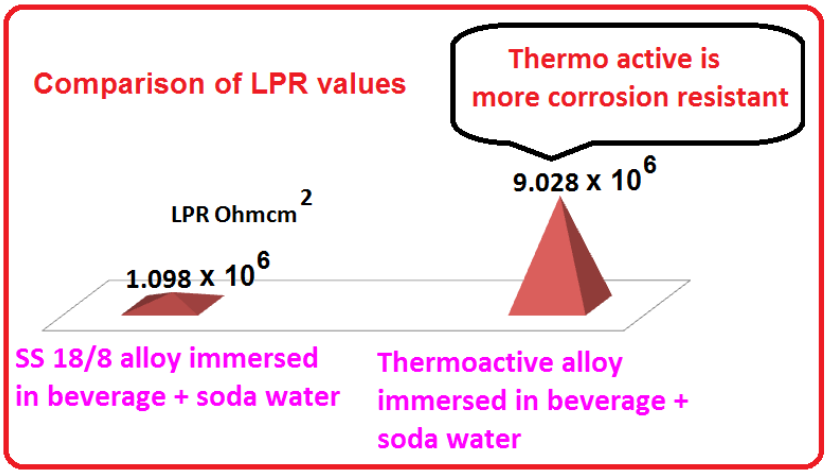


Figure 7. Comparison of corrosion resistance of SS 18/8 alloy and Thermo active alloy in beverage + soda water system.

Conclusions

Corrosion resistance of SS 18/8 alloy and Thermo active alloy in various systems are compared. The various systems are (i) beverage alone, (ii) beverage + water and (iii) beverage + soda water system. Polarization study has been employed for this purpose. The study reveals that:

1. Thermo active alloy is more corrosion resistant in as such beverage than in beverage + water system or beverage + soda water system.
2. SS 18/8 alloy is more corrosion resistant in as such beverage than in beverage + water system or beverage + soda water system.
3. In as such beverage system, Thermo active alloy is more corrosion resistant than SS 18/8 system.
4. In beverage + water system, Thermo active alloy is more corrosion resistant than SS 18/8 system.
5. In beverage + soda water system, Thermo active alloy is more corrosion resistant than SS 18/8 system.

Acknowledgement

The authors are thankful to their respective managements for their help and encouragement. Special thanks to Rev. Dr. Antony Pushpa Ranjitham (Superior General), Rev. Sr. Thanaseeli Sengole (Asst. General), Rev. Sr. M. Margaret Inbaseeli (College Secretary), Rev. Dr. Pramila (Principal), Rev. Sr. Gnana Soundari (Provincial) and Mrs J. Antony Justina Mary (Vice Principal) for their Prayer and Blessings.

Scope for further study

In the present study, corrosion resistance of SS 18/8 alloy and Thermo active alloy in various systems are compared. The various systems are (i) beverage alone, (ii) beverage + water and (iii) beverage +soda water system. The alloys used in the present study are used as orthodontic wires. Hence the present study can be carried out in presence of synthetic saliva. The findings will be useful for Dentists.

References

1. R. Catala, M. Alonso, R. Gavara, E. Almeida, J.M. Bastidas, J.M. Puente and N. de Cristaforo, Titanium passivated tinplate for canning foods, *Food Sci. Technol. Int.*, 2005, **11**, 223–227. doi: 10.1177/1082013205054933
2. S. Blunden and T. Wallace, Tin in canned food: a review and understanding of occurrence and effect, *Food Chem. Toxicol.*, 2003, **41**, 1651–1662. doi: 10.1016/S0278-6915(03)00217-5
3. A. Ismail, S.L. Kar and H. Ibrahim, Corrosion performance of aluminum and stannum as beverage packaging, *Key Eng. Mater.*, 2018, **791**, 88–94. doi: 10.4028/www.scientific.net/KEM.791.88
4. D. Peralta-Lopez, O. Sotelo-Mazon, J. Henao, J. Porcayo-Calderon, S.Valdez, G. Salinas-Solano and L. Martinez-Gomez, Electrochemical study of three stainless steel alloys and titanium metal in cola soft drinks, *J. Electrochem. Sci. Technol.*, 2017, **8**, 294–306. doi: 10.5229/JECST.2017.8.4.294

5. B.M.C. Soares, S.T. Dantas and C.A.R. Anjos, Corrosion of aluminum for beverage packaging in acidic media containing chlorides and copper ions, *J. Food Process Eng*., 2017, **40**, e12571. doi: 10.1111/jfpe.12571
6. D. Mareci, L.C. Trinca, V.V. Cotea and R.M. Souto, Electrochemical studies on the stability and corrosion resistance of two austenitic stainless steels for soft drinks containers, *Int. J. Electrochem. Sci*., 2017, **12**, 5438–5449. doi: 10.20964/2017.06.35
7. M. Sangeetha, S. Rajendran, N. Pavazhanayagam, C. Sobiga and P.V. Nancy, Corrosion resistance of SS 316 L alloy in artificial saliva in the presence of a soft drink, *Pharma Chem*., 2016, **8**, 334–337.
8. G.S. Duffó and S.B. Farina, Corrosion behaviour of a dental alloy in some beverages and drinks, *Mater. Chem. Phys*., 2009, **115**, 235–238. doi: 10.1016/j.matchemphys.2008.11.053
9. R.J. Tuama, M.E. Al-Dokheily and M.N. Khalaf, Recycling and evaluation of poly(ethylene terephthalate) waste as effective corrosion inhibitors for C-steel material in acidic media, *Int. J. Corros. Scale Inhib*., 2020, **9**, no. 2, 427–445. doi: 10.17675/2305-6894-2020-9-2-3
10. A.H. Al-Moubaraki and H. Awaji, 1-X-4-[4′-(–OCH_3)-Styryl] pyridinium iodides, potent inhibitors for stainless steel corrosion in 2 M HCl acid solutions, *Int. J. Corros. Scale Inhib*., 2020, **9**, no. 2, 460–501. doi: 10.17675/2305-6894-2020-9-2-5
11. G. Fekkar, F. Yousfi, H. Elmsellem, M. Aiboudi, M. Ramdani, I. Abdel-Rahman, B. Hammouti and L. Bouyazza, Eco-friendly *Chamaerops humilis L.* fruit extract corrosion inhibitor for mild steel in 1 M HCl, *Int. J. Corros. Scale Inhib*., 2020, **9**, no. 2, 446–459. doi: 10.17675/2305-6894-2020-9-2-4
12. W.M.K.W.M. Ikhmal, M.Y.N. Yasmin, M.F.F. Maria, S.M. Syaizwadi, W.A.W. Rafizah, M.G.M. Sabri and B.M. Zahid, Evaluating the performance of *Andrographis paniculata* leaves extract as additive for corrosion protection of stainless steel 316L in seawater, *Int. J. Corros. Scale Inhib*., 2020, **9**, no. 1, 118–133. doi: 10.17675/2305-6894-2020-9-1-7
13. A. Boumezzourh, M. Ouknin, E. Chibane, J. Costa, A. Bouyanzer, B. Hammouti and L. Majidi, Inhibition of tinplate corrosion in 0.5 M $H_2C_2O_4$ medium by *Mentha pulegium* essential oil, *Int. J. Corros. Scale Inhib*., 2020, **9**, no. 1, 152–170. doi: 10.17675/2305-6894-2020-9-1-9.

♦ ♦ ♦