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PROCESS PARAMETRS AFFECTING THE HYDROGEN PRODUCTION BY WATER ELECTROLYSIS AND ELECTROLYSER CHARACTERISTIC

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ABSTRACT

The hydrogen production by solar electrolysis depends on the distance between the electrode and the test tube. In fact, the height (h = 3cm) was the best taken as a parameter while relying on the rate of production as a measure of effectiveness. Raising the temperature increases the input electrolyzer voltage, which results in a temperature rise electrolyte to a value of 8.2V at 100 °C. Sunshine is strongly influenced the hydrogen production where changes from one site to another. The effects of the salinity degrees is investigated, which displayed a decrease of the hydrogen flow for the salt masses included between 50 and 130 g/l. Additionally, the current density was higher in acid-base environment, and lower in neutral for pH values around 6.4 and 8.4. Moreover, the hydrogen flow was higher for the electrolyte based margin.

Keywords: Hydrogen, Electrolyte, Temperature, Salinity, Sunshine.

Contribution/ Originality

This study documents summarizes the influence of key process parameters on electrolysis hydrogen production. The obtained information can also be used to design and operate the step processes for electrolysis production only. As result, hydrogen yields obtained in this study are improved. Additionally, this paper provides an insight to these parameters in regards to minimize the energy loss of the water electrolysis process.

1. INTRODUCTION

Most of the hydrogen is produced from fossil fuels which are intended for the petroleum refining industry and the chemical industry for the manufacture of ammonia and methanol [1].

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Most exercises prospective energy considering the development of the hydrogen is in transport applications and under highly stringent climate policies. Hydrogen is widely reported to an important future energy carrier and as the ultimate non-polluting fuel if it is produced in a sustainable manner [2]. The key to achieving the "hydrogen economy" is taken as the scale of hydrogen without fossil gas consumption and other emissions such as COx, SOx and NOx [3, 4] production. The electrolysis of water [5, 6], thermochemical cycles [7, 8] and photocatalysis process [9, 10] are some of the non-fossil fuels the most important processes for producing hydrogen.

In order to improve the production of hydrogen, a parametric optimization for the experimental conditions must be exploited. Electrolyzers performance effect of a number of factors must be included, among which are the pH, temperature, salinity and the nature of the electrolytes.

The prospect of higher returns on a massive hydrogen production excites particular interest to a higher temperature [11].

The electrolysis process does not require a high temperature source. However the sun (due to higher levels of greenhouse gas emissions in the atmosphere) must ensure energy supply, reduce air pollution and meet the growing energy demands of a growing population [12, 13]. Therefore, recent studies consider thermal energy sources with lower operating temperatures for water [14]. The effect of a number of factors must be included, among which are the pH, salinity, sunshine and the electrolyte temperature. Previous studies on the production of hydrogen by electrolysis were also used as a process [15, 16] and it was shown that for a neutral (pH = 7). Many parameters are interdependent, for example the rate of growth of the culture and the physical and chemical environment. It is therefore quite important to extrapolate the results obtained from studies at steady state.

In the standard condition (P, T = const) yields hydrogen production was evaluated daily by combining gas volumes recorded with a current density normalized to the cathode surface [17].

From simple design results, the performance of system is evaluated, some key parameters are optimized, and the effects of some parameters on system performance are discussed.

Electrolysis of water is currently only a few percent of the total hydrogen product. However, as it is a mode of production a priori, that provides clean hydrogen of high purity, it is therefore of great interest for applications such as fuel cells. Electrolysis of water is an electrochemical method, using electrical energy, to decompose water into hydrogen and oxygen, in which the two chemical reactions occur separately to the anode and the cathode:

So that oxidation of hydroxide ions

$$2H_2O\ (l) + 2e^- \longrightarrow H_2\ (g) + 2OH^-\ (aq) \tag{1}$$

In both cases, the overall reaction is written [5].

$$2H_2O\ (l) \longrightarrow O_2\ (g) + 4H^+(aq) + 4e^- \tag{2}$$

The dissociation enthalpy of the reaction at 25 °C and 1 bar is $\Delta H = 285$ kJ.mol^{-1}

$$H_2O\,(l) \longrightarrow H_2\,(g) + 1/2\,O_2\,(g) \qquad (3)$$

The decomposition of water is therefore not a spontaneous process and can therefore be done by electrolysis under different conditions. As indicated on the decomposition of water that can be performed in an alkaline medium, acid and high temperature in the latter two cases, respectively using the PEM and SOFC technologies [18].

2. EXPERIMENTAL AND PROCEDURES

The production of hydrogen by electrolysis of water occurs in the redox reaction between the two electrodes which are respectively registered by oxidation and reduction.

Depending on the case, the electrochemical half-reactions that occur at each electrode are different **Fig. 1**. This reaction requires a supply of reagent and an energy input made via a current generator. Thermodynamics provides an electrolyzer operation involving couples H + / H2 and O2/H2O a Gibbs potential of 1.23 V, the kinetic aspects which require a fixed voltage potential power of water to hydrogen and oxygen at a value of 1.48 V.

The electrodes are separated by an ion-conducting electrolyte which allows ionic transfer between the electrodes. During this process, the electric energy supplied to the system is converted into chemical energy in the form of hydrogen.

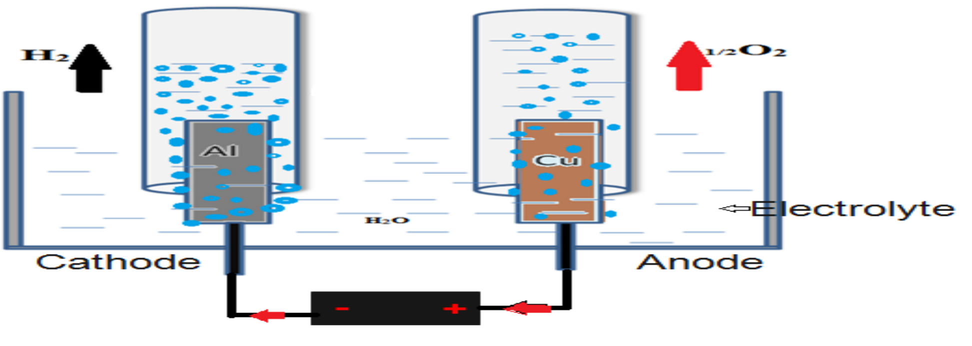

Figure-1.Schematic representation of the water electrolysis phenomenon.

