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Use of a local Saharan plant (*Cladium mariscus*) in the solar still under southeast Algeria climate

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ABSTRACT

This study presents an experimental comparison of three solar stills operating under identical weather conditions. The first still, designated as the control conventional solar still (CSS), was compared to two modified versions: one featuring plant *Cladium mariscus* in its green state modified solar still (MSS1) and the other with the same quantity of plant in its dry state. The primary objective was to assess how the presence of plant *Cladium mariscus*, available abundantly and free of cost in the region, influences the performance of the solar still. The underlying hypothesis was that such integration could enhance water production. The results of the experiments revealed notable improvement rates; with MSS1 achieving a 17.33% enhancement and MSS2 was demonstrating a remarkable 33.27% improvement. In terms of thermal efficiency, MSS1 achieved 28.25%, MSS2 reached 32.65%, while CSS recorded 25.37%. These findings offer valuable insights for the development of more effective strategies to address the challenges associated with drinking water scarcity.

Keywords: Solar energy; Solar radiation; Potable water; Water accumulation

1. Introduction

Ensuring access to clean and safe drinking water is crucial for people's health and well-being. Unfortunately, water scarcity and pollution are global challenges, especially in places like El Oued City, Algeria, where water is limited and contaminated. This highlights the need for effective water treatment techniques that can remove impurities and harmful microorganisms to ensure water quality. Traditional methods like filtration and chemical treatment are often impractical and expensive due to infrastructure and resource limitations. In this context, solar distillation has emerged as a simple and sustainable method for water purification, using solar energy to turn impure water into drinkable water through evaporation and condensation processes [1–3].

Scientific research has focused on improving the performance of solar stills based on bills that affect their output [4]. One of the easiest factors is increasing the temperature of the water to be treated. For this, we use storage materials in water [4]. The utilization of phase change materials (PCMs) to enhance the efficiency of solar stills is a relatively recent

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technique. Passive solar stills equipped with PCMs can boost efficiency by as much as 120%, and active systems can enhance productivity by up to 700%. Productivity increases with the mass of PCMs but decreases with saltwater. PCMs perform better at night than during the day. Organic PCMs, especially paraffin, are commonly employed, while inorganic and eutectic PCMs have been less explored [5,6].

The study highlights the use of paraffin and mixing nano particles, like silicon oil and Cu, to achieve better results, with paraffin wax and $n$$Al_2O_3$ increasing production by 60.53%. Solar stills have been tested with a nanometric phase change material (MSS-IR-PCM). This experiment was under the same weather conditions. Result shows increased thermal productivity/efficiency of 115%/51.3% [7].

In Algeria, scientific research has focused on improving the performance of solar distillation by exploring a variety of materials as thermal energy storage materials, for example, zinc, aluminum, pieces of iron and plastic fins. Each of its materials was introduced into a solar still to evaluate its impact on the production of pure water. Notable improvement rates have been observed for these materials. Zinc, with an impressive improvement rate of 54%, has been shown to improve distillation efficiency [8]. Aluminum showed a more modest improvement rate of 33.32% [9], while iron parts showed an improvement rate of 23.46% [10]. The study on plastic fins aimed to enhance solar distillers, which provide clean water in remote areas. By adding small plastic fins to the distiller basin, we increased evaporation rates. The best results came from a 0.5 cm fin diameter, which boosted productivity by 41.4%. This research demonstrates how plastic fins can improve solar distillers for better pure water output [11]. A special study coupled a greenhouse solar still with a heat storage water tank to heat the brine, increasing performance. The results show a 27.70% improvement over daily lighting conditions, with a stable nighttime thermal efficiency of 60%–61% [12]. These results are not far from the international results. An Indian study used various energy storage materials such as pieces of iron and wire mesh. The experiments concluded that the wire mesh had the highest productivity, with improvements of 41.35% and 10.33% over conventional solar stills and iron pieces, respectively [13].

The utilization of non-metallic materials has proven instrumental in augmenting the performance of solar stills. Local experiments have revealed notable improvement rates with various materials: sponge demonstrated a 10% boost [14], ethanol exhibited a 20% enhancement [15], and the different types of coal resulted in an increase between 18.18%–79.39% in water production efficiency [16,17]. Conversely, the sand showed no discernible improvement in the distillation process, indicating a very low rate of improvement [18].

