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Corrosion Behaviour of Ever Silver Vessels When in Contact with Payasam, Both With and Without The Addition of Sugar

I Vinnarasi Suganya[1], A Afsheen Fazeela[1], K Narmatha[1], S Harshitha[1], S Juvairiya Fathima[1], M Geetha[1], Susai Santhammal Rajendran[1*], Abdulhameed Al-Hashem[2]

[1]Corrosion Research Centre, St Antony's College of Arts and Sciences for women, Dindigul, (Affiliated to Mother Teresa Women's University, Kadaikanal) Tamil Nadu, India

[2]Petroleum Research Centre, Kuwait Institute for Scientific Research, Kuwait

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***Corresponding author:** Susai Santhammal Rajendran, 1Corrosion Research Centre, St Antony's College of Arts and Sciences for women, Dindigul, (Affiliated to Mother Teresa Women's University, Kadaikanal) Tamil Nadu, India

ABSTRACT

Payasam , also known as Kheer, or payesh is a classic and versatile dessert originating from South India, mainly made from milk combined with an assortment of cereals, grains, or lentils, often including fruits and vegetables. This delightful Indian sweet pudding is usually sweetened with sugar or jaggery and is flavored with spices like cardamom and saffron. Furthermore, many payasams are garnished with dry fruits that have been sautéed in ghee, adding to their luxurious flavor and fragrance. Before serving, payasam is stored in Ever Silver vessels. During this period, these vessels may undergo corrosion due to the components present in payasam. The present study seeks to evaluate the corrosion behavior of Ever Silver vessels in contact with payasam, both with and without sugar. To accomplish this, a polarization study has been performed to assess the corrosion resistance of the Ever Silver electrode in three distinct environments: water, payasam without sugar, and payasam with sugar. The linear polarization resistance of Ever Silver decreases in the following order: water system > payasam without sugar system > payasam with sugar system. The corrosion resistance also decreases in the same order. The study indicates that the corrosion resistance of Ever Silver vessels used for storing payasam diminishes when sugar is present. Consequently, it is advisable not to store sugar-containing payasam in Ever Silver vessels for extended periods.

Keywords: Corrosion behaviour; Ever Silver vessels; In contact with payasam; With and without the addition of sugar

INTRODUCTION

Metal food packaging encompasses a diverse range of products, including cans, closures, lids, tubes, and aerosol containers, among others. Cans are the most prevalent form, with canned foods and beverages constituting a significant portion of the global food supply.

The process of canning food and beverages remains crucial for food preservation, as items stored in metal cans typically enjoy a longer shelf life than those packaged in alternative materials.

To enhance food preservation, polymeric coatings are frequently applied to the inner surfaces of metal food cans. These coatings serve as a protective barrier between the food and the metal, playing a vital role in maintaining food quality while also safeguarding the metal substrate from corrosion. Numerous research studies have been conducted in this area, with several of them being presented.[1-10]

Examination of the Corrosion Characteristics of 3104 Aluminum Cans Utilized in the Packaging of Chinese Liquor

Aluminum cans are widely utilized for the packaging of soft drinks and low-alcohol beverages, primarily due to their excellent recyclability. To improve the economic cycle and broaden the packaging options for liquors, a study was conducted to assess the viability of commercial 3104 aluminum cans for packaging Chinese liquor. The migration of aluminum into alcoholic solutions was analyzed using inductively coupled plasma emission spectroscopy (ICP-OES). Additionally, electrochemical impedance spectroscopy (EIS) was employed to investigate the corrosion behavior of epoxy coatings on the aluminum cans. Various techniques, including scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), infrared attenuated total reflection (IR-ATR), and X-ray diffraction (XRD), were utilized to examine the internal coatings, surface adherence of the cans, and the corrosion mechanisms. The findings indicated that the highest aluminum migration observed in Chinese liquor reached 4.3572 mg/kg at 60 °C over a period of 30 days. Notably, the epoxy coating experienced significant corrosion, leading to a reduction in coating impedance and the exposure of the metal substrate after 25 days. The permeation and aging degradation of the coatings emerged as critical factors to consider in the packaging of liquor.[1]

Choice of Crosslinking Agents for Acrylic Resins Utilized in External Coatings for Aluminum Packaging in the Beverage Sector.

