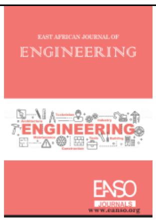

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*Original Article*

# Design and Construction of a Solar Powered Silver-Fish Dryer for Enhancing Food Security and Economic Livelihoods of Fishing Communities in East Africa

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*Silver Fish, Solar Drier, Solar Energy, Food Security.*

**ABSTRACT**

The aim of this study was to design and construct a solar-powered silver-fish dryer that would help reduce the post-harvest losses experienced by fishing communities in East Africa. The system was developed with the goal of promoting food security, improving preservation methods, and enhancing the quality of dried silver-fish. The construction process involved welding, wiring, and soldering various materials, with the trays made from wood and metallic meshes measuring 37 cm by 33 cm. The fabricated cover was also made of wood and measured 47 cm by 63 cm. Three 100-watt bulbs were utilized as heaters, while a CM 3024Z charge controller was connected to a 20W solar panel to manage energy flow. The system was successfully designed and constructed as planned. The direct current (DC) supplied to the dryer was 12 volts. The temperature sensor operated at 5 volts, the heater at 120 volts, and the fan at 12 volts. The charge controller regulated the solar panel's energy supply to the battery, and the inverter converted the direct current to alternating current (AC) to power both the fan and the heater, thereby minimizing energy losses. The dryer system ensures continuous drying, regardless of weather conditions, by efficiently harnessing solar energy to power the heating system. This results in improved cleanliness, reliability, and the ability to dry large quantities of silverfish effectively. The solar-powered silver-fish dryer designed and constructed in this study proves to be an effective solution for addressing post-harvest losses in East Africa's fishing communities. The system's integration of solar energy, combined with an efficient drying mechanism, ensures continuous operation regardless of weather conditions, thereby improving reliability and preserving the quality of the dried fish.

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## INTRODUCTION

The silverfish (Rastrineobola argentea), also known as mukene, is harvested from the drainage basins of Lake Victoria and Lake Kyoga in Uganda. It ranks as Uganda’s third most important commercial species, accounting for about 42% of all fish harvests and 60% of all fisheries (Omagor et al., 2020). This small, silvery fish can grow up to 9 cm in length. It has a highly compressed body with large scales that exhibit a pearlescent sheen and a yellow tail.

The post-harvest handling of silver fish (*Rastrineobola argentea*) in Uganda and other parts of Sub-Saharan Africa has drawn significant attention due to the high perishability of the fish and its importance to local economies. Traditional and modern drying methods have been employed in an effort to improve quality, reduce losses, and increase marketability (Karim et al., 1998). However, there are notable deficiencies in these approaches, especially when compared to the proposed solar-powered drying system (Mohsin, 2011).

One of the most widely documented methods is sun drying, which is the predominant technique used across the regions. For instance, a study by (Lwenya & Abila, 2004) on fish drying practices around Lake Victoria highlighted that sun drying is inexpensive and accessible to local fishermen. However, this method is highly weather-dependent, with spoilage rates increasing significantly during the rainy season. High contamination rates due to exposure to dust, insects, and other environmental pollutants, further compromise the quality of the dried fish(Sifuna et al., 2017).

Several efforts to improve traditional sun drying (Oparaku et al., 2010) investigated the use of smoking as a complementary method to sun drying in Nigeria. Although smoking improves preservation by reducing moisture content and enhancing shelf life, it presents health concerns due to the accumulation of polycyclic aromatic hydrocarbons (PAHs) in the dried fish, making it less suitable for international markets (Tyona & Ojiya, 2024). Moreover, the method does not address weather-related limitations and is labour-intensive, requiring constant monitoring to maintain consistent drying temperatures.