The researchers in the region embarked on a quest for innovative ways to boost the productivity of solar stills, turning to locally abundant and cost-free resources that is to say plant resource. They experimented with date kernels and olive kernels, observing an improvement of 176% for date kernels and 226% for olive kernels [19]. Subsequently, they tested discarded pieces of cardboard, achieving a 36% improvement [20], and even explored palm trees, which surprisingly yielded a remarkable 35% increase in pure water production [21]. These results propelled their focus toward harnessing readily available natural materials in their field, revealing a promising avenue for sustainable advancements and highlighting the potential of indigenous resources to address regional challenges in water treatment and beyond.

The objective of this research is to utilize both fresh and dried forms of plant material, which are readily available in the region, to enhance the efficiency of solar stills. These materials are relatively unexplored by researchers in this field, setting our work apart. Traditional materials typically employed are metallic or natural materials, as stones and coal. Through this study, we aim to emphasize the potential of plants and their residues as valuable resources for boosting the yield of solar stills, with the goal of drawing the attention of fellow researchers to this promising avenue.

2. Methodology

2.1. Experimental steps flowchart

This study follows a systematic and informative structure to unravel the potential of *Cladium mariscus* plant integration in enhancing solar distillation efficiency as shown in Fig. 1. The introduction sets the stage by delving into the existing literature on solar distillation, shedding light on research gaps concerning the incorporation of plant materials. The methodology section then introduces the *Cladium mariscus* plant and the experimental apparatus, providing a clear overview of the research objectives. The process of integrating *Cladium mariscus* into the distillation system is meticulously detailed, ensuring a comprehensive understanding. Moving to the results, the outcomes of the experiments are presented, displaying water accumulation data across different solar stills, namely conventional solar still (CSS), modified solar still (MSS1), and MSS2. These results are quantified through calculated percentage improvements, drawing connections to the initial hypothesis. Furthermore, our study contextualizes the findings by comparing them with other relevant works. Finally, the conclusion artfully

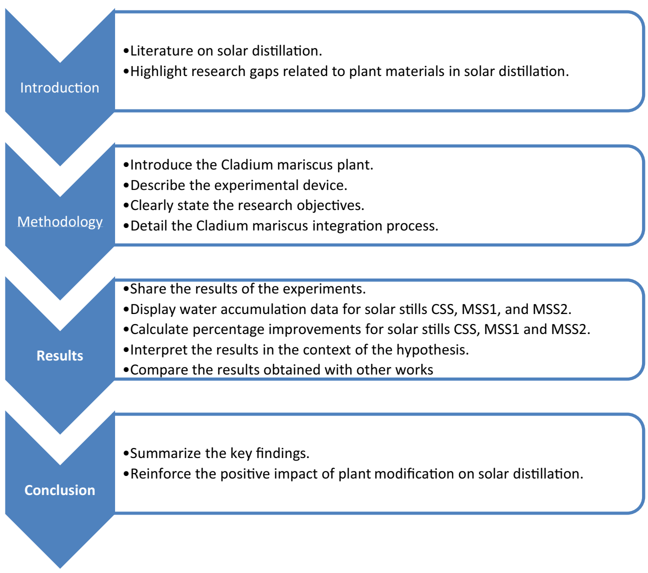

Fig. 1. Experimental steps flowchart.

summarizes the study's essential discoveries, reaffirming the positive influence of plant modification on solar distillation. Through this well-structured organization, our research contributes valuable insights to the realm of solar distillation and plant-based enhancements.

2.2. *Cladium mariscus plant*

The *Cladium mariscus* plant as shown in Fig. 1, abundantly found in the state of El-Oued, Algeria, as well as in various other regions worldwide, holds great significance for the local community. Apart from its utilization in the manufacturing of household utensils and other purposes, this allied plant has been valued for its medicinal properties. It serves as a key medicinal herb, known for its potential in addressing a wide range of health issues and diseases. The leaves and flowers of the *Cladium mariscus* plant possess numerous therapeutic and healing properties, making it a valuable component in alternative medicine. The rich benefits derived from this plant have further contributed to its esteemed status among local communities and its exploration as a valuable resource in various medicinal and wellness practices.