Paints and coatings find extensive application across a range of sectors, including walls, automobiles, packaging, and food products. The integrity of food packaging is crucial due to its potential direct or indirect interaction with food items. As production and consumption rates rise, the demand for superior food packaging continues to grow. Nevertheless, containers utilized in the beverage sector frequently encounter issues such as scratches and abrasions during transit. This research aimed to explore various formulations of external coatings for beverage cans to enhance their physical resistance properties and mitigate corrosion and surface damage. The investigation involved the reaction of an acrylic resin with six distinct amino resins: methylated melamine, butylated melamine, glycoluril, methylated urea, butylated urea, and benzoguanamine, in different ratios. The properties of 25 formulated samples were evaluated, focusing on adhesion, durability, and chemical resistance. The findings revealed notable variations among the crosslinking agents, with methylated melamine demonstrating the most advantageous results across nearly all assessments.[2]

Isothermal Titration Calorimetry Demonstrates Entropy-Driven Adhesion of Bisphenol A Epoxy Resin to Metal Oxide Surfaces

Polymer-coated metals are widely utilized across various industries as a method for corrosion protection. In particular, the food and beverage packaging sector benefits from bisphenol A (BPA)-based epoxy coatings, which provide exceptional barrier properties and strong adhesion to metal surfaces. However, there is an increasing necessity to develop safer alternative coatings that can achieve similar adhesion levels as BPA-epoxies, owing to the environmental and health risks associated with BPA. Current knowledge regarding epoxy-metal interactions and the impact of interfacial functional group concentration on overall adhesion is limited, primarily due to the restrictions of most experimental techniques that typically examine the interface only within a few nanometers in situ. In this study, we employ isothermal titration calorimetry (ITC) and molecular dynamics simulations to analyze the thermodynamics of epoxy-metal oxide binding in the liquid phase, while also identifying how the structure of epoxy resin and the surface chemistry of metal oxides influence the binding process. Through our investigation of various epoxy resins and three different metal oxides, we uncover a previously unrecognized significant role of entropy in the binding mechanism, largely driven by the release of solvent molecules from the epoxy/metal interface, along with potential contributions from dispersive OH-π interactions between the benzene rings of the resin and the -OH groups on the metal oxide surface. Additionally, enthalpy-driven hydrogen bonding between the -OH groups of the resin and the metal oxide contributes to the binding process, with its effectiveness being contingent upon the concentration of interfacial -OH groups. Thus, ITC provides essential molecular insights into the contributions of various functional groups to the adhesion mechanism, guiding the rational design of advanced polymer coatings.[3]

The presence of lactic and acetic acids in sour beers contributes to the corrosion of aluminum beverage cans during storage

Recent trends indicate that newer sour beers are frequently packaged in aluminum cans; however, the interaction between sour beer and its primary acids (lactic and acetic) with can materials remains uncertain. An initial investigation involved packaging commercial sour beers in cans lined with one of four distinct materials: bisphenol A (BPA) epoxy, two types of BPA–non-intent (BPA-NI) epoxy, and acrylic. The study found a positive correlation between corrosion—assessed through dissolved aluminum levels and visual deterioration of the liner—and the concentrations of lactic acid, acetic acid, and lower pH values. After a period of 48 weeks, one sour beer exhibited aluminum concentrations reaching 58 mg/L, which is nearly 100 times higher than the typical levels found in non-sour beers. The type of liner did not influence the corrosion observed. In a follow-up study using a model sour beer with two acrylic liners and one BPA-NI liner, a positive correlation was noted between molecular SO2 and corrosion, but this was only evident at concentrations five times greater than what is typically expected in sour beers. Other components added, such as chloride, copper, and ethanol, did not impact corrosion rates. When acetic, lactic, and phosphoric acids were added in various equinormal combinations to a non-sour beer, it was found that acetic and lactic acids (with an average dissolved aluminum of 2.54 mg/L after storage) caused more corrosion than phosphoric acid (which had an average dissolved aluminum of 0.47 mg/L). A strong correlation was observed between titratable acidity (TA) and corrosion, with increased dissolved aluminum levels noted at TA values exceeding 6 g/L as lactic acid equivalents. It was hypothesized that the corrosive nature of organic acids is linked to the proportion of the acid in its neutral form, making these findings pertinent for producers of other beverages that contain high levels of organic acids.[4]

Examination of Aluminum Soft Drink Packaging Corrosion in a Citric Acid Environment with Catalytic Ions Utilizing the Box-Behnken Design Methodology.

