Comparison of Copra Drying Performance Using a Modified Hybrid Solar Collector Dryer versus Conventional Drying

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ABSTRACT

Drying is an important postharvest process for reducing the moisture content of copra and maintaining its quality during storage. Conventional drying methods that rely on ambient conditions are strongly influenced by weather and temperature fluctuations, resulting in relatively slow and less controlled drying. This study evaluated the performance of a modified hybrid greenhouse dryer for copra drying by comparing its drying conditions with drying under ambient conditions. The experiment was conducted for five hours by monitoring drying temperature, initial and final moisture content, and moisture reduction rate. The results showed that the maximum temperature in the hybrid greenhouse dryer reached 45 °C, while the ambient drying condition reached 40 °C. The moisture content of copra dried using the hybrid system decreased from 65.91% to 11.61%, whereas the ambient-dried sample decreased from 52.51% to 16.88%. The corresponding moisture reduction rates were 10.86 %/h for the hybrid system and 7.13 %/h for ambient drying, indicating a 52.40% higher reduction rate in the hybrid system during the test period. The improved drying performance was associated with the utilization of solar energy through the collector, air circulation using a blower, and the thermal contribution of stone material within the drying system. Although the initial moisture contents differed between the two samples, the results indicate that the hybrid greenhouse dryer provided a more favorable drying condition and greater moisture reduction over the same drying period. Further studies should use uniform initial moisture content, sufficient experimental replications, and additional thermal-efficiency measurements to provide a stronger evaluation of system performance.

Keywords: *copra, hybrid dryer, greenhouse dryer, solar energy, moisture content*

I. INTRODUCTION

The coconut is a key plantation commodity yielding various economically valuable products, notably copra, which serves as the primary raw material for coconut oil production. Following harvesting and splitting, coconut meat retains a high moisture content; consequently, a drying process is required to reduce moisture levels and enhance the material's stability during storage. In general, copra drying aims to lower moisture content to a level that preserves quality and increases the material's oil concentration. Copra requires drying to reduce moisture from approximately 50% to nearly 7%, yet uncontrolled drying processes can compromise product quality (Prabhu, Dhanushkodi, & Sudhakar, 2025). Therefore, developing drying technologies capable of providing more controlled thermal conditions is crucial for supporting post-harvest coconut processing.

Conventional drying methods utilizing direct sunlight remain widely used due to their simplicity and lack of complex equipment; however, they are highly dependent on weather conditions, require a relatively long time, and carry a risk of material contamination. Prabhu et al. (2025) reported that direct sun-drying of copra can take approximately seven days and faces challenges during unfavorable weather, alongside risks of dust contamination and fungal growth. Furthermore, open drying exposes the material directly to the environment, limiting control over temperature and humidity. Such conditions can lead to non-uniform drying and increase the risk of quality degradation if the material remains in a moist state for too long. Research on various agricultural products also indicates that drying rates tend to be higher during the initial stages and decrease as the material's moisture content drops, because moisture migration from the interior becomes more difficult (Adejumo et al., 2023). Consequently, there is a need for a drying system capable of providing a more stable drying environment than direct sun-drying.

Solar energy utilization presents an attractive alternative due to the abundant availability of the energy source and its capacity to generate heated air without total reliance on fossil fuels. Advancements in solar drying technology have led to the adoption of hybrid systems – combining solar energy with supplementary mechanisms or energy sources – to maintain drying conditions despite fluctuations in solar radiation intensity. Adejumo et al. (2023) demonstrated that a hybrid solar dryer could achieve a drying chamber temperature of approximately 50.26°C – surpassing the ambient temperature of 26.69°C – and yield a higher drying rate compared to standard solar drying and open sun drying methods. Furthermore, the hybrid system in the study achieved a moisture content of approximately 10.19% within seven hours, whereas standard solar drying required 13 hours and open sun drying took about 35 hours (Adejumo et al., 2023). These results indicate that increasing the temperature and controlling drying air conditions can accelerate moisture removal from the material and reduce drying time.