2.3. *Experience set-up*

The experiment was meticulously conducted on a clear day in mid-April 2023 at the University of El-Oued, located in Algeria as shown in Fig. 2. To facilitate a thorough investigation, three distinct solar stills were employed as integral components of this study. The first still assumed the role of the conventional solar still (CSS) reference. This reference still, in line with its designation, contained only water without any additional elements. In contrast, the second solar still, designated as MSS1, was purposefully modified to incorporate dried *Cladium mariscus* plant. These desiccated plants, when integrated into the solar still, introduced an experimental variable. The third still, known as MSS2, followed a similar trajectory. However, rather than employing dried plants, this still harnessed the natural state of *Cladium mariscus* plant in its verdant form. A noteworthy point is that both MSS1 and MSS2 held an identical measure of *Cladium mariscus* plant, ensuring a controlled comparison between the two modified stills.

The central thrust of this experiment lay in scrutinizing the influence of *Cladium mariscus* plant in both its dry and green states on the output of a conventional solar still. The essence of this investigation was to decipher how the presence of *Cladium mariscus* impacts the efficiency of solar distillation, particularly in comparison to the conventional setup. To gather comprehensive data, measurements were meticulously taken at hourly intervals, capturing a comprehensive spectrum of the distillation process's behavior. This careful observation extended from the early hours of 8:00 AM to the late afternoon at 6:00 PM. This extended timeframe allowed for a comprehensive analysis of the effects of *Cladium mariscus* plant on the intricate processes of solar distillation. The consistent data collection over the entire daylight span provided insights into how the presence of *Cladium mariscus*, whether dry or green, can impact the complex and crucial process of solar distillation.

Our research presents a rigorous experimental exploration of the integration of *Cladium mariscus* plant material, both in dry and green states, within solar distillation systems. This innovation offers a fresh perspective on advancing solar distillation efficiency, addressing a critical research gap in the field. The practical significance of this work lies in its potential to provide a sustainable solution to the escalating challenge of clean drinking water scarcity. By investigating the effects of *Cladium mariscus* integration, we seek to directly address the issue of limited access to safe and potable water. As global water scarcity intensifies, our research delves into a practical avenue for enhancing the output of distilled water through a natural and locally available resource. This study not only contributes to scientific knowledge but also offers tangible insights into how harnessing

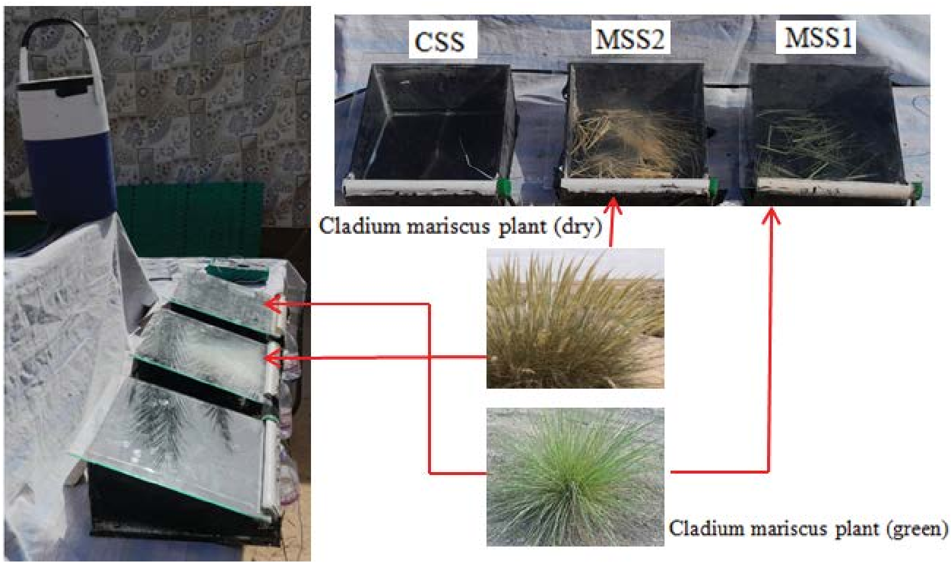

Fig. 2. Experiment presentation.

plant materials can be a valuable step towards mitigating water scarcity challenges, thus underscoring its real-world applicability and problem-solving nature.

3. Results

3.1. Solar radiation and ambient temperature

The insights provided in Fig. 3 offer valuable information on the patterns of solar radiation and ambient temperature observed during the experimental phase of the solar distillation system. The graph provides a visual representation of the temporal evolution of solar radiation, with its peak occurring between 12:00 h and 13:00 h, registering a maximum value of 935 W/m². This time frame corresponds to the period of highest solar intensity when the sun is positioned directly overhead. Furthermore, the graph captures the fluctuations in ambient temperature, highlighting that the highest temperature of 36°C was recorded at 13:00 h. It is important to note that the ambient temperature is influenced by various factors, including solar radiation, air temperature, and surrounding environmental conditions. These findings contribute to our understanding of the dynamic interplay between solar radiation and ambient temperature within the context of the solar distillation system.