The corrosion of aluminum beverage cans presents a considerable challenge for the industry, leading to both economic and health-related issues. There is a pressing need to collect scientific data that can provide insights to the food and packaging industries, facilitating improvements in materials and minimizing losses associated with this problem. This study investigated the interactions between aluminum cans and beverages by utilizing model solutions with copper and chloride concentrations that are representative of those typically found in beverages. The research focused on the effects of temperature (20-50°C), chloride concentration (25-1000 mg/L), and copper concentration (25-1000 µg/L) as independent variables influencing the corrosion of aluminum cans in a citric acid solution, employing Response Surface Methodology (RSM) with the Box–Behnken Design (BBD). The corrosion current density was measured through potentiodynamic polarization tests conducted under the varying conditions specified in the design matrix. The significance of the developed quadratic model was confirmed through ANOVA, with p-values below 0.05 and satisfactory regression coefficients (R2). The RSM results indicated a strong correlation between the predicted and observed outcomes. Notably, the chloride ion concentration ([Cl-]) had the most significant detrimental effect on aluminum dissolution. Additionally, the Electrochemical Impedance Spectroscopy (EIS) results suggested that the corrosion process is predominantly controlled by diffusion mechanisms.[5]

The Pyrolytic Characteristics of Polyethylene Terephthalate (PET) Plastic Waste in the Presence of Activated Montmorillonite Catalyst: Investigations Using TGA and EGA-MS Techniques

The production of PET-based plastics, primarily utilized in food and beverage packaging, has been steadily increasing each year, leading to significant environmental challenges. One potential solution for addressing PET plastic waste is pyrolysis, which can transform these materials into valuable products, including benzene-rich oil. However, the large-scale implementation of this method faces obstacles due to the generation of acidic byproducts, such as terephthalic acid, which can lead to reactor pipeline blockages and corrosion. This study explores the catalytic pyrolysis of PET using a thermally activated montmorillonite (AMMT) catalyst to enhance the viability of PET recycling for energy generation. The thermal and catalytic pyrolysis characteristics of PET in the presence of AMMT were thoroughly examined through TGA and EGA-MS analyses. The TGA results demonstrated that AMMT lowered both the onset and peak decomposition temperatures during PET pyrolysis. Additionally, isothermal TGA findings revealed that AMMT significantly decreased the quantity of carbonaceous residue produced. EGA-MS analysis further indicated that AMMT altered the quantity and distribution of gaseous products released, as evidenced by variations in the intensities of the extracted ion thermograms.[6]

Exploring the Viable Uses of Ginger Rhizomes as an Eco-Friendly Biomaterial: A Comprehensive Review

The rhizome of ginger (Zingiber officinale Roscoe), commonly referred to as ginger, is among the most widely utilized species in culinary practices and traditional medicine. Ginger is abundant in a variety of hydrophobic and hydrophilic active compounds, each exhibiting distinct properties. Its fresh aroma, sharp flavor, and numerous health benefits, coupled with its accessibility and affordability, contribute to the appeal of ginger rhizome. Beyond its applications in herbal medicine and as a flavoring agent in culinary dishes and beverages, ginger rhizome shows promise in various other domains. This review examines the existing evidence regarding the primary potential applications of ginger, which include its role in food preservation and packaging systems, meat tenderization, medicinal properties, inhibition of metal corrosion, preservation of biodiesel from oxidation, and its involvement in the synthesis of metal nanoparticles. In summary, this review offers significant insights into the versatility of ginger rhizome as a plant-based resource, extending beyond its traditional uses in herbal medicine and flavor enhancement in food.[7]

The enhancement of the synthesis procedure for acetylvanillin and the examination of the reaction mechanism

Acetylvanillin (4-acyloxy-3-methoxy-benzaldehyde) is a significant derivative of vanillin, characterized by its pronounced milk aroma. It serves as an intermediate in the synthesis of vanillin from eugenol, isoeugenol, and other starting materials. This compound is frequently utilized as a flavoring agent in a variety of dairy products, including modulated milk powder, fresh milk, yogurt, as well as in biscuits, beverages, cosmetics (such as perfumes), tobacco, wine, and food packaging, among others. The presence of various functional groups (-CHO, AcO-, MeO-) on the benzene ring of acetylvanillin enables it to participate in numerous chemical reactions. Consequently, it is also extensively employed in the synthesis of pharmaceuticals and other fine chemicals as a vital organic intermediate. Currently, the chemical synthesis of acetylvanillin primarily utilizes vanillin as the starting material, with the preparation involving acylation agents like anhydrides and acyl chlorides at room temperature, often in the presence of strong bases or catalysts. However, this method presents several challenges, including incomplete reactions, prolonged esterification times, complex post-treatment processes, equipment corrosion, and difficulties in obtaining catalysts. This study examines the impact of various experimental conditions on yield, such as the ratios of raw materials, choice of solvents, alkaline reagents, and reaction duration, while also focusing on optimizing the synthesis process and analyzing the reaction dynamics. Vanillin and acetic anhydride were employed as the primary raw materials.