In addition to temperature enhancement, the integration of thermal energy storage and air circulation systems is a crucial aspect of hybrid dryer development. Heat storage systems allow thermal energy captured during periods of solar radiation to be utilized to sustain the drying process when radiation intensity drops, while air circulation facilitates heat and mass transfer between the drying air and the material. Various hybrid dryer configurations have been developed by integrating auxiliary heat sources and energy storage systems to improve the efficiency and continuity of the drying process (Nnamchi et al., 2025). Other studies on hybrid solar dryers also indicate that integrating thermal energy storage can enhance drying performance while providing flexibility in maintaining the system's thermal conditions (Adera et al., 2026). Thus, the use of hybrid systems represents a promising approach for achieving more stable drying conditions, particularly amidst fluctuating solar radiation.

Based on the foregoing, the development and evaluation of a hybrid drying system for copra are necessary to achieve a more controlled drying process compared to drying under ambient conditions. This study evaluates the performance of an existing hybrid greenhouse-type dryer by comparing drying conditions within the unit against those of ambient drying. The parameters observed include temperature distribution, changes in moisture content, and the rate of moisture loss during the copra drying process. This comparison is expected to demonstrate the hybrid system's capability to improve thermal conditions and accelerate moisture reduction within the same testing timeframe. Consequently, this research aims to provide empirical data on the performance of the hybrid dryer as an alternative, more controlled copra drying technology suitable for post-harvest processing scales.

II. MATERIALS AND METHOD

2.1 Time and Location of the Study

The research was conducted over a period of three months at the Agricultural Machinery and Equipment Study Program's research site. Testing utilized an existing hybrid greenhouse-type dryer. The study focused on evaluating thermal conditions and copra drying performance by comparing drying using the equipment against drying under ambient conditions.

2.2 Tools and materials

The primary apparatus used is a hybrid greenhouse-type dryer equipped with a solar collector, a drying chamber, a blower, and stone media as part of the heating system. Measurement equipment includes thermometers for monitoring temperature and moisture analysis tools to determine the material's moisture content before and after drying. Copra was used as the test material. Copra samples were prepared prior to testing and placed in the drying chamber for treatment, while control samples were dried under ambient conditions.

2.3 Testing Process

Testing was conducted by comparing two drying conditions: drying using a hybrid-type greenhouse system and drying under ambient conditions. Copra samples were placed under each condition and monitored for five hours, specifically between 09:00 and 16:00 WITA. Throughout the test, temperatures within the drying chamber and ambient conditions were recorded periodically to track thermal changes during the drying process. The moisture content of the material was measured before and after drying to determine the extent of moisture reduction. The resulting data were then used to compare the effectiveness of the hybrid system and ambient conditions in reducing the moisture content of the copra.

2.4 Observation Parameters

The parameters observed in the study included drying temperature, copra moisture content, and the rate of moisture content reduction.

a. Temperature
emperatures were measured within the hybrid-type greenhouse system and in the surrounding environment during the drying process. The temperature data were used to assess changes in thermal conditions and the temperature differences between the two drying methods.

b. Moisture content
Copra moisture content was determined before and after the drying process. Changes in water content are used as the main indicator to evaluate the ability of each method to reduce the water content of materials. Calculation of copra moisture content is carried out using equation 1 (Nurwanto & Suswantinah, 2021):

$$KA\ (\%) = \frac{W - (W1 - W2)}{W} x100\% \qquad (1)$$

where,

KA = moisture content (%)
W = weight of the sample before drying (gr)
$W1$ = weight of dried sample + dish (gr)
$W2$ = weight of the empty dish (gr)

c. Rate of moisture content reduction
The rate of moisture content decrease is calculated based on the change in moisture content during the drying period using Equation 2 (Warianti & Darmanto, 2019):

$$v = \frac{\Delta KA}{t} = \frac{KA_i - KA_f}{t} \qquad (2)$$

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v = rate of moisture content decrease (%/h)
KA_i = initial moisture content (%)
KA_f = moisture content after drying for t hours (%)
t = drying time (h)

2.5 Data Analysis

Data on temperature, moisture content, and the rate of moisture loss were analyzed descriptively and compared between the hybrid-type greenhouse system and ambient environmental conditions. Temperature analysis was used to characterize the system's ability to generate and maintain thermal conditions during drying, while changes in moisture content and the rate of moisture loss served to evaluate the drying process performance. Observation results are presented in tabular form to illustrate the patterns of change for each parameter throughout the testing process. Differences in results between the two methods are then discussed in terms of the relationship between temperature conditions and the moisture transfer process from the material.