In more recent efforts, researchers have begun exploring mechanical and solar-assisted drying systems. A study conducted by (Omojowo, 2009) explored the use of solar tents and hybrid solar dryers to enhance the drying process in Kenya. While solar tent dryers provide some protection against environmental contaminants and allow drying during cloudy weather, they lack the capacity to regulate internal temperatures effectively. The system relies on ambient conditions, which often result in uneven drying, leading to inconsistencies in product quality. Hybrid solar dryers, which combine solar energy with electrical or thermal backup, were found to offer better control over the drying process(Ndirangu et al., 2020). However, these systems are often costly and require significant capital investment, which limits their adoption by local fishermen (Whiston et al., 2022).

Improved solar dryers with air circulation systems were used in Ghana Jensen, (2002). The system demonstrated better drying efficiency compared to traditional methods, but its dependence on electrical power for air circulation made it

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impractical in remote areas with limited or unreliable access to electricity. This highlights a major deficiency in most solar-assisted technologies currently in use while they show potential, their reliance on electrical power or costly infrastructure limits their applicability in rural, off-grid areas.

The solar-powered drying system designed in this research addresses many of the deficiencies found in current technologies. Unlike sun drying and smoking methods, the solar-powered system provides consistent heat through controlled solar energy storage, allowing for year-round operation regardless of weather conditions. Unlike hybrid solar dryers that rely on external electricity, this system operates entirely on solar energy, making it more accessible to rural fishermen without access to the grid. Additionally, by providing a controlled environment, the system reduces contamination risks, ensuring high-quality fish that meet international standards for export. The system's ability to dry large quantities at once also enhances efficiency, addressing the limitations of capacity found in solar tents and other traditional methods. (Rana et al., 2024)

While there has been notable progress in developing improved drying methods for silver-fish across Sub-Saharan Africa, many existing technologies remain impractical due to their cost, dependence on weather conditions, and limited capacity (Al Haddabi1 & Rajakannu, 2024). The constructed solar-powered drying system offers a more sustainable, scalable, and efficient solution, capable of addressing the shortcomings of previous research and providing a pathway to higher-quality, export-ready dried fish.

## MATERIALS AND SYSTEM DESIGN

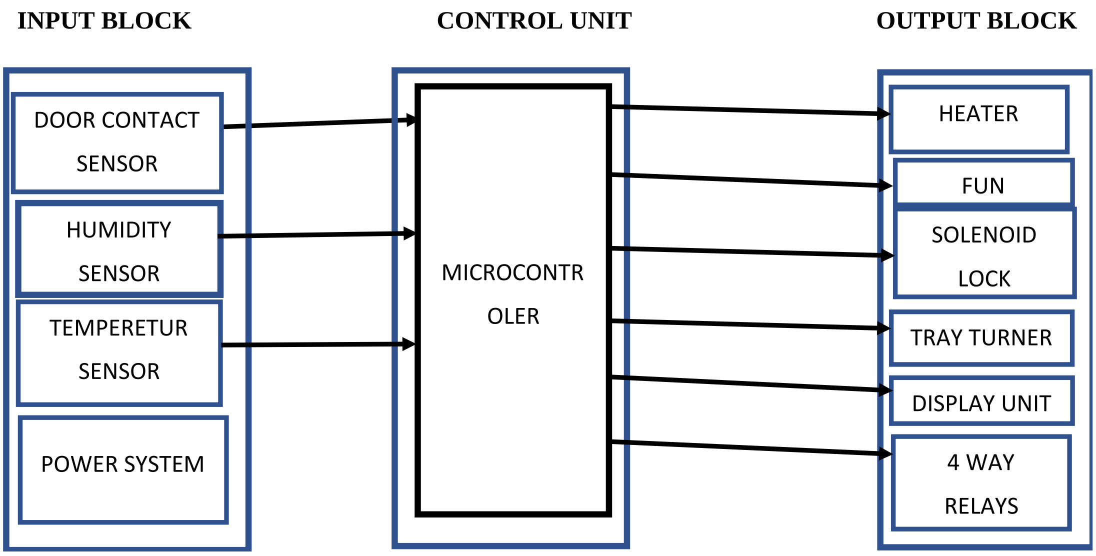
### Constructing the Solar Dryer

Construction of the system was done by welding, wiring and soldering different materials. The trays were made of wood and metallic meshes measuring 37cm by 33 cm. The fabricated cover was made of wood and it measured 47cm by 63cm. Three Bulbs of 100 watts were used as heaters and a charge controller CM 3024Z was connected to a 20W solar panel.