The reaction process of acetylvanillin was examined and characterized using the capillary melting point method, FT-IR, and GC-MS/MS techniques. The findings indicated that the optimal synthesis conditions for acetylvanillin were established as follows: the molar ratio of the reactants n(vanillin): n(acetic anhydride): n(triethylamine) was 1:1.3:0.5; the reaction duration at ambient temperature was 0.5 hours, resulting in a yield of 99.0%. The role of triethylamine as a catalyst in the reaction was analyzed, and its catalytic mechanism was hypothesized. This method offers several advantages, including mild reaction conditions, a brief reaction time, high yield, low cost, and the easy availability of raw materials, along with straightforward operational procedures. This research may serve as a valuable reference for optimizing synthesis processes, analytical methods, and foundational theoretical studies.[8]

Research and progress of chemical depolymerization of waste PET and high-value application of its depolymerization products

Polyethylene terephthalate (PET) is characterized by its excellent transparency, resistance to corrosion, effective gas barrier properties, and robust mechanical attributes. It finds extensive applications in various sectors, including beverage containers, textiles, food packaging, tires, films, and engineering plastics. However, the increasing demand and utilization of PET materials have led to significant environmental concerns regarding waste PET pollution. The primary methods for recycling waste PET encompass primary recycling, mechanical recycling, chemical recycling, and energy recovery. Among these, chemical recycling plays a crucial role in addressing environmental challenges and diminishing the plastic industry's reliance on petrochemical resources, making it a vital approach for achieving closed-loop recycling of PET. This paper reviews the chemical depolymerization techniques for waste PET, identifies the alcoholysis catalysts with the highest potential for industrial application, and explores the research on high-value applications of chemical recovery products, aiming to provide valuable insights and promote the recycling and high-value utilization of waste PET.[9]

A comprehensive review of chemical analysis, migration, and risk assessment concerning coatings used in food and beverage containers

The inner surfaces of food and beverage cans are typically lined with polymeric coatings designed to preserve the contents and safeguard the metal substrate from corrosion. These coating materials consist of intricate formulations that include various starting substances such as monomers, prepolymers, and additives. Additionally, during the manufacturing process, several compounds may be generated, including reaction and degradation products. These substances possess the potential to migrate into the food, with many remaining unidentified and only a few having undergone toxicological assessment. This article seeks to deliver a thorough review of the analytical techniques employed to identify potential migrants in can coatings. It also examines the migration and exposure to chemicals originating from these coatings, which is crucial for risk assessment. Furthermore, a concise overview of the current legislative framework regarding varnishes and coatings for food contact in Europe is included. Techniques such as liquid chromatography coupled with diode array and fluorescence detectors, as well as mass spectrometry and gas chromatography–tandem mass spectrometry, are particularly favored for identifying potential migrants in can coatings. Some research has indicated that migration levels of bisphenol A (BPA) and bisphenol A diglycidyl ether (BADGE) and their derivatives have surpassed the specific migration limits established by European legislation. Overall, studies have reported low dietary exposure to migrants from can coatings; however, it is noteworthy that these investigations have not accounted for the combined exposure to multiple chemicals.[10]

Payasam

Payasam is a traditional and adaptable dessert from South India, primarily composed of milk along with various cereals, grains, or lentils, and frequently incorporates fruits and vegetables. This delectable Indian sweet pudding is typically sweetened with either sugar or jaggery and is enhanced with spices such as cardamom and saffron. Additionally, most payasams feature a tempering of dry fruits sautéed in ghee, which contributes to their rich taste and aroma.

Prior to serving, payasam is kept in Ever Silver vessels. During this time, these vessels may experience corrosion as a result of the ingredients found in payasam. The current study aims to assess the corrosion behavior of Ever Silver vessels when in contact with payasam, both with and without the addition of sugar. To achieve this, a polarization study has been conducted to evaluate the corrosion resistance of the Ever Silver electrode across three different systems: water, payasam without sugar, and payasam with sugar.

EXPERIMENTAL

Ever silver Composition

Ever silver is a type of silver alloy composed of 92.5% pure silver and 7.5% of another metal, typically copper .The inclusion of these additional metals enhances the hardness of the alloy, resulting in a more durable material.

Semiya payasam recipe

Kheer, also known as payasam or payesh, is a pudding or porridge popular in the Indian subcontinent, usually made by boiling milk, sugar or jaggery, and rice. It can be additionally flavoured with dried fruits, nuts, cardamom and saffron. Instead of rice, it may contain cracked wheat, vermicelli (sevai), sago or tapioca (sabudana).