III. RESULTS AND DISCUSSION

A solar collector is a device capable of absorbing solar radiation, thereby heating the air within the collector's chamber. The heat generated inside the collector can be utilized for various purposes, including agricultural drying.

3.1 Distribution of Temperature

Temperature distribution is a crucial parameter for evaluating dryer performance, as an increase in drying chamber temperature accelerates heat transfer and the evaporation of moisture from the material. In this study, testing was conducted over two days between 09:00 and 16:00 WITA, comparing the temperatures of a hybrid greenhouse-type drying system and the ambient environment; the temperature observations are presented in Tables 1 and 2.

Based on observations, the temperature in the hybrid greenhouse system was recorded at 39°C at 10:00 (Day 2), rising to 45°C at 11:00, then dropping to 42°C at 12:00 and continuing through 16:00. In the environmental system, the recorded temperature showed greater fluctuation – ranging from 24°C to 40°C – peaking at 40°C at 11:00 and subsequently falling to 23°C by 16:00.

Table 1. Temperature Observation Results for the Drying Apparatus

Time	Temperature (ºC)	
	Day 1	Day 2
09.00	-	23
10.00	-	39
11.00	49	45
12.00	50	42
13.00	40	30
14.00	40	30
15.00	38	31
16.00	37	29

Table 2. Environmental Temperature Observation Results

Time	Temperature (ºC)	
	Day 1	Day 2
09.00	-	24
10.00	-	28
11.00	40	40
12.00	42	29
13.00	30	25
14.00	40	26
15.00	38	28
16.00	32	23

These differences in temperature patterns show that the hybrid type greenhouse system is able to provide thermal conditions that are more supportive of the drying process than the environmental system. In the hybrid system, heat is obtained through a solar collector and channeled to the drying room using a blower, while stones are used as a heating or heat storage medium before the hot air enters the drying room. This mechanism allows the solar radiation energy received by the system to be utilized to increase the temperature of the drying air, while the presence of thermal mass helps maintain heat in the system. This principle is in line with Suresh, et al. (2023) who explains that a mixed-mode or hybrid system combines the use of solar radiation with air heated through a collector, while heat storage materials can help maintain the drying process when the intensity of solar radiation changes.

The pattern of increasing temperature until the midday period and decreasing after that period also shows that the thermal performance of the device is still influenced by changes in the intensity of solar radiation. This condition is in line with Adejumo et al. (2023), who reported that the temperature of the hybrid drying chamber increased during the radiation period and reached the highest value around noon, while temperature changes in the solar drying system were closely related to fluctuations in solar radiation and weather conditions. In this research, the hybrid drying room temperature reached around 50.26 °C, while the environmental temperature was around 26.69 °C, thus showing the ability of the hybrid system to produce a higher drying temperature compared to environmental conditions. The research results of Reza & Hossain,

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2023 also show a similar trend, namely that the temperature of the hybrid drying chamber can be increased far above the ambient temperature through a combination of solar collectors, air circulation and heat storage.

In this study, the maximum temperature of the greenhouse system was recorded at 45 °C (on the second day), whereas the maximum ambient temperature reached 40 °C. Although the difference in maximum temperatures was only about 5 °C, the hybrid system demonstrated more favorable thermal conditions; this is because the heat was not solely dependent on the ambient temperature but was generated through a heating mechanism within the collector and air circulation driven by a blower. This distinction is significant when considered alongside the moisture content test results, as the temperature increase and control in the hybrid system facilitated the evaporation of moisture from the copra-even though drying effectiveness was also influenced by weather conditions, air circulation, and material characteristics.