The prototype was designed and a virtual online simulator (virtual laboratory) was used to interconnect and design the virtual prototype. After installing the code program on the virtual platform, connections on the breadboard were done.

### Block Diagram of the System

**Figure 1: Block Diagram of the *S*olar *D*ryer *S*ystem**



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**Input block**

The input block consists of the sensors and the power supply system. The power supply block consists of a 9V battery that supplies a Direct Current voltage to the Arduino board. The Arduino is run by voltage between 7V-12V Direct Current therefore the battery lies in the range of voltages that run the Arduino.

**Sensors:** The sensor block consists of sensors that keep the system working normally and once there is an input they automatically send a signal which will turn send the signal to the notifying block. The sensors pick the environmental information, converts it into electrical information and sends it to the controller block for interpretation.

**The Controller Unit**

The microcontroller section is basically the brain of the system. An Arduino board that carries a microcontroller gives a set of instructions that sends a command on how different modules relate to the system.

**The Output Blocks**

The output block consists of the Display unit that helps the user to know the Parmenter's being ready by the microcontroller like the temperature of the drier.

**Designing the Software**

The program that runs the drier was designed using the Arduino software. It was done in four steps: writing the pseudocode, drawing the necessary flow chat, writing the source code and then uploading the program onto the microcontroller.

