CORROSION BEHAVIOUR OF 18 CARAT GOLD IN RINGER SOLUTIONS IN THE PRESENCE OF SODIUM CHLORIDE AND GLUCOSE

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This work aims at studying the electrochemical behaviour of metals like 18 carat gold in presence of Simulated Ringer's Solution and Lactated Ringer's Solution in presence of 100 ppm of NaCl and also 100 ppm of glucose are used to simulate the body fluids. The behaviour of the metal was monitored by polarization study and electrochemical impedance spectroscopy (EIS). All the experiments were carried out at a constant temperature of 37 °C. From these studies, it was concluded that the avoid of excess of NaCl and also glucose in both Ringer solutions in medicinal uses.

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INTRODUCTION

Surface properties and anti-corrosion characteristics are the most important material characteristics determining the biofunctionality of all implant materials. 18 Carat gold has been a valuable biomaterial for manufacturing implants due to its unique properties such as shape memory effect, super elasticity and good mechanical properties.[1-4] Many devices such as stent, orthodontic wires and root canal files have been used clinically.[2-5]

Ringer's analysis of the influence of blood constituents on contraction of the frog heart (1882-1885) pioneered general development of artificial extracellular media for maintenance of living material during in vitro physiological studies. "Ringer's solutions" are thus defined here as those designed to substitute for the blood plasma, hemolymph, or other extracellular fluids of any species with respect to variables such as ionic concentrations, pH, and osmotic pressure. Media described in the literature as "physiological salines" and "balanced salt solutions" are included here under the general Ringer's heading. Mimicry of native conditions is achieved in varying degrees by the many different Ringer's formulations.Ringer's solutions are typically intended for relatively short-term maintenance of living material, not for its growth or extended culture. In this respect they differ from cell, tissue, and organ culture media, which are more complex and beyond the scope of this Compendium.

Since Na^+ is normally the principal extracellular ion, sodium chloride is the major component of most Ringer's solutions. Some formulations have relatively few additional ingredients but are nevertheless more complex than most "buffered salines", consisting principally of sodium chloride and a pH buffer, presented Ions such as Na^+, K^+, Ca^{2+}, and Mg^{2+} are critical for many functions. Researchers initiating work are urged to select physiological solutions carefully for the particular species to be studied, and to consider developing new ones based on analysis of the natural extracellular medium. Many Ringer's solutions,[6-8] are the product of empirical testing for retention of the activity being studied. Thus, in addition to being used directly, recipes provided here can serve as a starting point for improved formulations.

The Electrochemical impedance spectroscopy (EIS) is a relatively modern technique widely extended in several scientific fields. The EIS consists on a non-destructive technique when working under equilibrium conditions (free corrosion potential or open circuit potential), particularly sensible to small changes in the system that allows to characterize material properties and electrochemical systems even in low conductive media.

The impedance method consists in measuring the response of an electrode to a sinusoidal potential modulation of small amplitude (typically 5-10 mV) at different frequencies. The alternative current (AC) modulation is superimposed either onto an applied anodic potential or cathodic potential or onto the corrosion potential.[9,10]

EXPERIMENTAL

Materials and methods

Corrosion resistance of 18 Carat Gold in Ringer's Solution and lactated Ringer solution has been investigated by polarization study and AC impedance measurements. All measurements were performed at 37±1 °C. Ringer's Solution was composed of 6.0 g L^{-1} NaCl, 0.075 g L^{-1} KCl, 0.1 g L^{-1} $CaCl_2$ and 0.1 g L^{-1} $NaHCO_3$. The lactated Ringer solution comprised of 6.0 g L^{-1} NaCl, 0.3 g L^{-1} KCl, 0.2 g L^{-1} $CaCl_2$ and 3.1 g L^{-1} sodium lactate. [6-8,11]

The 18 carat gold was composed of 75 % gold and 25 % copper.

AC impedance measurements

H and CH electrochemical workstation impedance analyzer model CHI 660 was used to record AC impedance measurements. A three-electrode cell assembly was used. The working electrode was the studied metal. A saturated calomel electrode (SCE) was the reference electrode and platinum the counter electrode.[13,14] The real part (Z') of the cell impedance was measured in ohms for various frequencies. The change transfer resistance (R_t) and double layer capacitance (C_{dl}) values were calculated

$$R_t = (R_s + R_t) - R_s \qquad (1)$$

where R_s = solution resistance, and

$C_{dl} = 1/2\pi R_t f_{max}$,

where f_{max} = maximum frequency.

