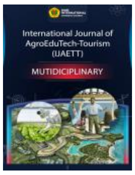

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Analysis of Dome Drying System for Coffee in the Perspective of Philosophy of Science as a Supporter of Sustainable Agriculture

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Abstract
Solar energy is derived from sunlight received by the Earth and is the largest renewable source of energy available. Beyond its scientific utility, the Qur'an identifies the sun as a sign of divine power, a source of light, a time marker for prayers, and a guide for shadow and calculations. This study discusses the sun's functions from a scientific and Qur'anic perspective in relation to the need for electricity in household and industrial applications to enhance societal economic productivity. The focus is on the Solar Dryer Dome, a UV-filtered drying system aimed at enhancing efficiency and energy savings in drying agricultural and fishery products. This research responds to the problems of conventional drying methods: time-consuming, non-uniform quality, and energy inefficiencies. Using mix-method Quan-Qual analysis in combination with experimental methods, observation, and literature study, this study applies the philosophy of science to drying systems, focusing on temperature control and optimization of moisture content. Results show that the Solar Dryer Dome retains higher interior temperatures than surrounding ambient conditions and thus optimizes the drying process. Proper moisture levels in coffee beans, for example, are very important for sustainable agriculture to maintain product quality and to provide easy storage and transportation. The study epitomizes the practical benefits that come with Solar Dryer Dome technology by offering valuable insights on sustainable agricultural practices and as a reference for future research.

Keywords: Dome Drying System, Philosophy of Science, Sustainable Agriculture

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1. Introduction

Solar energy is energy produced from sunlight received by the earth. The sun is the largest renewable energy source available in the universe, and the energy produced can be used to meet human needs such as heating water, generating electricity, and driving vehicles, and others (Kalair et al., 2021). Meanwhile, the function of the sun in the perspective of the Qur'an is: as a sign of the power of Allah SWT, as a source of light, as a guide to prayer times, as a guide to shadows, and as a calculation (Mahmudah & Rahmatika, 2020). The theories that science explains regarding the function of the sun between science and the Qur'an have a good correlation. Science and the Qur'an are two fields of study that have a good relationship that are interrelated and not contradictory (Fauzian et al., 2024). Science as a result of human thought based on scientific research has continuous development and is always updated, while the Qur'an is a source of definite knowledge that never changes. Understanding the function of the sun from two perspectives will lead us to deep thinking and add to the treasury of knowledge between science and the Qur'an in explaining the function of celestial bodies that are very influential for this life (Fauzian et al., 2024).

Sustainable agriculture is a cornerstone of global efforts to balance food security, environmental conservation, and economic growth (Amirova et al., 2022; Rehman et al., 2022). One critical aspect of agricultural sustainability is the post-harvest handling of crops, where drying processes play a pivotal role in preserving product quality and extending shelf life (Osei-Kwarteng et al., 2024). Traditional drying methods, however, often face significant challenges such as prolonged drying times, uneven moisture content, and dependency on weather conditions, which can compromise efficiency and product quality (Ntwali et al., 2021).

Renewable energy sources, particularly solar energy, offer transformative potential for addressing these challenges (Ntwali et al., 2021). Solar energy, as the most abundant and inexhaustible renewable resource, has long been recognized for its role in driving ecological cycles, supporting life, and enabling technological innovations. Beyond its scientific applications, the

Qur'an presents the sun as a symbol of divine power, a marker of time, and a guide for human activities, highlighting the multidimensional significance of this natural resource (Mahmudah & Rahmatika, 2020).

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This study explores the Solar Dryer Dome as a empirical observation through the lens of the philosophy of science, emphasizing the integration of empirical observation, technological innovation, and interdisciplinary perspectives. By examining temperature control, moisture optimization, and the broader implications of solar energy utilization, the research aims to provide actionable insights into sustainable agricultural systems. Furthermore, the study bridges scientific exploration with the philosophical and theological dimensions of solar energy, reinforcing its relevance in advancing human well-being and ecological balance.