2.1. Materials

A plexiglas is the electrolyzer for the electrodes are based on copper and aluminum (d = 6mm). Are used as measures of computers working: -A voltmeter (0-30V), A-Ammeter (0-l0A), Test-tubes, A-Timer, A photovoltaic module consists of 36 polycrystalline silicon cells, supplying a rated current of 3.4 and at rated voltage L5V.

The electrolyzer is connected to the generator, it is best to begin the experiment with the highest voltage U = 2 V and gradually decrease [19]. At the beginning of the transaction value of the current can be high, about 1 minute after the system becomes stable.

2.2. Calculated Test Parameters

Table-1. Different calculated parameters.

Parameters	Symbols	Equations	Units
Hydrogen flow	Q	Q=V/t	cm^3min^{-1}
Absorptive power	Pa	Pa=U*I	J
Useful efficiency	Pu	Pu=PCI*Q * ρ	Jcm^{-3}
Consumed Energy	W	W=Pa*t in (J)	J
Energy consumption per unit of volume	W/v	W/v = Pa*t/V	(Jcm^{-3})

Where PCI was the lower calorific value of hydrogen = (119.9 10 6 J/Kg) and ρ was the density of hydrogen (0.09 Kg/m^3).

3. RESULTS AND DISCUSSION

3.1. Characteristic of the Electrolyzer

The values of current and voltage is recorded, and the characteristic curve of the electrolyzer is plotted (Fig. 2). The characteristic curve of the electrolyser allows us to determine the value of the open circuit voltage Voc (power balance) to start the electrolysis.

We limit the measurements to a maximum voltage of 18 VDC. This curve varies according to the in series number of electrolyzer, and its surface which can limit the progress of the reaction of hydrogen composition [20].

Thus, the surveys tell us that the trigger voltage electrolysis is V = 18 V (a current of 1.50 A). This reference allows us to determine for the modeling, the power required by the electrolyzer: P min = 0.7 W for the electrolyzer.

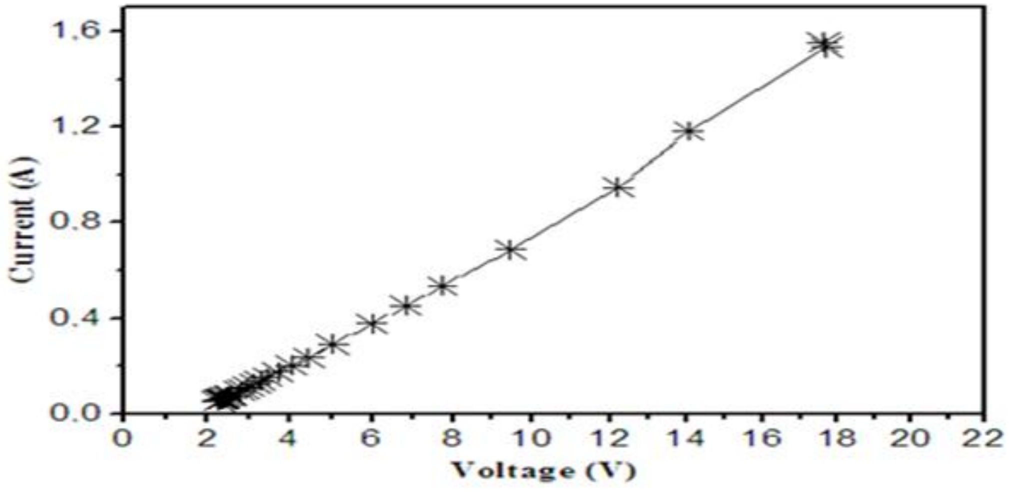

Figure-2. Change of the intensity of input in the electrolysis according to the voltage

3.2. Characteristic of the Photovoltaic Panel

The curve IPV = f (VPV) reflects its energy behavior under the influence of incident radiation, temperature and load. The experiment is carried out under conditions known as 'natural' as follows: direct sunlight and not in halogen lamp with variable power [3]. For the first steps, the module is fixed in a position and an orientation with an inclination of 35° to the horizontal. We choose among the measurements at a maximum variation of solar radiation.

We see Fig. 3, the open circuit voltage between 18 V and 20 V. The short-circuiting varies according to sunlight. Sunshine is a much more important parameter the current delivered by the module is proportional to the light received by the module surface.

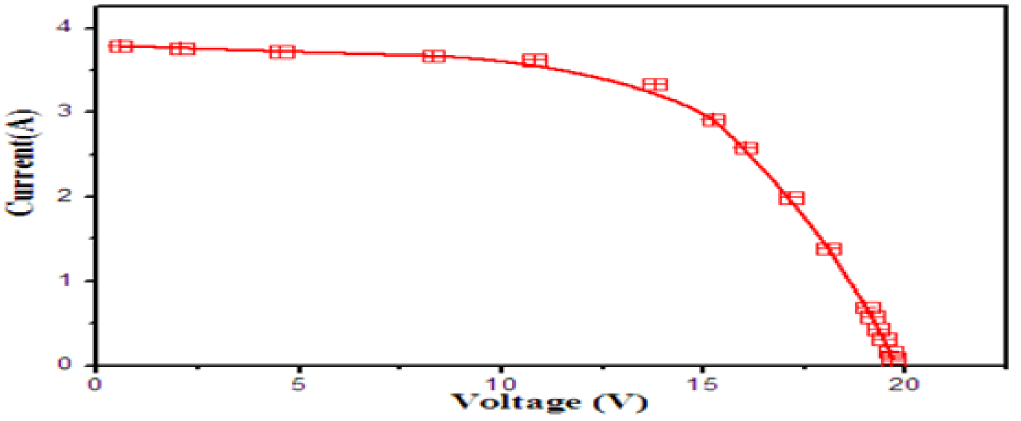

Figure-3.Characteristics of the photovoltaic module.

3.3. Operating Point of Origin of the Hydrogen

The operating point is the intersection of the curve of the photovoltaic module with the curve of the electrolyzer (Fig. 4) [21]. Graphically discloses the operating point at the following coordinates (17.92 V; 1.50 A).