3.2. Glass cover internal temperature

Fig. 4 presents the temperature variations observed on the inner face of the cover glass in the solar distillation system throughout the duration of the experiment. Notably, a significant temperature difference is observed between the conventional solar still (CSS) and modified solar still (MSS1 and MSS2) configurations. The maximum temperatures reached 38°C for CSS and MSS1 and MSS2. At the end of the experiment, all temperatures dropped to between 28°C and 29°C.

3.3. Water temperature evolution

Fig. 5 showcases the temporal fluctuations in water temperature for both the conventional solar still (CSS) and modified solar still (MSS) stills. The graph highlights a significant divergence in water temperature between the two configurations throughout the duration of the experiment. The most notable temperature difference occurs at 13:00, with CSS recording a temperature of 41°C, while MSS1 reaches 46°C and MSS2 reaches 48°C. This discrepancy can be attributed to the incorporation of the *Cladium mariscus* plant in the MSS stills. The *Cladium mariscus* plant acts as an additional heat-absorbing material, effectively capturing and retaining more solar radiation. As a result, the water temperature in the MSS stills surpasses that of the conventional CSS still. This modification enhances the overall heat transfer process, facilitating efficient evaporation and condensation, thus leading to improved distillation efficiency. The findings from this graph underscore the positive impact of integrating the *Cladium mariscus* plant in the modified solar still configurations, offering potential advancements in solar distillation technology.

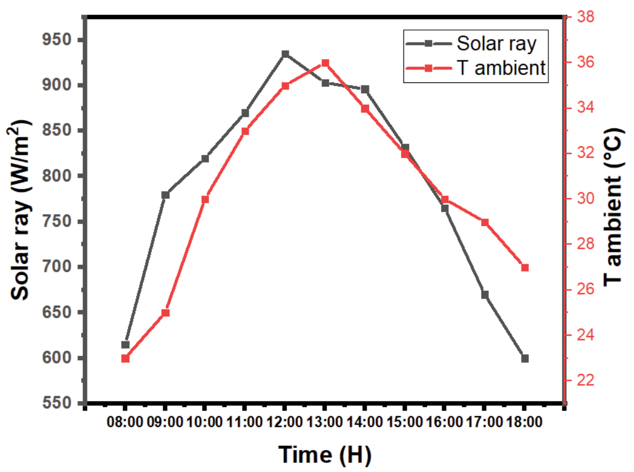

Fig. 3. Solar radiation and ambient temperature.

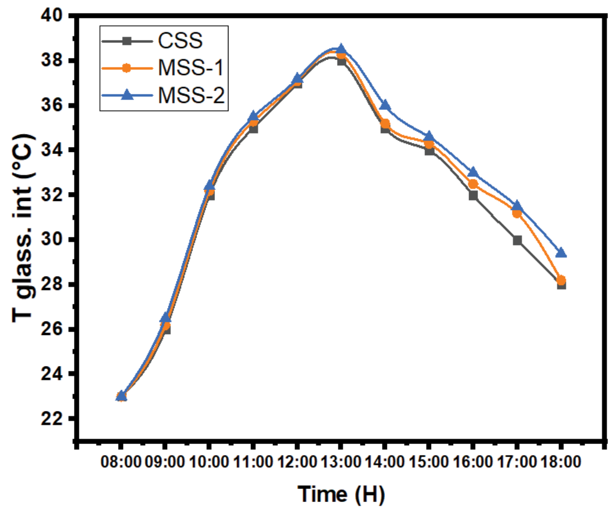

Fig. 4. Glass cover internal temperature.

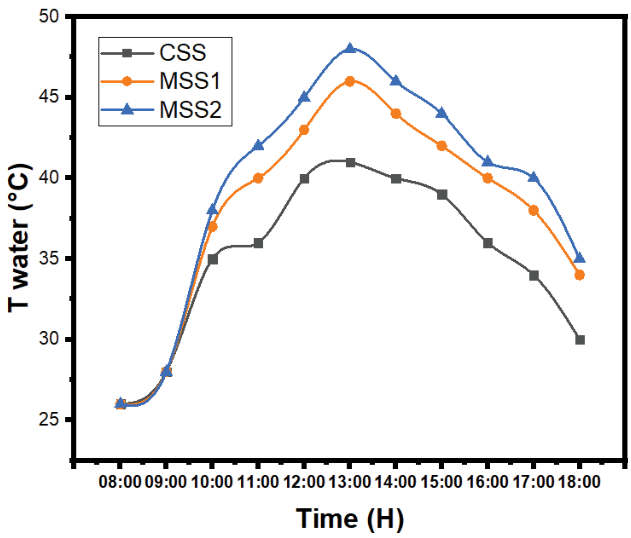

Fig. 5. Water temperature evolution.