3.2 Changes in Copra Moisture Content

Moisture content is a key parameter in determining the success of the copra drying process, as it influences the material's stability and quality during storage. In this study, changes in moisture content were monitored in copra dried using a hybrid greenhouse system, with ambient environmental conditions serving as a control. Test results (Table 3) indicate that the initial moisture content of the copra in the greenhouse system was 65.91%, whereas the sample under ambient conditions had an initial moisture content of 52.51%. After five hours of drying, the moisture content of the copra in the greenhouse system dropped to 11.61%, while that under ambient conditions fell to 16.88% (Table 4). Consequently, the reductions in moisture content amounted to 54.29 and 35.63 percentage points, respectively, demonstrating that the hybrid greenhouse system achieved a greater reduction in moisture content during the test period.

Table 3. Copra Moisture Content Test Results

Materials Code	W (gr)	W1 (gr)	W2 (gr)	KA (%)
A1	30,60	241,56	231,13	65.91
A2	30,63	264,83	250,28	52.51

Note:
A1: using a drying device
A2: utilizing ambient temperature (conventional)

Table 4. Copra Moisture Content After 5 Hours of Drying

Materials Code	W (gr)	W1 (gr)	W2 (gr)	KA (%)
A1	30.40	368.68	341.81	11.61
A2	30.03	374.49	349.53	16.88

The differences in the rate of moisture reduction are linked to the thermal conditions established within the drying chamber. The hybrid greenhouse system utilizes a solar collector to raise the drying air temperature and a blower to facilitate air circulation, whereas ambient conditions depend directly on the temperature and atmospheric state during testing. Higher temperatures inside the drying chamber increase the energy available to evaporate moisture from the material, while air circulation helps transport water vapor away from the copra surface, thereby maintaining a vapor pressure gradient between the material and the drying air. This principle aligns with the findings of Adejumo et al. (2023), who demonstrated that increasing the temperature in a hybrid solar dryer results in a higher drying rate compared to drying under ambient conditions.

3.3 Moisture Content Reduction Rate

The rate of moisture content reduction was used to evaluate the drying speed of the hybrid greenhouse-type system compared to drying under ambient conditions. Based on observations over a five-hour period (Table 5), the rate of moisture content reduction in the hybrid greenhouse-type system reached 10.86%/hour, whereas under ambient conditions, it was 7.13%/hour. These figures indicate that the hybrid system achieved a drying rate approximately 52.40% higher than that of ambient conditions. This difference demonstrates that the increased temperature and air circulation within the drying chamber contributed to accelerating the release of moisture from the material.

Table 5. Rate of Moisture Content Decrease

Materials Code	KA_i (%)	KA_f (%)	t (h)	v (%/h)
A1	65.91	11.61	5.00	10.86
A2	52.51	16.88	5.00	7.13

The higher drying rate observed in the hybrid system is attributed to the thermal conditions established within the drying chamber. Drying chamber temperatures exceeded ambient levels for the majority of the observation period, reaching maximums of 45°C (on day 2) and 40°C, respectively. These elevated temperatures increased the energy available for evaporation, while the use of a blower facilitated air circulation within the chamber. This combination of increased temperature and airflow enhanced heat and mass transfer between the drying air and the copra surface. These findings align with Adejumo et al. (2023), who reported that hybrid solar dryers achieve higher drying rates compared to ambient drying due to elevated chamber temperatures and more controlled drying conditions.

Differences in drying rates can also be attributed to the hybrid system's ability to maintain thermal conditions throughout the process. The system in this study employs a solar collector and rock media as part of the heating setup, allowing thermal energy derived from solar radiation to be utilized during the drying process. This principle aligns with the findings of Suresh et al. (2023), who explained that integrating thermal energy storage into solar drying systems helps retain heat and reduces the process's reliance on fluctuations in solar radiation. Reza & Hossain (2023) also demonstrated that combining solar heating, air circulation, and heat storage in a hybrid dryer can yield more stable drying conditions and enhance dryer performance compared to conventional drying methods.