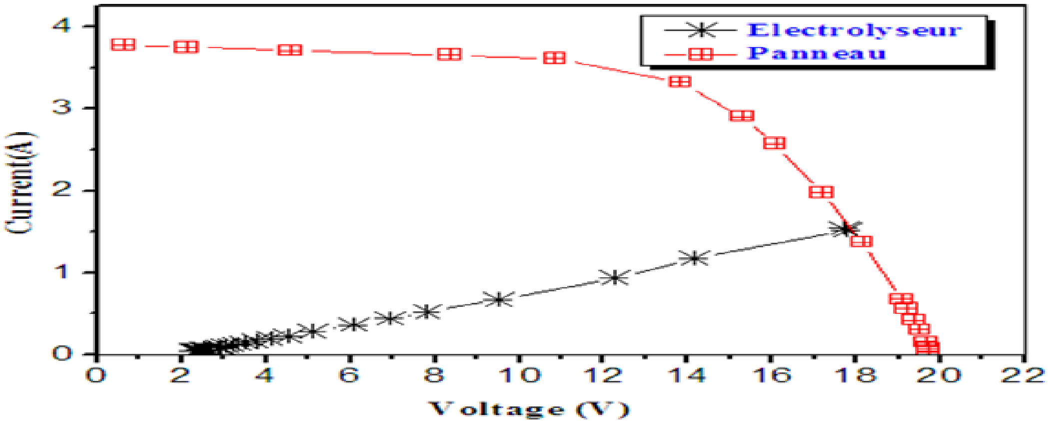

Figure-4. Graphical determination of the operating point

3. 4. Influence of the Height between the Electrode and Test Tube Production

In order to improve the performance of water electrolysers, hydrogen production by solar electrolysis depends on the distance between the electrode and the test tube, in fact, the height h is an important parameter in the hydrogen flow. In our case we have studied the influence of this parameter for both voltages, one of which is said to a maximum value U max = 19 V and another said minimum U min = 7 V.

- For U min= 7 V :

In order to have the influence of the height h of the production efficiency, a series of mistakes have been made for different heights h.

Examination of the results **Fig. 5** shows that the yield increases with height h and reaches a value of 3.5% when h = 3 cm.

- For U max= 19 V:

It is also necessary to increase the voltage in order to promote the reactions at the electrodes. The study of the variation in production yield as a function of height h shows that the increase in yield is proportional to the distance between the test tube and the electrode, that the best performance is achieved when the height h = 3cm. Indeed, the variation of the height h influences the measuring current; elevated h resulted in a significant current Fig. 6. Increasing the distance between the base of the electrolyzer and test tube increase the conversion has a direct impact on yields of H_2 production.

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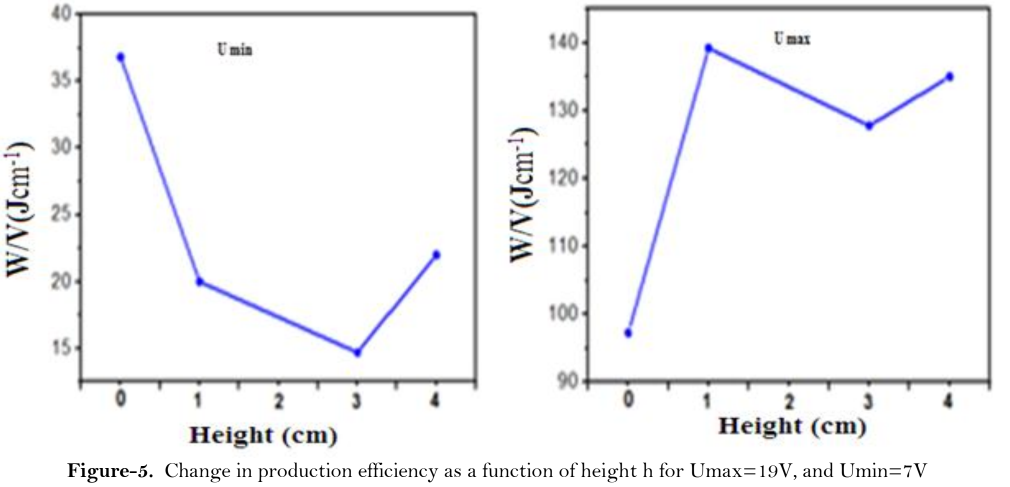

Figure-5. Change in production efficiency as a function of height h for Umax=19V, and Umin=7V

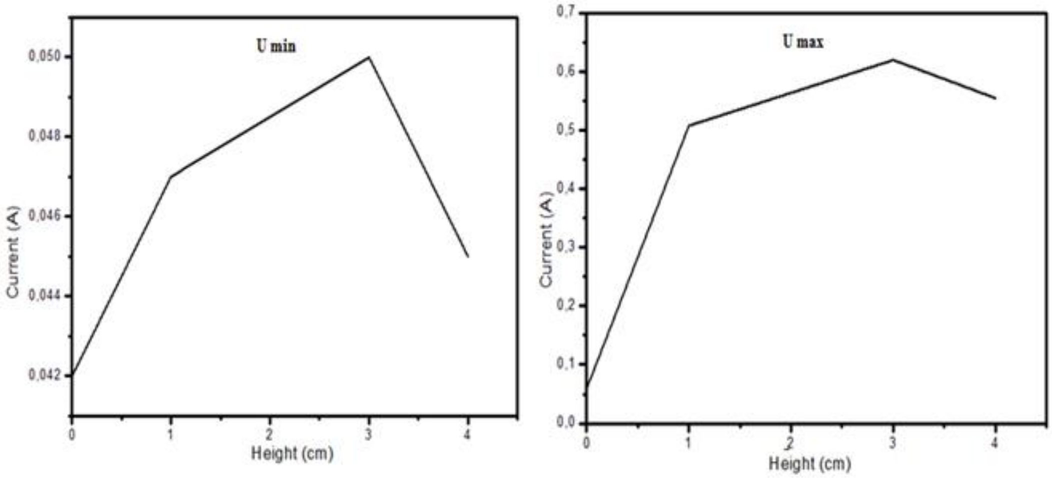

Figure-6. Variation of current as a function of height.

3.5. Regulator

The realization of our experience can be provided by a system controller to avoid the risk that we may back problems to experimental conditions, and it allows us to reserve the power source and stabilizes.