The equivalent circuit diagram for such system is shown in Figure 1.

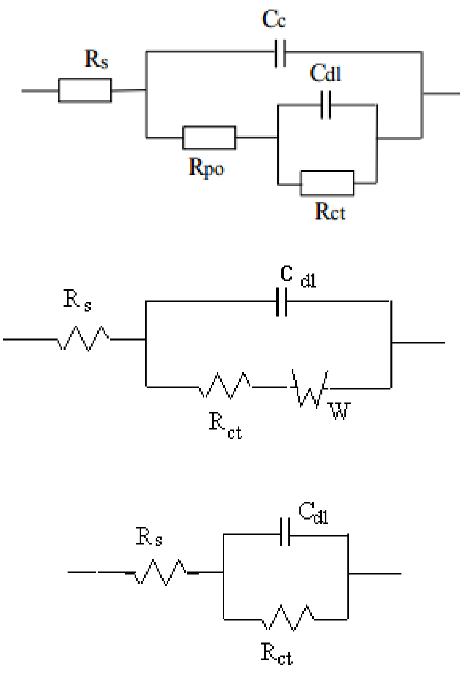

Figure 1. Equivalent circuit for a failed coating. C_c - The capacitance of the intact coating, R_{po} - pore resistance, R_{ct} - charge transfer resistance, R_s - solution resistance, C_{dl} - double layer capacitance, W - Warburg diffusion resistance.

RESULTS AND DISCUSSION

Corrosion resistance of 18 carat gold in simulated Ringer's solution and lactated Ringer's solution has been measured by polarization study and AC impedance spectra[13,15-33]

An increase in corrosion resistance results in increase in *LPR* value, decrease in corrosion current, increase in charge transfer resistance, increase in impedance value and decrease in C_{dl} value.

Polarization study

In the polarization study, shown in Figure 2 to 7, the corrosion parameters like corrosion potential (E_{corr}), Tafel slopes (b_c=cathodic, b_a=anodic), *LPR* (linear polarization resistance) value and corrosion current were measured. They are given in Table 1.

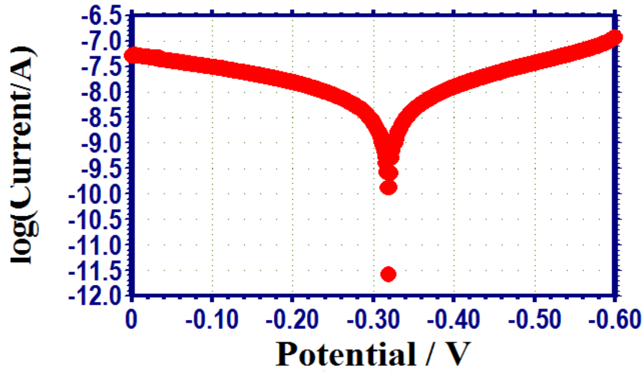

Figure 2. Polarisation curve of 18 carat gold immersed in Simulated Ringer's Solution.

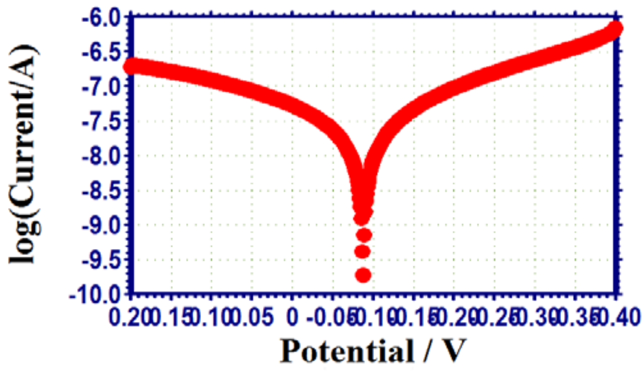

Figure 3. Polarisation curve of 18 carat gold immersed in Simulated Ringer's Solution + 100 ppm of NaCl.