**Figure 2: Circuit Diagram of the Silver Fish Dryer**

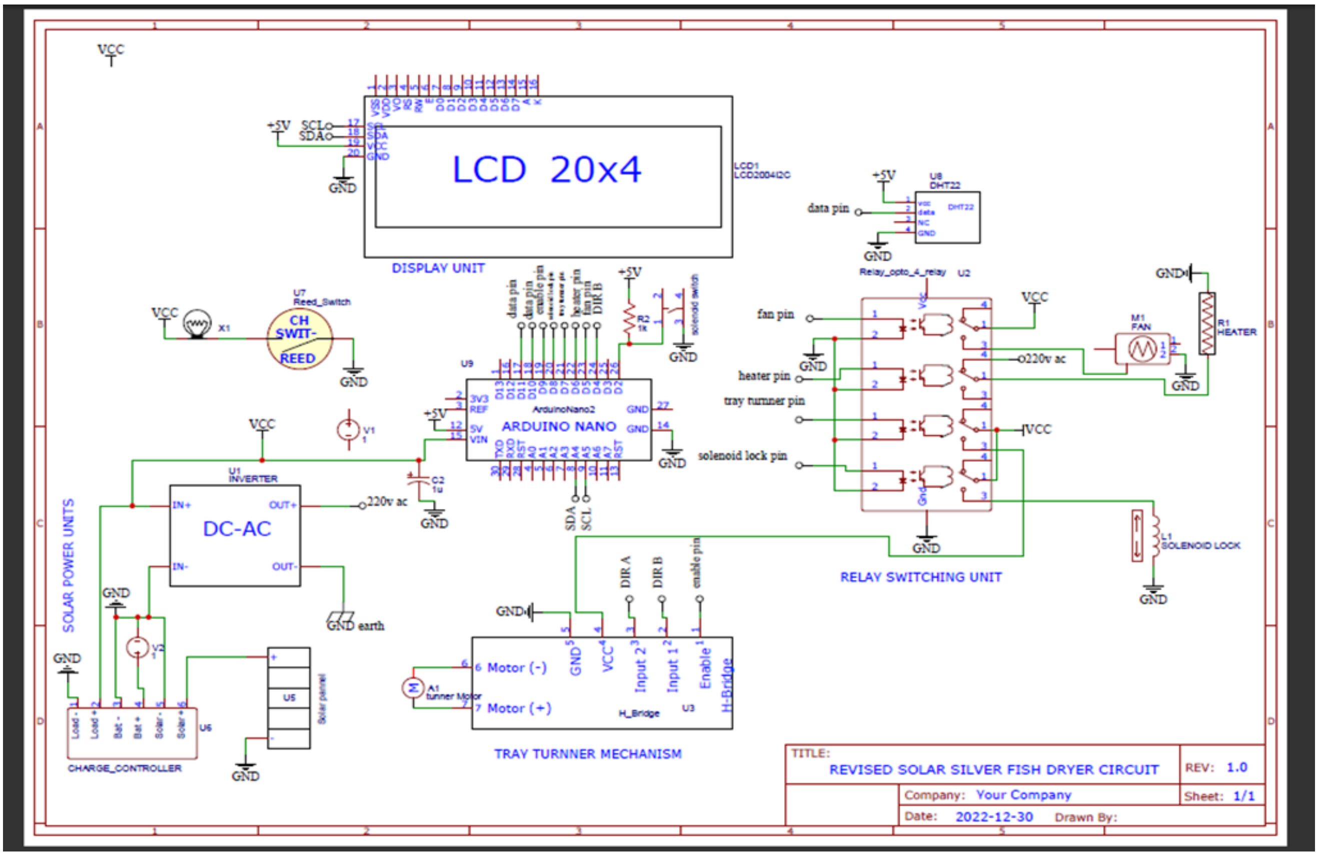


**Figure 2** above shows all components that were used to design the drier and these include Arduino board, battery, solar panel, charge controller, sensors, Liquid Crystal Display screen, Direct Current -Alternating Current inverter, transistor, motor, Relay switches, solenoid lock, heater, and Fan.

All the modules and different components were supplied with a battery voltage of 12V except the

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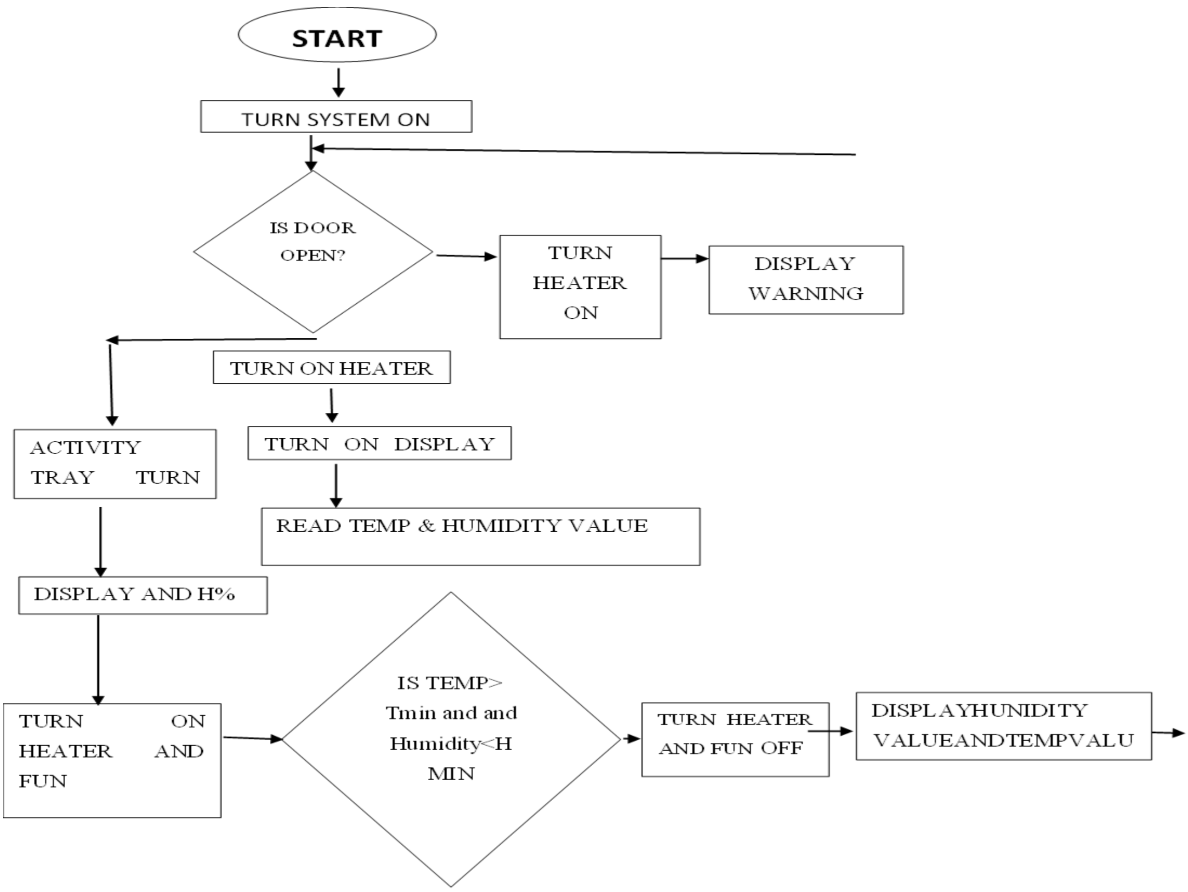
heater which used a Direct Current -Alternating Current inverter. All the components were grounded as a safety measure. Arduino NANO was the brain of the drier onto which the program was uploaded and was responsible for taking in humidity sensors, temperature sensors, heaters, fans, and the tuning mechanism. It was also used to communicate with the display unit to display information from the sensors to turn on and off loads like the solenoid lock and to detect the opening of the door. The Relay switches help the microcontroller to switch heavy loads like the heater, fan, and motor using a low voltage.