Figure 1: Payasam in Ever Silver vessel

In Southern India, it is known as payasam and it is made in various ways. The most popular versions are the ones made with rice and vermicelli (semiya). In the present study vermicelli was used.[11,12]

How to make Semiya Payasam?

Stepwise process is given below.

1. In a heavy pan or kadai, add 2 tablespoons ghee first. Let it melt. Once it melts, then add 12 to 15 cashews.
2. On a low heat fry the cashews in ghee until they become golden.
3. Remove the golden fried cashews with a slotted spoon and then add 1 tablespoon raisins to the hot ghee.

4. Fry the raisins on a low heat. The raisins will soon start to swell up. Stir often while frying.
5. Once the raisins swell, then remove them with a slotted spoon.
6. Set the raisins aside with the fried cashews.
7. Before you begin roasting semiya, you may have to break them with your hands if you are using longer semiya. This makes it easier for you to stir them when roasting.
8. Mix well. Keep the heat to a low and begin to roast the semiya stirring often.
9. Roast until the semiya becomes golden. Stir often while roasting semiya for even browning and so that they do not burn. These get cooked fast, so do not leave them unattended.
10. Once the strands becomes golden add 3.5 cups whole milk. Milk can be chilled, hot or at room temperature. For a thin payasam you can add 4 cups milk.
11. Mix very well.
12. Keep the heat to a low or medium-low and simmer until the vermicelli strands softens. Do stir at intervals so that the milk or semiya does not stick or get burnt at the bottom of the kadai or pan.
13. Simmer until the semiya is softened. Do scrape the sides of the kadai where milk solids will be collected and add them into the vermicelli payasam.
14. When the semiya has softened add 4 tablespoons sugar or add according to the sweetness desired. 4 tablespoons of sugar works perfectly for us. If you want a more sweeter payasam, add more sugar.
15. Sprinkle ½ teaspoon cardamom powder.
16. Mix very well and simmer semiya payasam on a low to medium-low heat for further 2 to 3 minutes. The sugar should dissolve.
17. Switch off the heat and then add the fried cashews and raisins. You can even keep a few raisins and cashews for garnishing your payasam.
18. Serve semiya payasam hot or warm.

Electrochemical study

Electrochemical investigations, including polarization studies were conducted using the CHI workstation model 660A. A three-electrode cell assembly was used (Figure 2). Ever Silver was used as working electrode. Platinum was used as counter electrode. Saturated calomel electrode (SCE) was used as reference electrode.