2. Materials and Methods

2.1 Research Design

This study employs a mixed-methods framework that combines quantitative experimental research with qualitative philosophical and theological analysis. The purpose of this approach is to comprehensively achieve the research objectives by integrating empirical data with contextual insight. The quantitative aspect deals with the experimental analysis of how effective the Solar Dryer Dome is in the drying process of coffee beans. The qualitative aspect examines philosophical and theological ramifications associated with the use of solar energy interpreted from the Qur'an and scientific philosophy. Taken together, these approaches provide a holistic understanding of how the Solar Dryer Dome works to further sustainable agricultural practices.

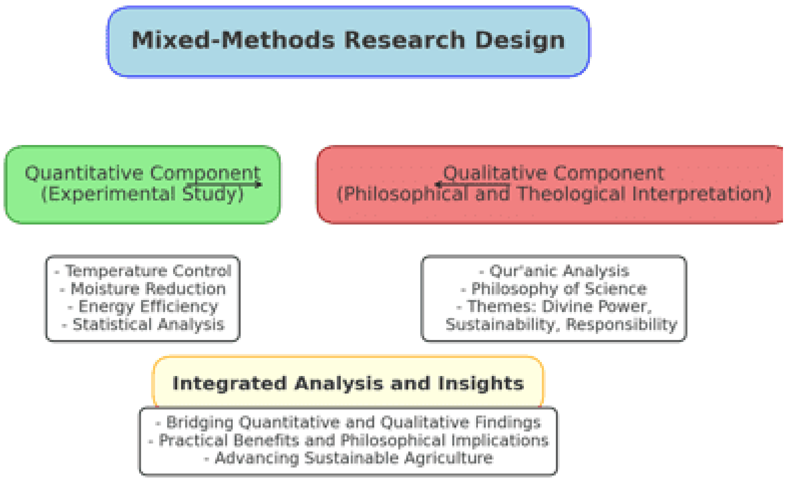


Figure 1. Research Design

2.2 Quantitative Component: Experimental Study

The quantitative component is designed to evaluate the performance of the Solar Dryer Dome in terms of Wind Velocity, Solar Intensity, Electric Current, Temperature, and Humidity. The experimental study was conducted in an agricultural area with abundant sunlight to maximize the system's potential. The dome utilized in this study is equipped with UV-filtering material and a controlled ventilation system to enhance drying efficiency. Freshly harvested coffee beans were selected as the study sample, and measurements were conducted using thermometers to record internal and ambient temperatures, moisture meters to track the drying process, and other tools to monitor drying time.

2.3 Qualitative Component: Philosophical and Theological Interpretation

The qualitative aspect of the research centers on analyzing the scientific results through the lens of philosophical discourse on science and the insights derived from the Qur'an regarding solar energy. This analysis was conducted utilizing thematic examination of pertinent Qur'anic passages that underscore the importance of the sun and its correlation with sustainable methodologies. A review of scholarly works concerning the philosophy of science and renewable energy was undertaken to offer a contextual framework for comprehending the wider ramifications of solar energy application. The themes of divine authority, ecological equilibrium, and human accountability emerged from the literature reviewed. These were later related to quantitative findings, as this established how the material benefits were linked with the philosophical insights