The examination of the results shows that the regulator importance more efficient, while note that the measurement of the current speaker of the solution rather larger electrolyzer in the absence of the regulator. However, the current is low in existence regulator Fig. 8 (a) with regulator, and greater in the absence of regulator Fig. 7 (b) without regulator.

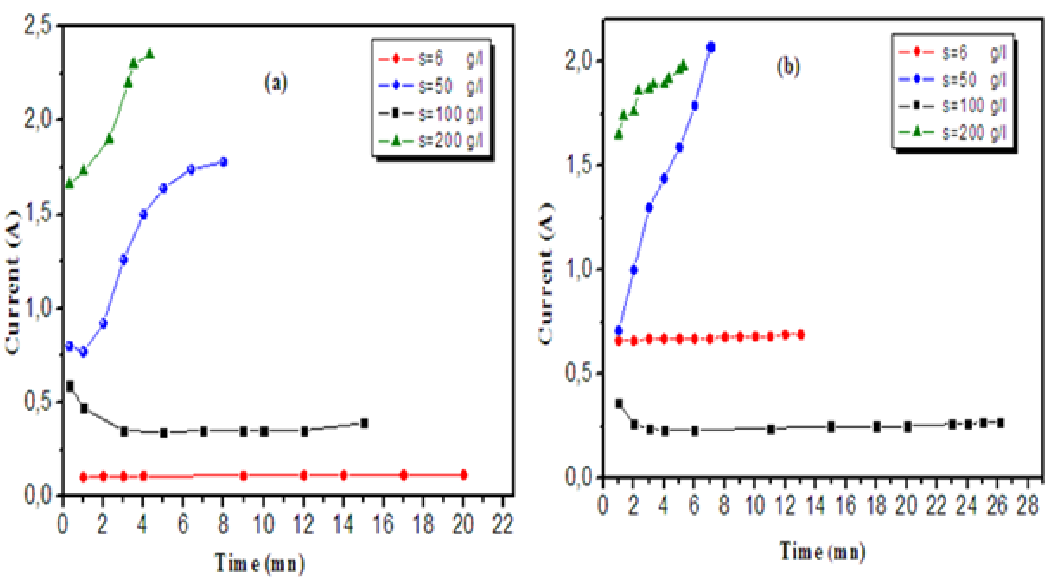

Figure-7. Change of current with time in the presence of regulator (a), and without a regulator (b).

3. 6. Electrolyte Temperature

The temperature and pressure of water dissociation are the parameters that influence the performance of electrolysis of water [22, 23].

This work is done at atmospheric pressure, and then we can only study the second parameter.

The increase in the electrolyte temperature of 25 ° C to 100 ° C greatly rise the current from 1 to 8.2A for the electrolyzer voltage is 11 V. So, it is ensured that the performance of the electrolysis is a function of temperature which increases the conductivity, and reduces surges at the electrodes [24].

In addition, when the operating temperature increases, the input voltage of the electrolyser decreases. This is because the high operating temperature will enhance the reactivity of the electrode to increase the ionic conductivity and reduce surges [25].

The hydrogen flow rate variation as a function of time shows that increasing the temperature decreases the flow of hydrogen. However we find that the kinetics is lower with an increase in temperature Fig. 8.

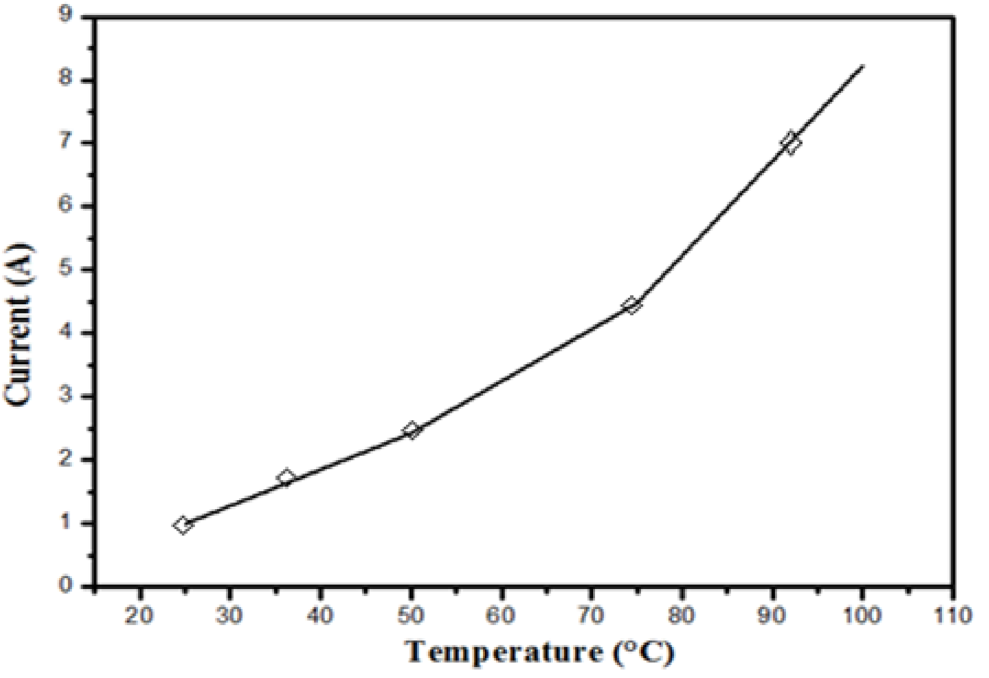

Figure-8. Current variation for different electrolyte temperatures.

The study of the variation of the current as a function of time show that it grows rapidly for a short time with elevated electrolyte temperature until a maximum value (1A).

Beyond this value, it appears that the current remains constant for long periods of time, the continuous current. This can be explained by the chemical interaction of the electrode and the environment, with an increase in temperature does not involve the passage of electric current to the metal surface. Moreover, the process of decomposition of water needs of thermal energy.

Indeed, if the heat generated in the water is used, the thermal energy required for the electrolyte per unit time can be reduced. Over time, and an increase in temperature is observed that the current undergoes a fall then it stabilizes and takes constant values. Research has defined the load current into two, one of steady, the other is continuous transient Fig. 9.