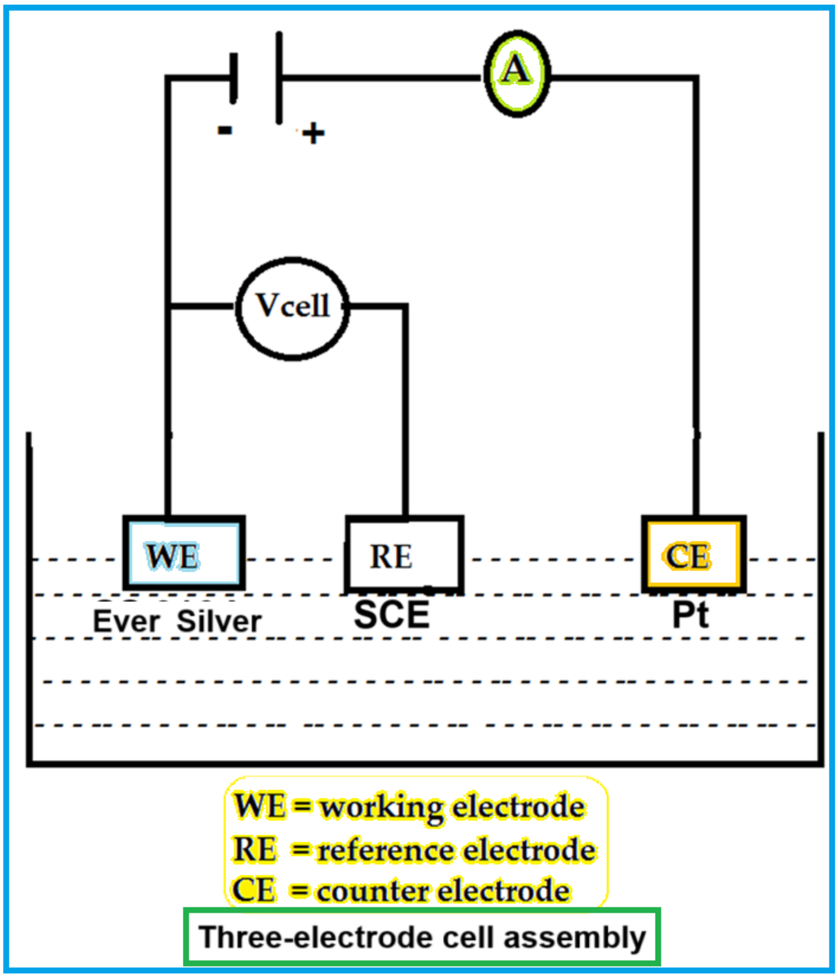

Figure 2: Three-electrode cell assembly

RESULTS AND DISCUSSION

Polarization study

The polarization curves are illustrated in Figure 3, while the corrosion parameters are presented in Table 1. Generally, a decrease in corrosion resistance corresponds to a decrease in linear polarization resistance (LPR) values and an increase in corrosion current values (Figures 3-7). The data presented in the Figures 3-7 and Table1 suggest that the corrosion resistance of ever silver vessel containing payasam decreases in the presence of sugar.