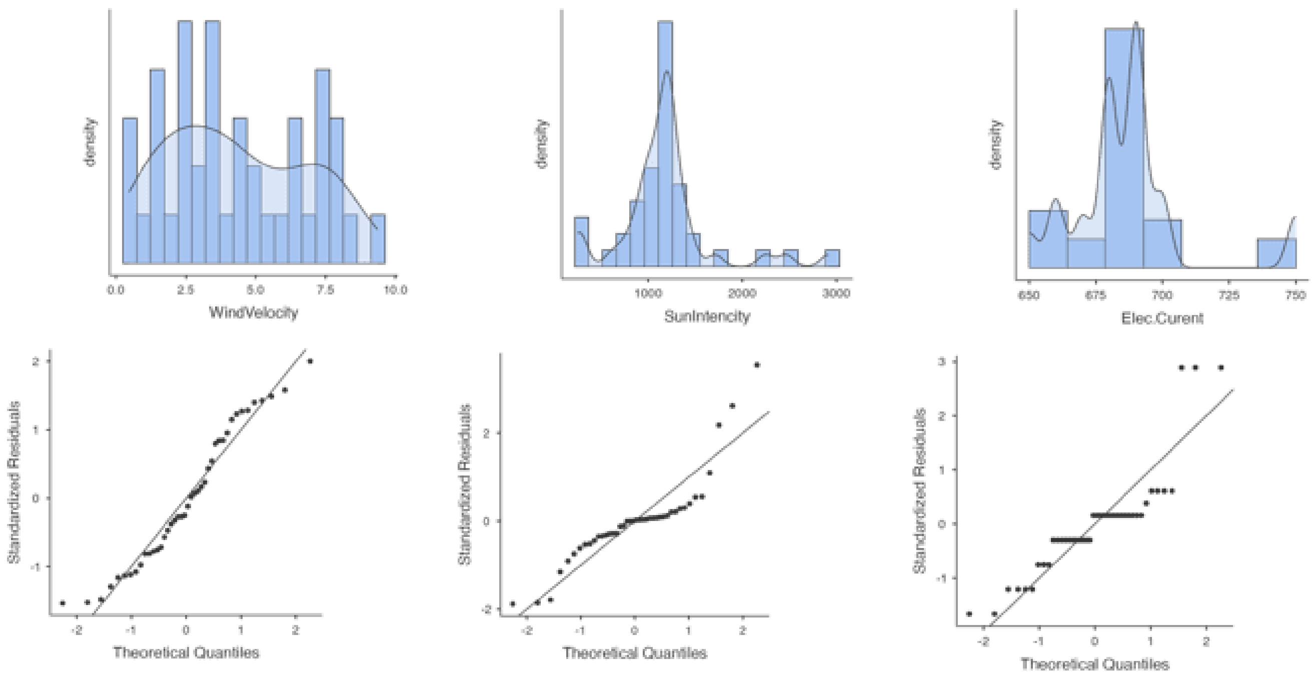
3. Finding and Discussions

3.1 Time series of Wind Velocity, Solar Energy, and Voltages of Solar Dryer Dome

The temporal data set on wind velocity, solar energy, and voltage output from the Solar Dryer Dome, as summarized in Table 1 and figure 2, provides much revelation of operational dynamics and interrelation of environmental variables that affect the efficiency of the system. The data clearly shows that there is a linear relationship between solar energy and voltage produced by the Solar Dryer Dome. The peak solar energy value of 1994.67 Joules at 9:25 hours coincides with the highest voltage of 721.67 Volts. As solar energy decreases throughout the day, voltage output follows a similar downward trend, with the lowest voltage of 663.33 Volts occurring at 14:25 hours when solar energy drops to 527 Joules. This trend highlights the vital reliance of the system's effectiveness on the accessibility of solar energy, underscoring the significance of placement and structural refinement to achieve optimal sunlight exposure.

Table 1 Time series of Wind Velocity, Solar Energy, and Voltages of Solar Dryer Dome

Time (Hours)	Solar Energy (Joule)	Wind Velocity (Km/Hours)	Voltages (Volt)
9,25	1994,67	1,31	721,67
10,25	1186,17	5,05	685,00
11,25	1226,33	5,68	683,33
12,25	1231,33	6,74	691,67
13,25	1077,67	5,84	689,17
14,25	527,00	3,80	663,33
15,25	996,83	1,87	671,67



(a) (b) (c)

Figure 2 (a) Wind velocity, (b)Solar Intensity, and (c)Electric Current data distribution