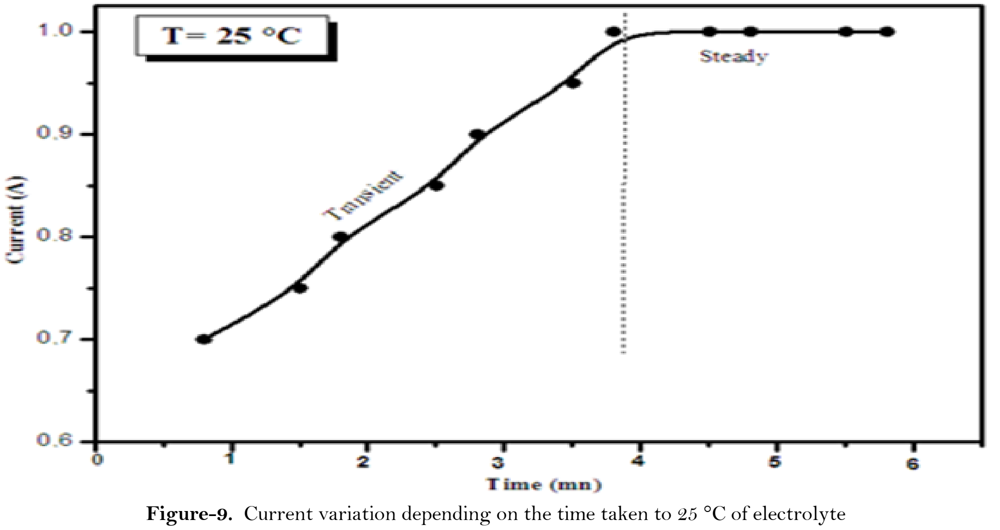

Figure-9. Current variation depending on the time taken to 25 °C of electrolyte

The transient current is attributed to a phenomenon of slow polarization, while the continuous current conduction characteristic of the phenomenon [26]. From an energy point of view, the optimal solution is handled at 50 ° C Fig. 10.

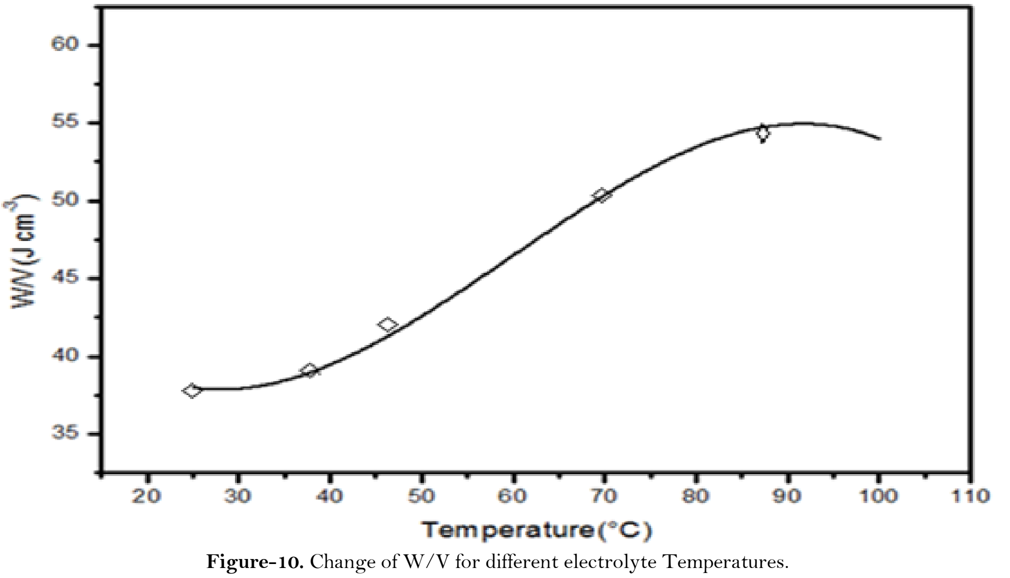

Figure-10. Change of W/V for different electrolyte Temperatures.

3.7. Sunshine

The nature and working environments can also reacted and influences the production of hydrogen by electrolysis of water. Sunshine is a parameter that changes from one site to another, even for the day. Fig. 11 shows that the production yield is higher at noon, is explained by the positioning of the sun, made noon climate temperature while decreasing energy consumption increases, and increases the flow.

We note that production time is greatly reduced beyond which it reaches a minimum value at noon and then it increases Fig. 12.

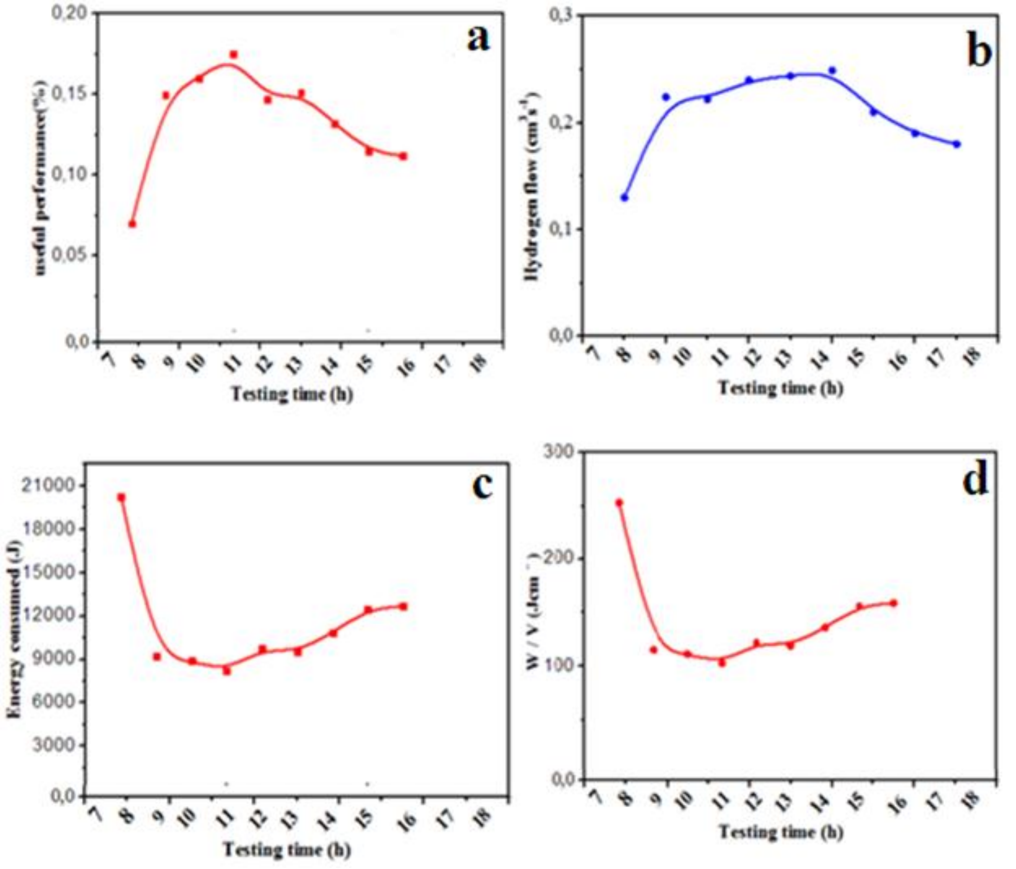

Figure-11. Change in yield, useful performance **(a),** Hydrogen flow **(b),** energy consumed **(c),** and W/V(**d**) for a day.