The significant difference in moisture reduction rates–10.86%/hour for the hybrid system versus 7.13%/hour under ambient conditions–indicates an improvement in drying performance of 3.73%/hour. These results demonstrate that the system modification not only achieved higher drying chamber temperatures but also accelerated the rate of moisture removal from the copra. However, this difference must be interpreted with caution, as the tests were conducted under varying ambient conditions and with differing initial moisture contents for the two samples. Consequently, the drying rate values in this study are best regarded as indicators of comparative performance during the test period rather than as absolute characteristic values of the drying apparatus.

3.4 Performance Comparison of Hybrid Solar Collector Dryer and Conventional Drying

A performance comparison was conducted to evaluate the capability of a hybrid-type greenhouse system to accelerate the copra drying process compared to drying under ambient conditions. Based on five hours of testing, the hybrid system achieved a maximum temperature of 45 °C, whereas the maximum temperature under ambient conditions reached 40 °C. This difference in thermal conditions corresponded to a difference in copra moisture content, with moisture reduction rates of 10.86%/hour for the hybrid system and 7.13%/hour for ambient conditions. These results indicate that the hybrid system delivered superior drying performance during the test period, despite the relatively small difference in maximum temperatures between the two systems.

The advantages of a hybrid system are determined not only by the maximum temperature achieved but also by the system's ability to provide more controlled drying conditions. In a greenhouse-type system, solar energy is captured via collectors to generate heat, while blowers facilitate the flow of hot air into the drying chamber; additionally, the use of stone media supports heat energy storage and utilization throughout the process. In contrast, drying under ambient conditions relies heavily on temperature variations and atmospheric states, making the process more susceptible to fluctuations. Suresh et al. (2023) explain that hybrid solar drying systems–integrated with thermal energy storage–were developed to reduce the drying process's dependence on fluctuating solar radiation and to ensure a more continuous heat supply.

The results of this study align with the findings of Adejumo et al. (2023), which demonstrated that a hybrid solar dryer yields higher drying chamber temperatures and drying rates compared to drying under ambient conditions. In that study, the elevated temperature within the drying chamber contributed to the accelerated removal of moisture from the material. Reza & Hossain (2023) also reported that integrating a solar collector, an air circulation system, and heat storage into a hybrid dryer can create more controlled drying conditions than conventional drying methods. Thus, these results reinforce the conclusion that utilizing solar energy through a hybrid system can enhance drying process performance compared to relying solely on ambient conditions.

However, the interpretation of the comparison needs to consider that the initial water content of the two samples is not the same, namely 65.91% in the hybrid system and 52.51% in environmental conditions. Therefore, the difference in final water content cannot be used alone to state the level of effectiveness of the two methods. A more representative parameter in this study is the rate of decrease in water content, because both systems were tested during the same drying period. Based on these parameters, the hybrid system produces a drying rate 3.73%/hour higher than environmental conditions. This difference provides an indication that the hybrid system is able to improve the drying process, although tests with uniform initial water content and repeated experiments are still needed to obtain a more statistically robust comparison.

IV. CONCLUSION

Research results indicate that the hybrid-type greenhouse drying system improved thermal conditions and copra drying performance compared to drying under ambient conditions during the test period. The maximum temperature reached by the hybrid system was 45°C (on the second day), whereas ambient conditions peaked at 40°C. After five hours of drying, the copra moisture content in the hybrid system dropped from 65.91% to 11.61%, while under ambient conditions it decreased from 52.51% to 16.88%; the respective moisture reduction rates were 10.86%/hour and 7.13%/hour. These results demonstrate that the hybrid system delivered superior drying performance, facilitated by the utilization of solar energy, blower-driven air circulation, and the use of stones as a thermal medium. Future research should involve testing with uniform initial moisture content, an adequate number of replicates, and more comprehensive measurements of thermal parameters and energy efficiency to obtain a statistically robust evaluation of system performance.

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