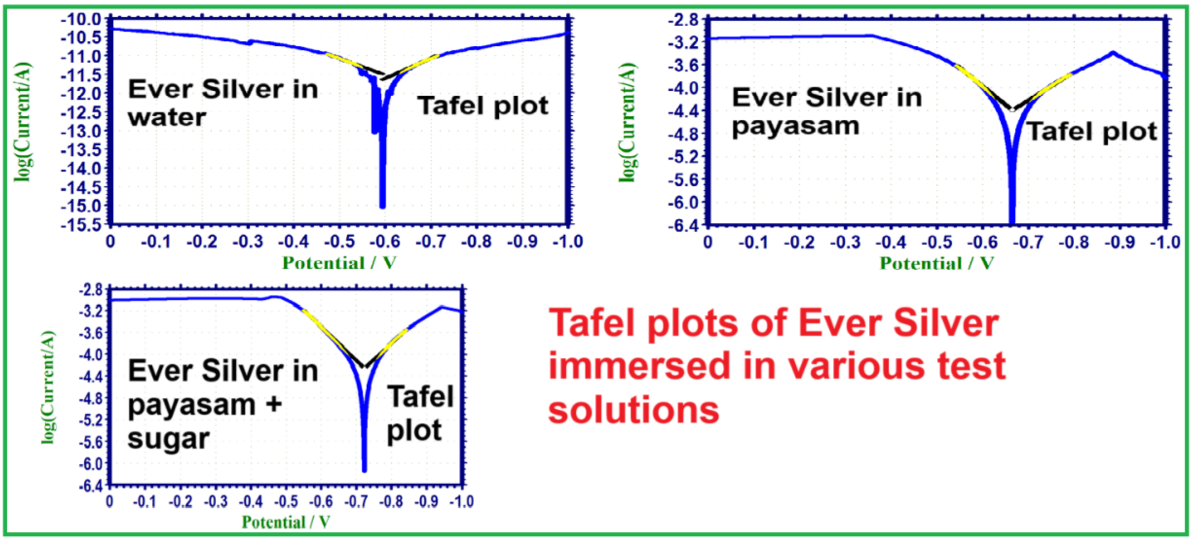

Figure 3: Tafel plots of Ever Silver immersed in various test solutions

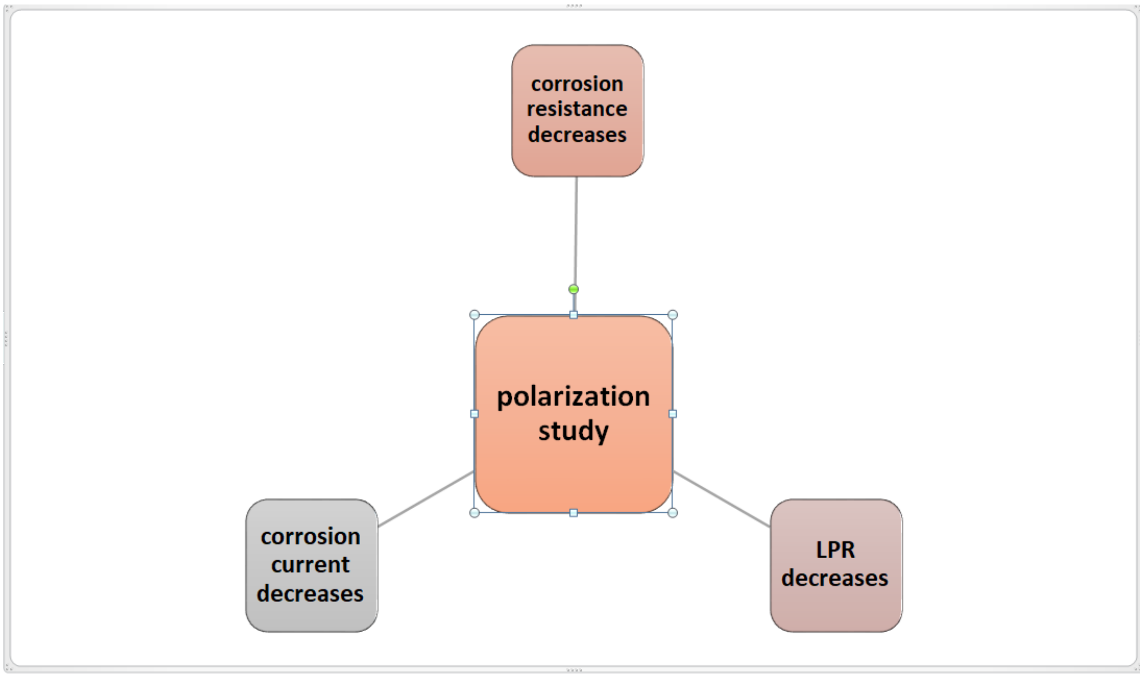

Figure 4: Correlation among corrosion parameters of polarization study

The linear polarization resistance of Ever Silver is observed to decrease in the following sequence: water system, payasam without sugar system, and payasam with sugar system.

The corrosion current increases in the order: payasam with sugar system > payasam without sugar system > water system

Correspondingly, the corrosion resistance follows the same trend.

This study reveals that the corrosion resistance of Ever Silver vessels utilized for the storage of payasam is adversely affected by the presence of sugar. Therefore, it is recommended to avoid storing sugar-containing payasam in Ever Silver vessels for prolonged durations.

Implication

Payasam that includes sugar should not be preserved in any silver container for a longer time. This information is particularly beneficial for office workers and students and the public during festivals and marriage parties.

System	E_{corr} V vs SCE	β_c V/decade	β_a V/decade	LPR Ohmcm2	I_{corr} A/cm2
Water	-0.594	5.363	4.524	13645369128	3.223x 10^{-12}
Payasam	-0.664	4.968	6.498	758	5.002 x10^{-5}
Payasam + sugar	-0.723	5.979	6.205	536	6.660 x10^{-5}
In presence of Payasam	Shifts to cathodic side			LPR decreases. So corrosion resistance decreases	Icorr increases. So corrosion resistance decreases
In presence of Payasam + sugar	Shifts to cathodic side			LPR decreases. So corrosion resistance decreases	Icorr increases. So corrosion resistance decreases

Table 1: Corrosion parameters of Ever Silver immersed in payasam in the absence and presence of sugar obtained from polarization study

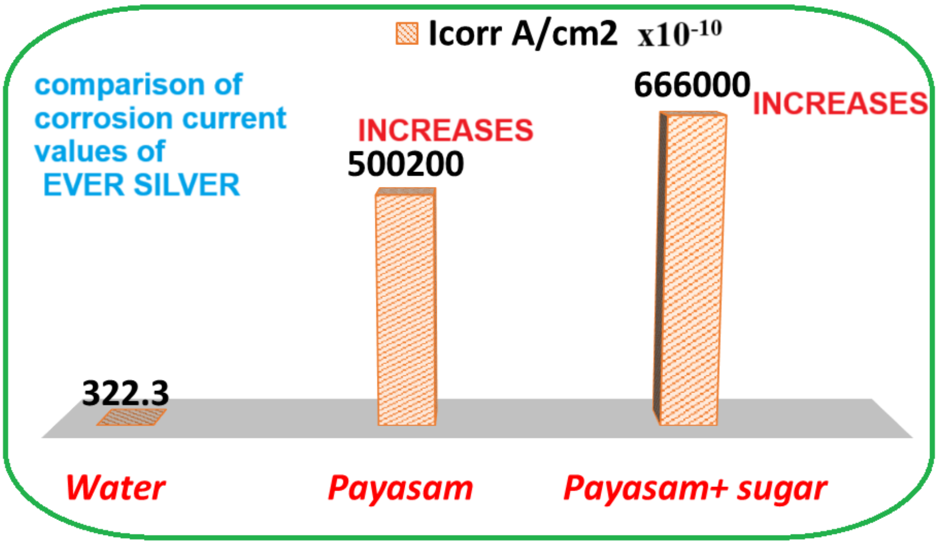

Figure 5: Comparison of corrosion current values of EVER SILVER in various test solutions