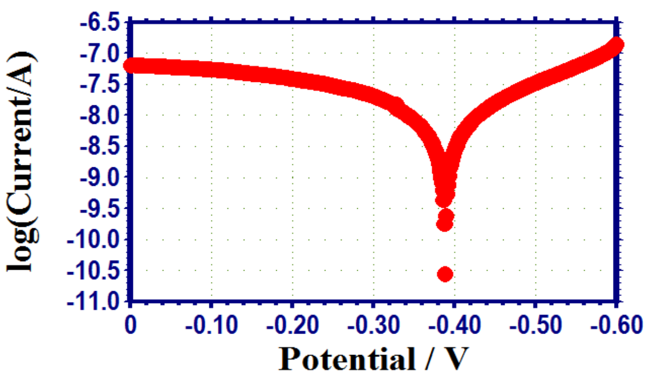

Figure 4. Polarisation curve of 18 carat gold immersed in Simulated Ringer's Solution + 100 ppm of glucose.

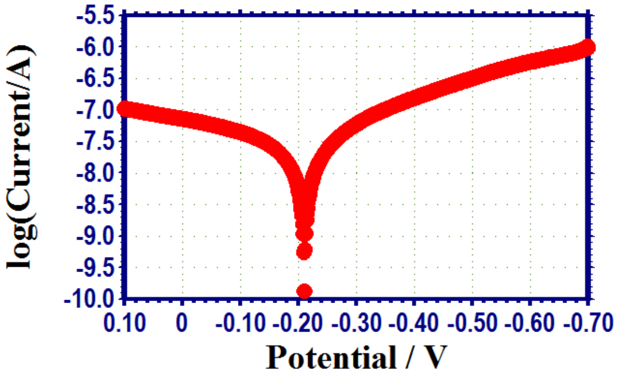

Figure 5. Polarisation curve of 18 carat gold immersed in Lactated Ringer's Solution.

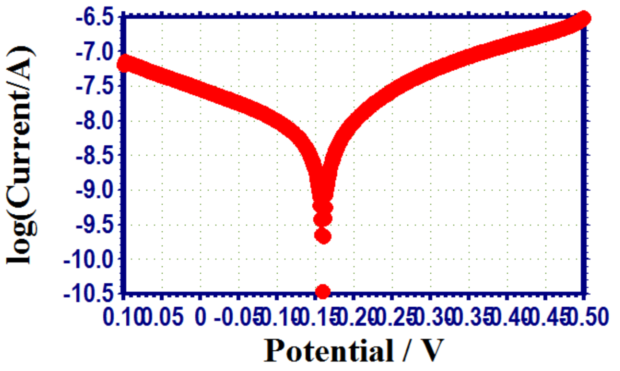

Figure 6. Polarisation curve of 18 carat gold immersed in Lactated Ringer's Solution + 100 ppm NaCl.

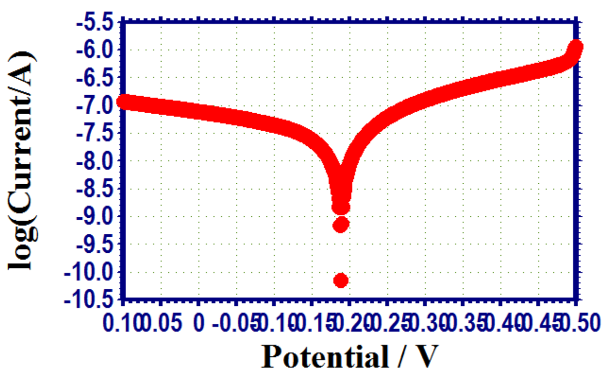

Figure 7. Polarisation curve of 18 carat gold immersed in Lactated Ringer's Solution + 100 ppm glucose.

Ringer's Solution

Influence of 100 ppm of NaCl

It can be seen from the Table 1, that the corrosion resistance of 18 carat gold decreases in presence of 100 ppm of NaCl. In the presence of NaCl, *LPR* value decreases from 7361238 to 4472869 ohm cm^2. The corrosion current increases from 5.44×10^{-9} to 2.657×10^{-8} A cm^{-2}.

Influence of 100 ppm of glucose

Similarly, the corrosion resistance of 18 carat gold decreases in presence of 100 ppm of glucose. In the presence of glucose, *LPR* value decreases from 7361238 to 1540062 ohm cm^2.The corrosion current increases from 9.584×10^{-9} to 2.657×10^{-8} A cm^{-2}.