3.4. Hourly output of pure water

Fig. 6 visually presents the hourly production and cumulative accumulation of pure water for both the modified solar still (MSS) and conventional solar still (CSS) stills. The graph clearly demonstrates that the MSS still consistently surpasses the CSS still in terms of pure water output at every hour. It is noteworthy that the highest output is achieved at 14:00 h, with MSS1 producing 95 mL and MSS2 producing 110 mL of pure water, while the CSS still generates 85 mL. This significant difference in output can be attributed to the integration of *Cladium mariscus* plant in the modified stills, which enhances the thermal efficiency of the distillation process, as indicated by the previous figures. The findings from this graph affirm the superiority of the modified stills in terms of water production, suggesting its potential as an improved solar distillation technology for obtaining greater quantities of pure water.

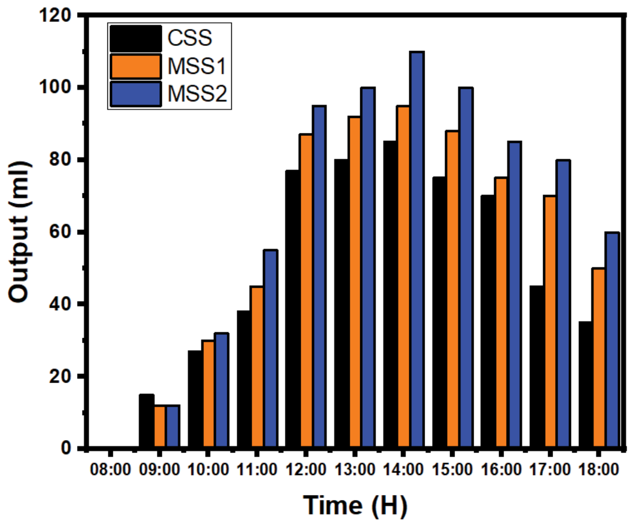

Fig. 6. Hourly output of pure water.

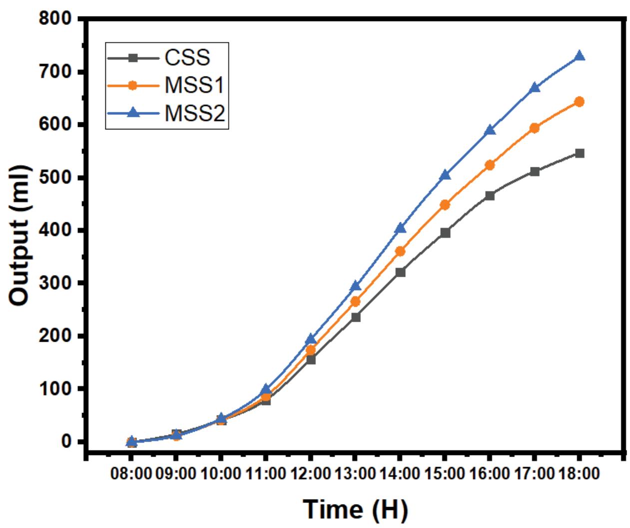

Fig. 7. Accumulation output of pure water.

3.5. Accumulation output of pure water

Fig. 7 displays the total accumulation of pure water for both the modified solar still (MSS) and conventional solar still (CSS) stills. The graph indicates that MSS1 has accumulated a total of 729 mL of pure water; MSS2 has accumulated 644 mL, while the CSS still has accumulated 547 mL. Although the MSS stills demonstrate higher output per measurement, the CSS still exhibits a slightly higher overall accumulation of pure water. These findings underscore the effectiveness of the *Cladium mariscus* plant modification in enhancing the performance of the solar distillation system, resulting in increased output and accumulation of pure water. The graph provides valuable insights into the cumulative water production capabilities of the different still configurations, contributing to our understanding of the overall effectiveness of the modifications implemented in the MSS setups.