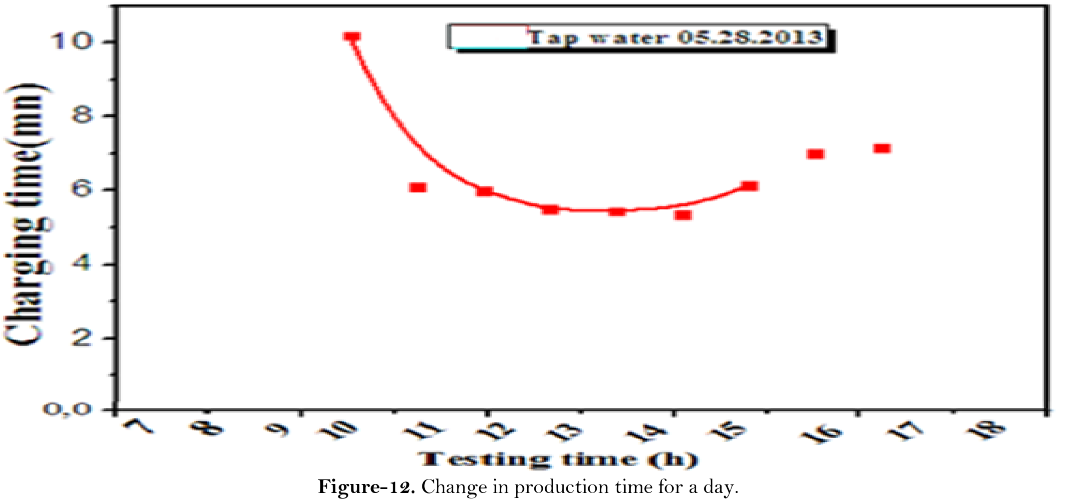

Figure-12. Change in production time for a day.

3.8. Salinity

The water contains numerous dissolved species, the majority of enter it as ions. This is defined as the mass in grams of dissolved species contained in one kilogram of water.

The salinity is strongly influences the production of hydrogen by electrolysis. But most water is salty it is more dense, causing a downward movement of the water.

Indeed, the addition of salt to affect the concentration of the electrolyte. The yield decreases with increasing salinity of the medium. When the salinity increases, the output increases, while the holding time decreases. This trend continues until a mass of salt is 50 g / l, around which the performance has a maximum value and where she uncrossed with the addition of NaCl. In addition, if we continue increased salinity, yield and throughput decreases. From 130 g/ l, both values began to grow with the addition of NaCl up to saturation of the electrolyte. This highlights the existence of changing the nature of the medium Fig. 13.

The change in amount of added salt shows that the existence of two transformations in the evolution of current and time of production. Indeed the addition of NaCl for quantities of 90, 110, 130 g / l resulted in a decrease in the current from the ideal course of the electrolyte. By cons for masses greater than 130 g / l and less than 90 g /l shows that the current increases while referring to the intensity of the normal liquid state.

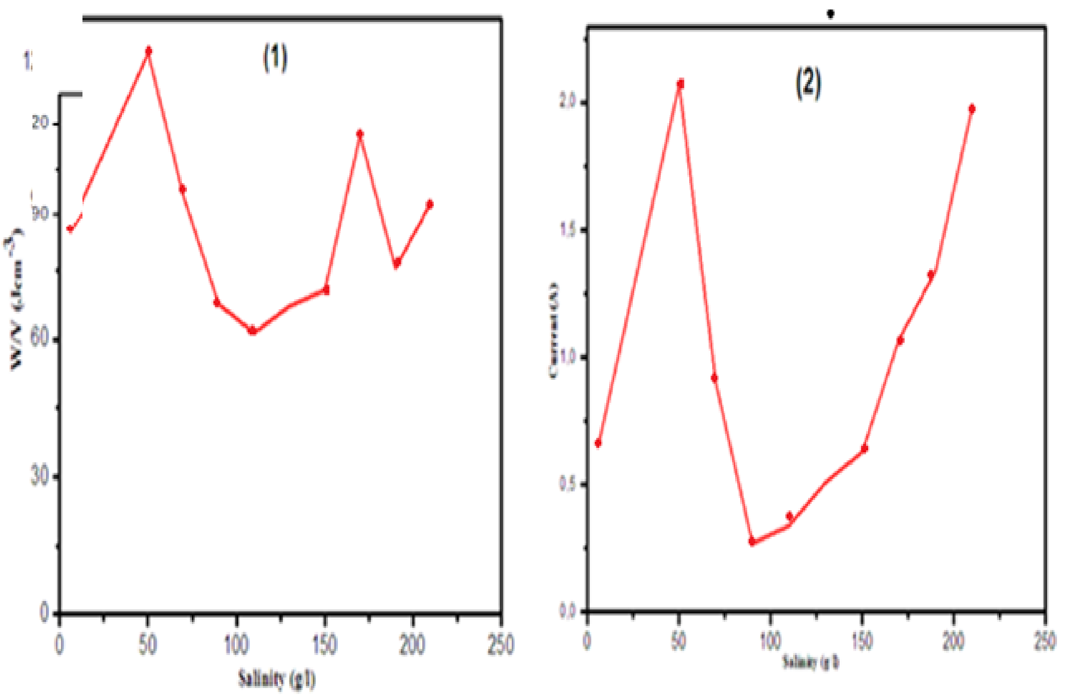

Figure-13. Dependence of W / V (1) andcurrent (2), with time for different salinity

3.8.1. Dependence of the Salinity and the pH Value

In order to investigate the variation of the degrees salinity with the current values, Fig. 14 showed the current dependence for different amount of added NaCl. Both a decreased and increase again, these results can be explained by the neutral reaction medium [27]. However in the case where the added mass of salts was around 90 to 130 g/l conduct to neutralizing the electrolyte (pH = 7.36).