Lactated Ringer's Solution

Influence of 100 ppm of NaCl

It is observed from the Table 1, that the corrosion resistance of 18 carat gold decreases in presence of 100 ppm of NaCl, the corrosion resistance decreases. In the presence of NaCl, LPR value decreases from 5028338 ohmcm^2 to 1873424 ohmcm^2. The corrosion current increases from 3.605 x 10^{-9} A cm^{-2} to 2.467 x 10^{-8} A cm^{-2}.

Influence of 100 ppm of glucose

Similarly, the corrosion resistance of 18 carat gold decreases in presence of 100 ppm of glucose. In the presence of glucose, *LPR* value decreases from 5028338 to 1403355 ohmcm^2.The corrosion current increases from 7.625 × 10^{-9} to 2.467 × 10^{-8} A cm^{-2}.

AC impedance spectra

The instrument polarization study was used to record AC impedance spectra also are shown in Figure 8 to 13. Corrosion parameters such as charge transfer resistance (R_t), double layer capacitance (C_{dl}), Impedance are measured. They are given in Table 2.

Ringer's solution

Influence of 100 ppm of NaCl

It is noted from the Table 2, that the corrosion resistance of 18 carat gold decreases in the presence of 100 ppm of NaCl, the R_t value decreases from 537220 to 139115 ohm cm^2. C_{dl} value increases from 9.493×10^{-12} to 3.666×1 0^{-11} F cm^{-2}. The impedance value decreases from 5.775 to 5.247.

Influence of 100 ppm of glucose

Similarly, the corrosion resistance of 18 carat gold decreases in the presence of 100 ppm.of glucose, the R_t value decreases from 537220 to 9430 ohm cm^2. C_{dl} value increases from 9.493 × 10^{-12} to 5.408 × 10^{-10} F cm^{-2}. The impedance value decreases from 5.775 to 4.430. From this, it is inferred that the corrosion resistance of 18 carat gold in Ringer's solution decreases in the presence of 100 ppm of NaCl and also 100 ppm of glucose.

Table 1. Polarization study of the study of corrosion of 18-carat gold.

System	E_{corr}, mV vs SCE	b_c, mV decade^{-1}	b_a, mV decade^{-1}	*LPR*, Ω cm^2	I_{corr}, A cm^{-2}
Ringer's solution	-319	169	202	7361238	2.657X10^{-8}
Ringer's solution+100 ppm NaCl	-389	179	220	4472869	5.442X10^{-9}
Ringer's solution+100 ppm Glucose	-88	167	215	1540062	9.584 X10^{-9}
Lactate Ringer's solution	-160	141	235	5028338	2.467 X10^{-8}
Lactate Ringer's solution+100 ppm NaCl	-211	171	279	1873424	3.605 X10^{-9}
Lactate Ringer's solution+100 ppm Glucose	-189	165	394	1403355	7.625 X10^{-9}

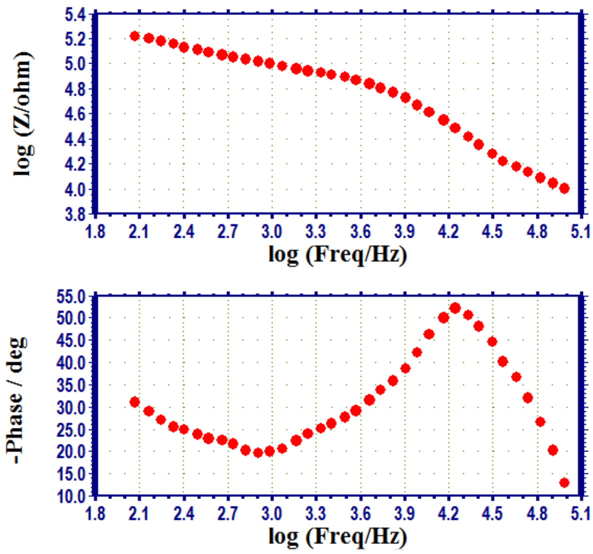

Figure 8. AC impedance spectra of 18 carat gold immersed in simulated Ringer's solution.