Wind velocity appears to have a very insignificant direct effect on voltage generation, considering the irregular relationship between wind speeds and voltage produced. For instance, at 12:25 hours, wind velocity reaches its peak of 6.74 km/h, while the voltage output remains the same at 691.67 Volts. On the other hand, at 15:25 hours, when the wind velocity drops to 1.87 km/h, the voltage records a moderate value of 671.67 Volts. This observation suggests that wind speed has an insignificant effect on the energy output of the system. Instead, its primary function seems to be ensuring air circulation inside the dome to support the drying process rather than increasing energy production. The noon period (10:25–13:25 hours) shows relatively constant solar energy values, ranging from 1077.67 to 1231.33 Joules, with equally stable voltage values (683.33–691.67 Volts). The observed stability corresponds with the hours of maximum solar illumination, during which the system operates at peak efficiency. Nonetheless, a marked decrease in solar energy at 14:25 hours coincides with a discernible reduction in voltage, indicating the necessity for supplementary energy storage systems to maintain functionality during intervals of diminished solar intensity. These results emphasize the dependence of the Solar Dryer Dome on solar energy as the fundamental factor influencing its electrical performance (Ekechukwu & Norton, 1999). Efficiency could be improved by strategies that include energy storage solutions, such as batteries, to deal with the fluctuating availability of solar radiation, and further improve the insulation by enhancing dome materials. Again, due to minimal influence of wind velocity, the design of the dome should focus on passive air mechanisms rather than active reliance on wind for internal cooling or ventilation. The ability of the system to consistently generate voltage under changing solar intensities strengthens its role in the development of sustainable agricultural practices (Yao et al., 2022). The Solar Dryer Dome, by providing effective drying for agricultural products like coffee beans, reduces the reliance on traditional drying methods that are often associated with high energy use and negative environmental effects. This further underscores the system's role in using renewable energy and is consistent with international efforts toward bettering agricultural sustainability.

3.2 Temperature, Humidity, and Water Content relationship

The correlation matrix gives more detailed insight into the relationship between temperature, humidity, and water content within the solar dryer dome. Table x Temperature and Humidity A perfect negative correlation ($rs=-1.000, p=0.003 rs=-1.000, p=0.003$) shows that an increase in temperature regularly decreases the humidity level. This relation is very important in creating an ideal condition for drying. Temperature and water content A moderate positive correlation ($rs=0.600, p=0.242 rs=0.600, p=0.242$) indicates that as the temperature increases, the water content decreases. While this trend is in line with expected results, a lack of statistical significance indicates variability in data that should be explored further. Humidity and Water Content: A moderate negative correlation ($rs=-0.600, p=0.242$) aligns with the understanding that high humidity slows down the evaporation of moisture from coffee beans; however, it has to be noted that the result is not statistically significant.

Table 2 Spearman rho analysis of correlation on Temperature, Humidity, and Water Content relationship

		Temperature	Humidity	WaterContent
Temperature	**Spearman's rho**	—		
	df	—		
	p-value	—		
Humidity	**Spearman's rho**	-1.000	—	
	df	4	—	
	p-value	0.003	—	
WaterContent	**Spearman's rho**	0.600	-0.600	—
	df	4	4	—
	p-value	0.242	0.242	—

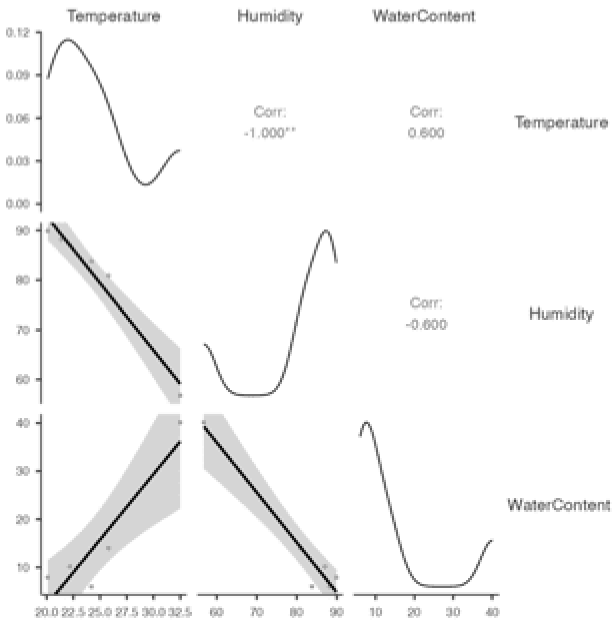


Figure 4 Temperature, Humidity and Water content correlation

These findings highlight the importance of temperature control in maintaining low humidity levels and achieving effective drying. The interplay between these variables is critical for reducing water content in coffee beans to optimal levels for storage and export.