The heater provides the heat energy which increases the temperature inside the dryer leading to a reduction of humidity levels inside the dryer and the fan ensures uniform transfer of heat inside the dryer for uniform drying. The motor provides the rotation mechanism of the trays to ensure proper drying of all the silver fish at a given time. The solenoid lock provides controlled access to the inside of the dryer. The transistors are used to build a Direct Current – Alternating Current converter circuit that powers the Alternating Current rated heater and also to come up with an H-Bridge circuit that controls the rotation mechanism of the trays. The Liquid Crystal Display screen displays parameters from the sensors. The sensors detect physical parameters like the humidity and door opening by the door sensors.

**Figure 3: Flow Diagram of the Silver Fish Dryer System**




## Testing the System

The testing was done in three ways which included source test, timing test and output test. The timing test was aimed at testing the working speed of the dryer, the output test was aimed at testing the moisture content of the output product so as to test the accuracy. The source test aimed at determining the maximum production for the approved operating range of the dryer.

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**System Testing and Validation**

Testing of the electronic components was done and they were all functioning in the desired ranges.

These tests were also carried out to ensure that the requirements of the system were met to perform exactly as what was expected.

**Table 1: Measured Voltages During System Testing**

| Test | Voltage(V) | | Comment |
|---|---|---|---|
| | Tested | Expected | |
| DC SUPPLY TO ARDUINO | 12.0 | 12 | Within range |
| HUMIDITY SENSOR | 4.92 | 5 | Within range |
| DOOR SENSOR | 4.8 | 5 | Within range |
| TEMPERATURE SENSOR | 4.75 | 5 | Within range |
| HEATER | 119 | 120 | Within range |
| SOLENOID LOCK | 4.56 | 5 | Within range |
| FAN | 11.8 | 12 | Within range |

**Component Testing**

A digital multimeter was used to measure two or more electrical values. It was also used to measure voltage (volts), current, resistance (ohms), capacitance and continuity. Using the multimeter, the voltage supply to different components and the voltages were all in the required ranges.