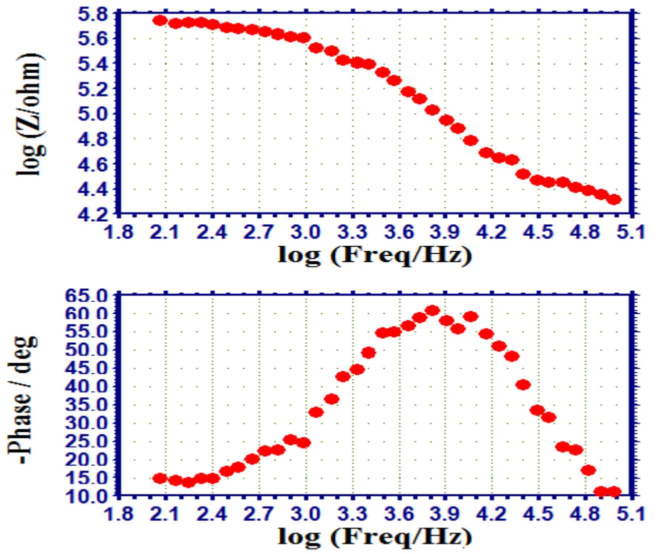

Figure 10. AC impedance spectra of 18 carat gold immersed in simulated Ringer's solution +100 ppm of glucose.

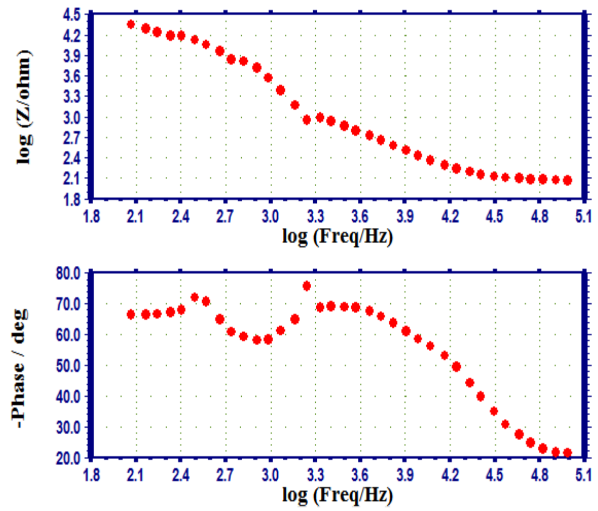

Figure 9. AC impedance spectra of 18 carat gold immersed in simulated Ringer's solution +100 ppm of NaCl.

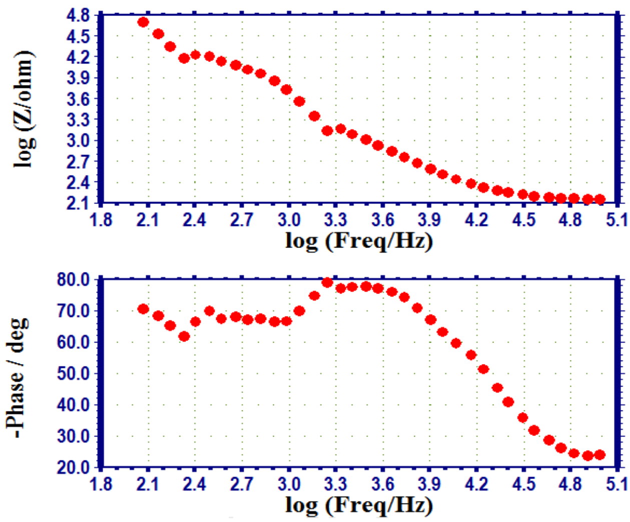

Figure 11. AC impedance spectra of 18 carat gold immersed in Lactated Ringer's Solution.