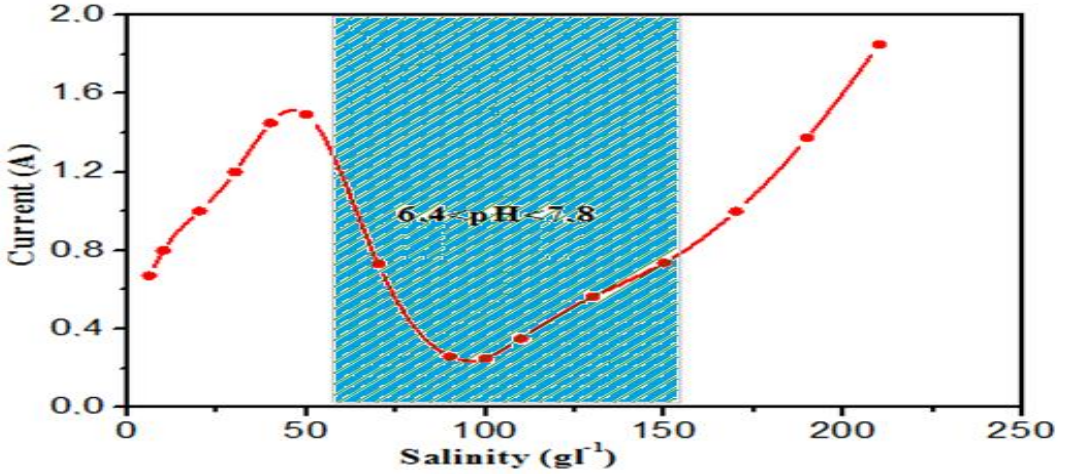

Figure-14. Dépendance entre la salinité du milieu et du courant.

Additionally, to confirm these results Fig. 15 displayed the dependence of the amount of NaCl mass and the electrolyte coloration. In fact, it is observed that for the masses ranging from 90 to 130 g/l the yellowish coloration persists indicated the neutrality of the medium. By cons for lower masses than 90 g/l or above 150 g/l electrolyte takes the blue coloration.

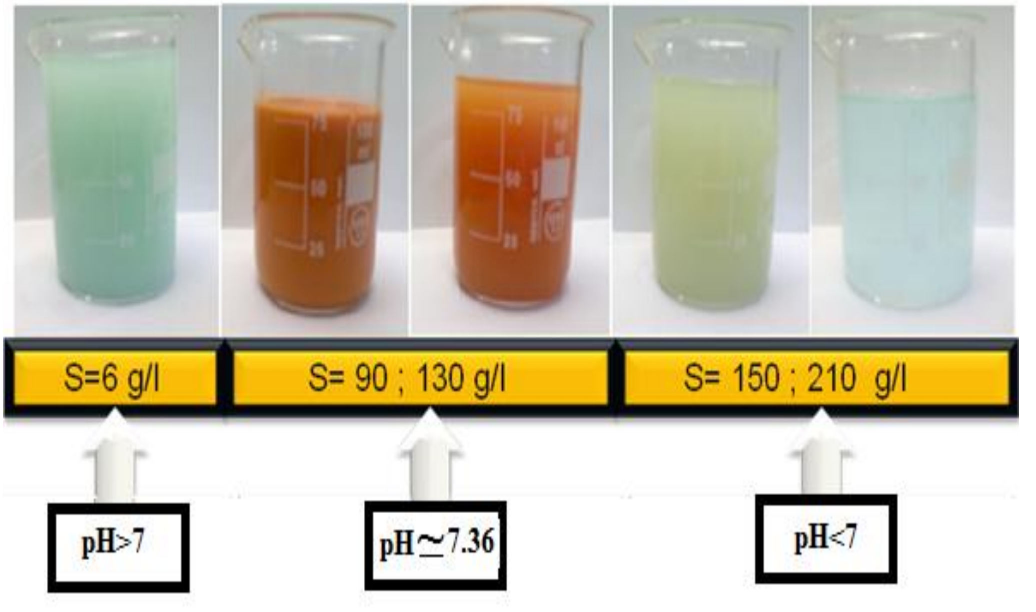

Figure-15. Dependence between the color and the salinity.

A typical behavior of the degrees salts to hydrogen flow is presented in **Fig. 16**. It was regenerated that at both degree of salinity the hydrogen flow was in dependence with time. As thetime increases, hydrogen flowdecreases, this trend continues to a particular hydrogen flow values merge with X-axis. Additionally, it is observed that follows the same path for different salinity. These results were explained by the existence of the deposit in the electrolyte.

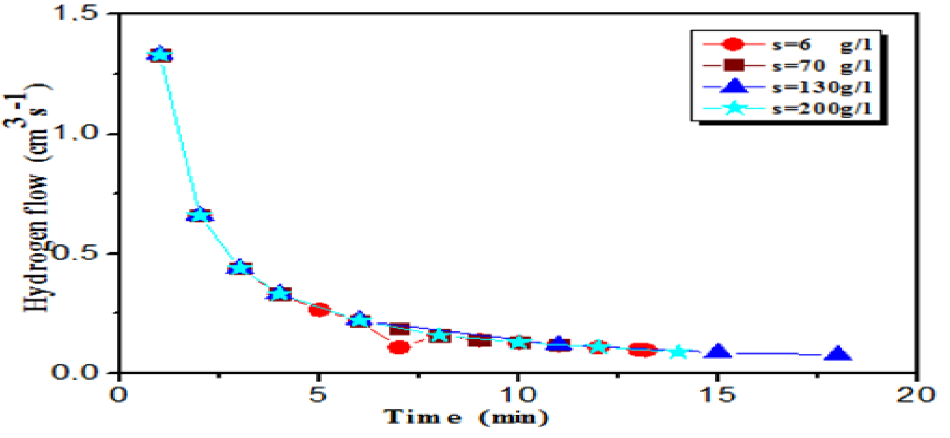

Figure-16. Variation of hydrogen flow as a function of time for different salinity degrees.