3.6. Thermal efficiency

Fig. 8 illustrates the thermal efficiency trends of the three solar stills over the course of the experiment, spanning from 08:00 h to 18:00 h. It is evident that the efficiency of all three stills steadily increases until 10:00 h. However, after this point, distinctions in their performance become apparent. MSS2 consistently outperforms MSS1 and the CSS reference distiller. Notably, the peak efficiency for all three distillers occurs between 13:00 h and 14:00 h, with values of 25.37%, 28.25%, and 32.65% for CSS, MSS1, and MSS2 stills, respectively. This performance gap persists throughout the experiment, culminating at 18:00 h. This difference and surely to the prison of the *Cladium mariscus* plant in the distillers.

3.7. Similar studies

Table 1 presents a comparison between our experimental study conducted at the University of El Oued in southeast Algeria and a similar experiment carried out at

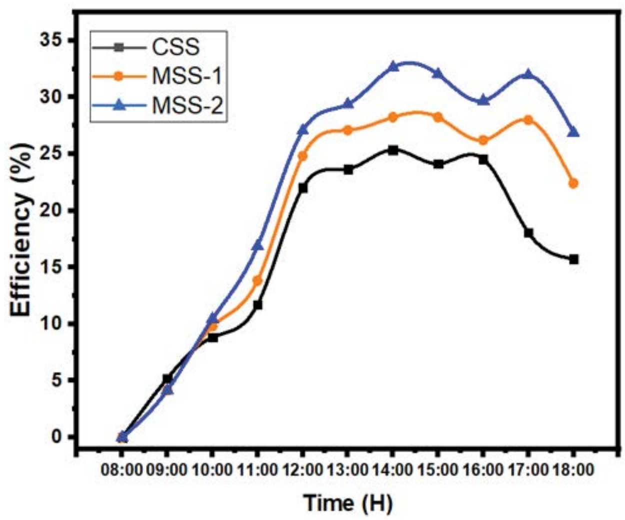

Fig. 8. Thermal efficiency evolution.

Table 1
Comparison table

N°	References	Articles	Improvement %
1	[8]	Improvement of solar distiller productivity by a black metallic plate of zinc as a thermal storage	54%
2	[9]	Aluminum wastes effect on solar distillation	33.32%
3	[10]	Iron pieces effect on the output of single slope solar still	23.46%
4	[14]	Effect of using sponge pieces in a solar still	10%
5	[15]	Ethanol effect on the performance of a conventional solar still	20%
6	[16]	Effect of different carbon types on a traditional solar still's output	18.18%–79.39%
7	[18]	Illizi city sand impact on the output of a conventional solar still	Negative effect
8	[19]	Energy performance improvement of a solar still system using date and olive kernels: experimental study	Olive kernel 226% Date kernel 176%
9	[20]	Cellulose cardboard effect on the performance of a conventional solar still	35%
10	[21]	Palm fibers effect on the performance of a conventional solar still	36%
	Our work	Use of a local Saharan plant (*Cladium mariscus*) in the solar still under southeast Algeria climate	17.33%–33.27%

the same university. The investigation aimed to assess the impact of integrating the *Cladium mariscus* plant on solar distillation performance. The findings revealed a notable improvement rate ranging from 17.33% to 33.27% due to the utilization of the *Cladium mariscus* plant. When comparing this improvement rate with other locally used materials such as aluminum waste and rubber, the *Cladium mariscus* plant emerged as a competitive material capable of rivaling these alternatives. The results underscore the potential of *Cladium mariscus* as a valuable and effective material for enhancing solar distillation systems, contributing to the development of sustainable water production and purification technologies.

4. Conclusion

The experiment involved testing three similar solar stills under identical atmospheric conditions. The first still served as the control still, while the second contained dried *Cladium mariscus* plant, and the third held the same quantity of this plant in its green state. The aim of this experiment was to assess how *Cladium mariscus*, in both its dry and green states, affects the production of pure water in solar stills. The results are unequivocal, showcasing the enhanced performance of the modified stills (MSS1 and MSS2) in terms of total pure water output, surpassing the conventional CSS still. MSS1 achieved a total output of 644 mL, whereas MSS2 produced 729 mL, compared to the CSS still's output of 547 mL. This translates to improvement rates of 17.33% and 33.27% for MSS1 and MSS2, respectively. In terms of thermal efficiency, MSS1, MSS2, and CSS achieved 28.25%, 32.65%, and 25.37%, respectively.

These findings underscore the substantial positive impact of modifying the *Cladium mariscus* plant on solar distillation for pure water production.

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