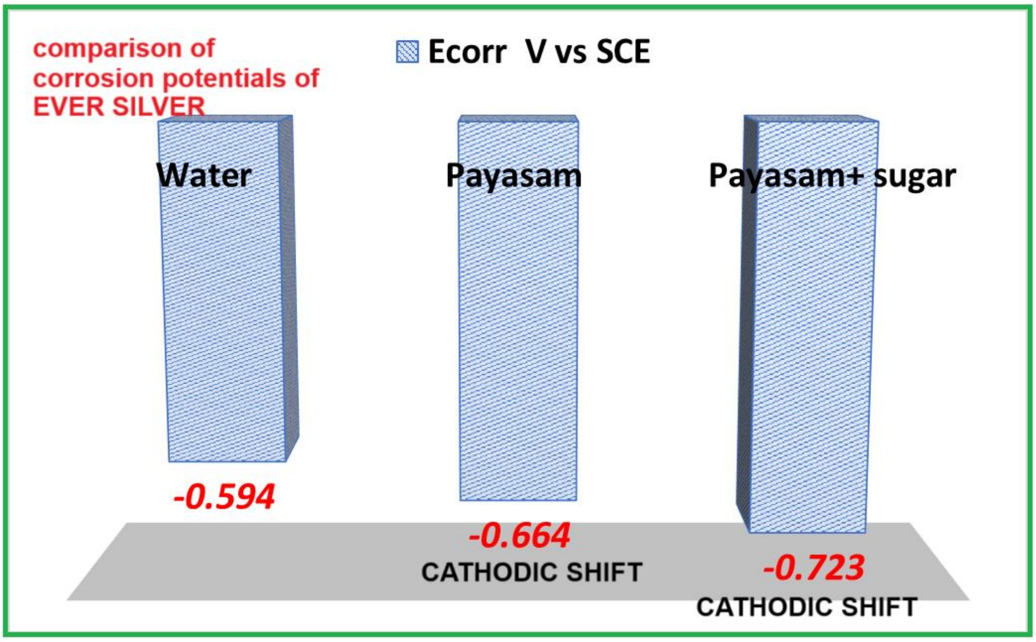

Figure 6: Comparison of corrosion potential values of EVER SILVER in various test solutions

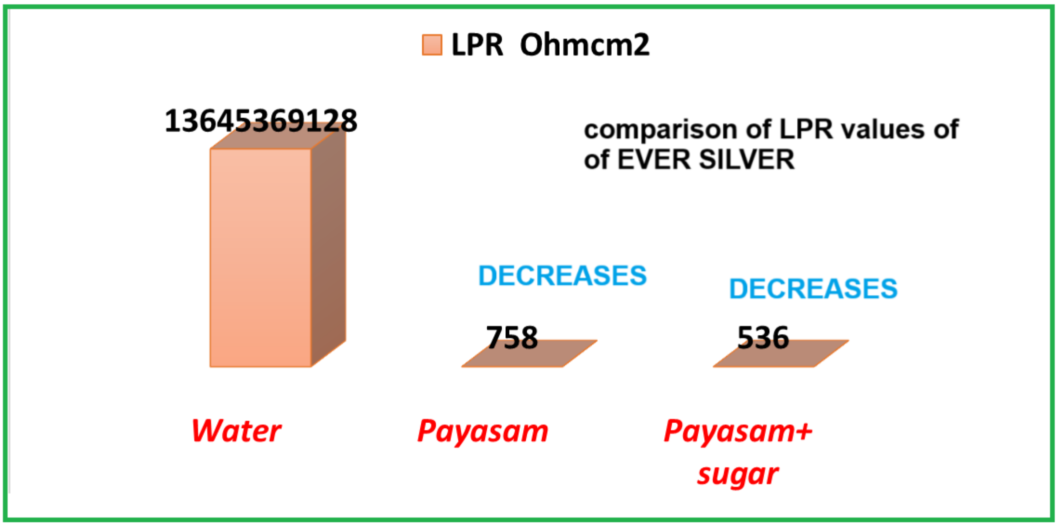

Figure 7: Comparison of LPR values of EVER SILVER in various test solutions

CONCLUSIONS

- A polarization study has been performed to assess the corrosion resistance of the Ever Silver electrode in three distinct environments: water, payasam without sugar, and payasam with sugar.
- The linear polarization resistance of Ever Silver decreases in the following order: water system > payasam without sugar system > payasam with sugar system.
- The corrosion resistance also decreases in the same order.
- The study indicates that the corrosion resistance of Ever Silver vessels used for storing payasam diminishes when sugar is present.

- Consequently, it is advisable not to store sugar-containing payasam in Ever Silver vessels for extended periods.

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