3.9. Reaction Medium

The nature and phase of which is that the electrolyte can also affect the production of hydrogen, while noting changes in the electrolysis system. To study the influence of pH on the rate of hydrogen, a series of mistakes have been made for different values of pH for the same electrolyte (tap water discharge). Examination of the results shows that the current density is higher in acid-base environment [28]. While it is lower in neutral media for pH values between 6.4 and 7.4. The hydrogen evolution could be expected to increase (numerically) for each decrease of one pH unit. Thus, operations at low pH increases the hydrogen production and reduce the overall electrical power consumed by the system. In the tests performed in this study, the voltage is 17.8 V, current and hydrogen production increased with decreasing pH (Fig . 17).

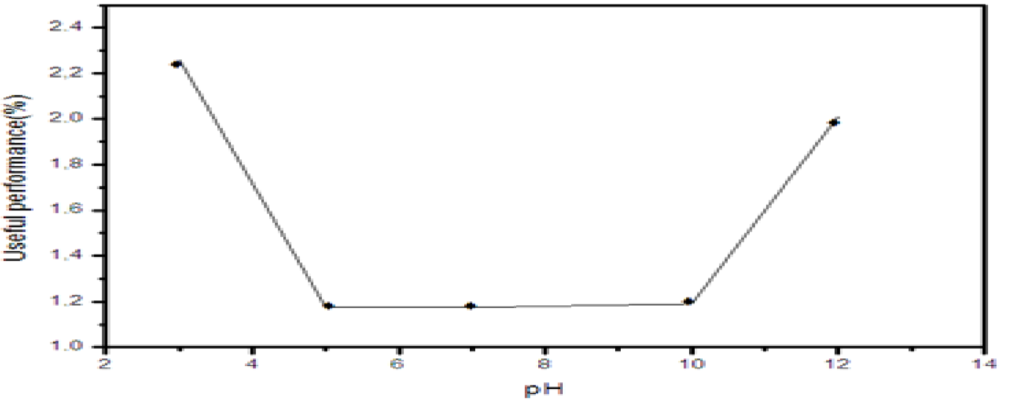

Figure-17. Evolution of the usual performance based on pH.

3.10. Types of Electrolytes

In order to improve the hydrogen flow, each liquid have a different physical and chemical properties that influenced on hydrogen production. The obtained results in this work indicate that different electrolytes have an action which varies with other electrolyte. Indeed, the hydrogen yield was higher for the vegetable, which the oily crater Fig. 18, 19. In addition, we find that the current is more important for the rejection of gypsum water [29, 30]. This increase in current can be explained by the phenomenon of electron transfer at the electrode surface.

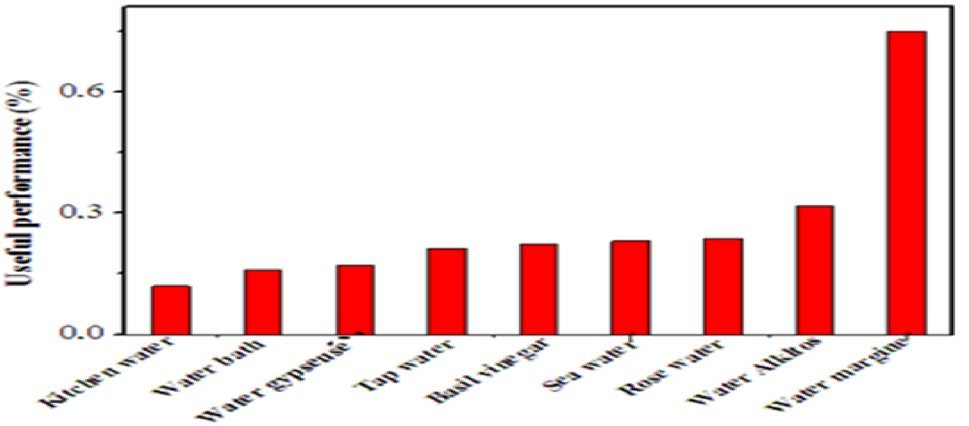

Figure-18. Evolution of the useful performance for different electrolytes.

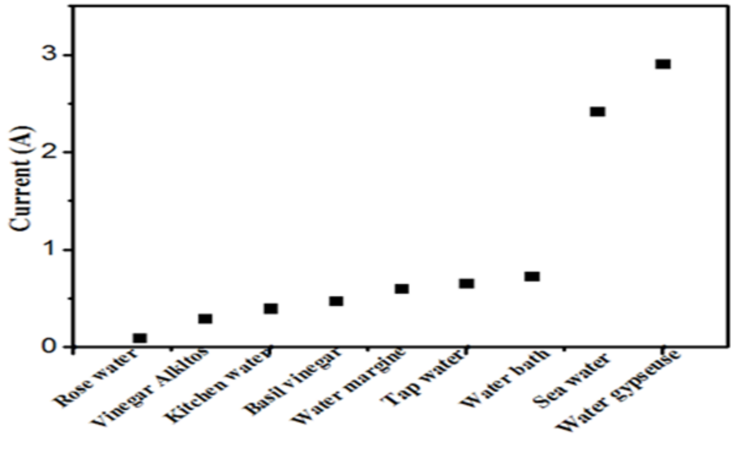

Figure-19. Evolution of the current for different electrolytes.

4. CONCLUSION

The production of hydrogen has been improved for the pH values of acidity or basicity greater while departing from pH = 7, the largest being at a voltage of 17.8 V at pH = 3 effect. The maximum hydrogen production is observed for values of lower mass concentration NaCl 70g / l, and greater than 130 g / l, giving a greater H_2 efficiency with lower energy consumption. The temperature of the electrolyte plays a more effective role in the recovery of H_2, in fact the current is higher is provided by a temperature increase. The nature of the electrolyte can also change the parameters of production, however, the vegetable water has a higher hydrogen flow.

NOMENCLATURE

I : Electrical current (A). // U : Tension (V) // P : Might (W) // PCI : Lower calorific value (J/kg) // Q : Flow rate (m^3/s) // V : volume of the test tube (m^3) // t : tube filling time (s) // W : electrical energy (J) // ρ: density of hydrogen (Kg/m^3) // DC :Courant continue // PV :Panneauphotovoltaïque.

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