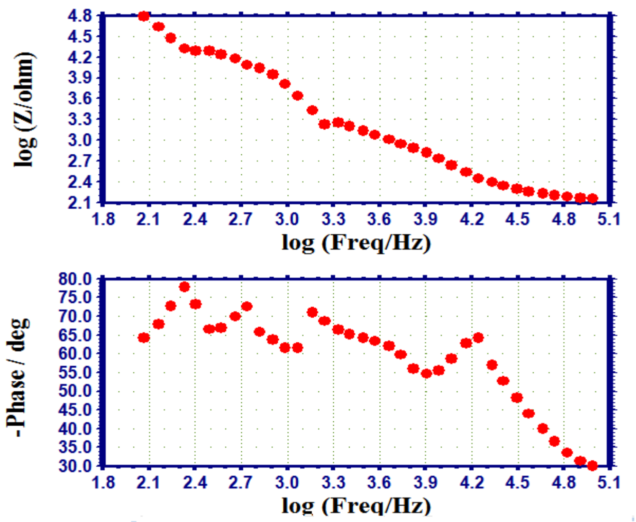

Figure 12. AC impedance spectra of 18 carat gold immersed in Lactated Ringer's Solution + 100 ppm of NaCl.

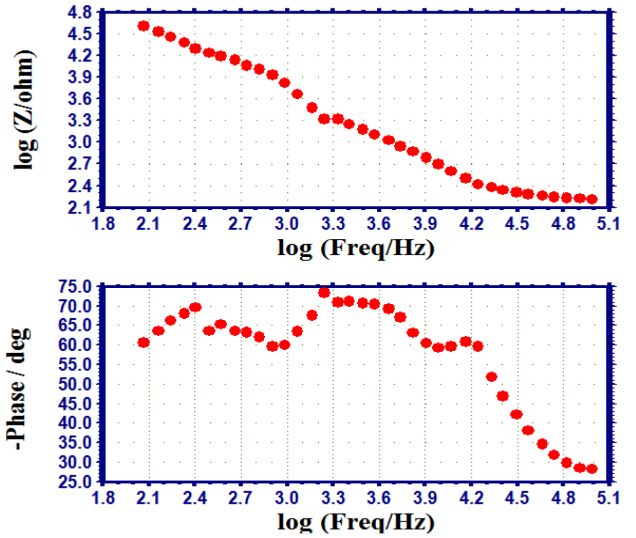

Figure 13. AC impedance spectra of 18 carat gold immersed in Lactated Ringer's Solution + 100 ppm of glucose.

Lactated Ringer's Solution

Influence of 100 ppm of NaCl

It is observed from the Table 2, that the corrosion resistance of 18 carat gold decreases in the presence of 100 ppm of NaCl, the R_t value decreases from 27920 to 19990 ohm cm^2. C_{dl} value increases from 1.827×10^{-11} to 2.551×10^{-10} F cm^{-2}. The impedance value decreases from 4.792 to 4.769.

Influence of 100 ppm of glucose

Similarly, the corrosion resistance of 18 carat gold decreases in the presence of 100 ppm.of glucose, the R_t value decreases from 27920 to 17550 ohm cm^2. C_{dl} value increases from 1.827×10^{-11} to 5.569×10^{-9} F cm^{-2}. The impedance value decreases from 4.792 to 4.679.

From this, it is inferred that the corrosion resistance of 18 carat gold in Lactated Ringer's solution decreases in presences of 100 ppm of NaCl and also 100 ppm of glucose.

Table 2. Corrosion parameters as determined by AC Impedance.

System	R_t	C_{dl}	Impedance
Ringer's solution	537220	9.493×10^{-12}	5.775
Ringer's solution +100 ppm NaCl	139115	3.666×10^{-11}	5.247
Ringer's solution +100 ppm glucose	9430	5.408×10^{-10}	4.430
Lactate Ringer's solution	27920	1.827×10^{-11}	4.792
Lactate Ringer's solution +100 ppm NaCl	19990	2.551×10^{-10}	4.769
Lactate Ringer's solution +100 ppm glucose	17550	5.569×10^{-9}	4.679

CONCLUSION

The corrosion resistance of 18 carat gold in Ringer's solution and in lactated Ringer's solution has been evaluated by polarization study and AC impedance spectra. The influence of 100 ppm of NaCl and also of 100 ppm of glucose on the corrosion resistance of 18 carat gold has also been investigated. This study leads to the following conclusions.

Corrosion resistance of 18 carat gold in Ringer's and lactated Ringer's solutions decreases in presence of 100 ppm of NaCl and also of 100 ppm of glucose. This is confirmed by polarization study and AC impedance spectra. It implies, care must be taken to avoid excess of NaCl and also glucose in Ringer's and also in lactated Ringer's solution.

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