Time-Series Analysis of Temperature, Humidity, and Water Content

Both temperature and humidity affect the reduction of water content in coffee beans. The table 3 below is a demonstration of how temperature and humidity of the Dome Drying System affect the water content of the coffee beans.

Table 3. Time-Series Analysis of Temperature, Humidity, and Water Content

Time (hours)	Temperature (celcius)	Humidity	Water content
1	32.5	**56.8**	**40,14**
2	25.8	80.9	14
3	22.2	87	10,13
4	20.1	89.9	**7,9**
5	21.4	88.2	6,06
6	24.2	83.8	6,01
7	42.9	31.5	5,8

Water content, at first, starts high—that is, at (40.14%)—when the temperature is high—that is, at (32.5°C)—and when humidity is moderate—that is, at 56.8%—but experiences significant reduction as time stabilizes conditions. At a temperature up to about 20.1°C, associated with high levels of humidity (89.9%) the moisture content decreases slowly up to a value of (6.01%) at the end of the drying time. On the contrary, at a low level of relative humidity (31.5%) and high temperature 42.9°C the moisture content drops to a value of (5.8%) to prove this combination as a very suitable parameter for drying speed. Based on the ideal export standard, where coffee beans should have a water content of approximately (13%), the drying process in the Solar Dryer Dome at (32.5°C) and (56.8%) humidity, with a water content of (40.14%), shows that beans are far from being export-ready.

This shows that, at a reduced temperature—say, 20.1°C and relative humidity of 89.9%—the moisture content drops to 7.9%, which is regarded as too dry according to export specifications. At 42.9°C and relative humidity of (31.5%), it further drops to (5.8%), which is way below acceptable limits, rendering the beans too dry. This gives clear evidence that the correct temperature and humidity levels have to be observed to adequately dry and still maintain quality coffee beans.

3.3 Philosophical and Theological Interpretation

The Solar Dryer Dome is a very important convergence of technological advancement and the ethical and spiritual tenets highlighted in the Qur'an. This use of solar energy in sustainable agriculture is totally in line with the Qur'anic point of view that promotes the judicious use of natural resources like sun, wind, and water (Manan Cheema & Alvi, 2022). The resources that are described in the Qur'an are articulated as blessings from the divine, which serve to fulfill human necessities while simultaneously urging ethical management that harmonizes human endeavors with environmental conservation(Gada, 2024). This congruence illustrates the dual function of renewable energy as a scientific advancement and a theological obligation, promoting sustainable practices as an integral aspect of a wider spiritual duty.

Furthermore, the incorporation of Indonesia's renewable energy initiatives, which seek to enhance the utilization of solar, wind, and bioenergy resources, offers a relevant framework for the Solar Dryer Dome (Maulidia et al., 2019). These initiatives highlight the significance of renewable energy in mitigating dependence on fossil fuels, lessening environmental harm, and attaining energy autonomy. The Solar Dryer Dome is a manifestation of how such policies can be put into practice to effectively meet the challenges in agricultural post-harvest operations while ensuring energy efficiency and improving product quality. This nexus of scientific knowledge with theological perspectives puts into light a holistic approach toward sustainability, where innovation seeks to answer not only practical questions of energy conservation and post-harvest losses but also theological and spiritual imperatives. In this regard, the Solar Dryer Dome is a symbol of the confluence of empirical knowledge, policy frameworks, and theological beliefs that can all combine to foster sustainable agriculture and environmental equilibrium..

4. Conclusions

The Solar Dryer Dome represents a significant innovation in sustainable agriculture, addressing inefficiencies in traditional drying methods by utilizing renewable solar energy to achieve optimal moisture removal and energy conservation. Experimental findings confirm its effectiveness in maintaining appropriate temperatures for drying coffee beans while reducing reliance on non-renewable energy sources. The study also bridges scientific innovation with philosophical and theological perspectives, emphasizing the ethical use of natural resources as aligned with Qur'anic teachings on sustainability. By integrating empirical research and interdisciplinary insights, this research highlights the Solar Dryer Dome's potential to advance agricultural sustainability, improve product quality, and promote environmental stewardship. Future improvements could focus on refining dome designs and incorporating energy storage systems to enhance efficiency and scalability.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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