## RESULTS AND DISCUSSION

**Block Testing**

Block testing is simply carrying out a test to validate the function ability of the entire block of the system. This helps in quick troubleshooting of which block is not serving the intended purpose. The system consists of three blocks, the input block, the control unit and the output block. Tests were done on each block and confirmed to be working.

**Input Block Testing**

The input test was used for testing the door contact sensor, Humidity sensor and the temperature sensor's correct functioning. This block was tested by first switching it on and powering the system when the door was sensed open the heat was turned off together with the warning alarm being turned on the same thing happened when the temperature value was above (Tmin) and also when the humidity sensor sensed a value below (Hmax) the heater and Fun went off and when input block is disconnected the system does not give an output since no signal is being received.

**Processing Block**

The control block consists of the microcontroller. A block of output samples is computed for each input block, no output is given out when they are not connected through the processor unit and once, they are connected through the programmed processor unit, they are able to work as required.

 

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**Figure 4: Running a Program that was Uploaded on the Micro Controller**


**Output Block**

Just as with the other blocks, this block was eliminated from the system and no results were given but once it was reconnected, the system worked as required.

**Final Prototype Testing**

**Table 2: Prototype Results**

| Test | Validation |
|---|---|
| Heater | OK |
| Door sensor | OK |
| Humidity sensor | OK |
| Solar panel | OK |
| Charge controller | OK |
| Invertor | OK |

The Direct Current supply measured was 12V which is a common voltage for most solar-powered systems as developed by Velukumar et al., (2024) who designed a solar fish dryer with a 12V Direct Current supply. The temperature sensor operated at 5V which is comparable to Reza & Hossain, 2024) that designed the solar dyer at 5V.

The heater operated at 120V which is high compared to (Reza & Hossain (2024) who used a 12V heater in their design for the solar dryer. The fan operated at 12V which is consistent with recent advances in solar drying studies by Abdul Razak et al., (2021). The charge controller regulated the amount of energy from the solar panel to the battery. The Inverter converts the Direct Power to Alternating power to energize the fan and the heater and this is done to minimize the energy losses. The final prototype was tested and the components worked well as designed.

## CONCLUSION

The fish dryer was designed and automated using sensors. It dried the silver fish faster than sun drying. It was able to dry the fish evenly with the help of the rotating mechanism which is connected to the motor. Local materials were used to design the dryer so if utilized very well it can help enhance food security and economic livelihood of the fish farmers in East Africa. The use of renewable energy in this process not only promotes food security but also reduces dependence on traditional, less efficient drying methods. By minimizing spoilage and improving the preservation of fish, this dryer contributes to the sustainability of fishing practices and enhances the livelihoods of fishing communities

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in the region. Overall, the solar dryer offers a clean, reliable, and efficient alternative for large-scale fish drying, fostering greater resilience in the face of environmental challenges.

### Limitations

The silver fish dryer lacks a mechanism for informing the user that the fish is dry. The efficiency of solar dryers depends on energy storage systems (batteries) to ensure operation during nighttime or cloudy weather. Low-capacity batteries may not store enough energy to run the dryer continuously, leading to interruptions in the drying process especially in the rainy season. Solar fish dryers require regular maintenance, including cleaning the solar panels, checking the battery and wiring, and ensuring the trays and heating components are in good condition. Lack of proper maintenance could reduce the system's efficiency over time.

### Recommendations

Installing advanced sensors to monitor real-time temperature, humidity, and energy consumption would improve the system's efficiency. An automatic control system could adjust the heating levels based on the conditions, ensuring optimal drying and energy use. It is essential to provide training programs for fishing communities on how to properly use and maintain the solar dryer. Awareness campaigns can also highlight the benefits of using renewable energy for fish preservation and encourage widespread adoption.

Future designs could explore alternative materials for the construction of the dryer to enhance durability and reduce costs. Using locally available and affordable materials would make the dryer more accessible and sustainable in the long term. Although solar energy is abundant, the system could be designed to integrate other renewable energy sources like wind power, ensuring a more consistent energy supply in varying weather conditions.

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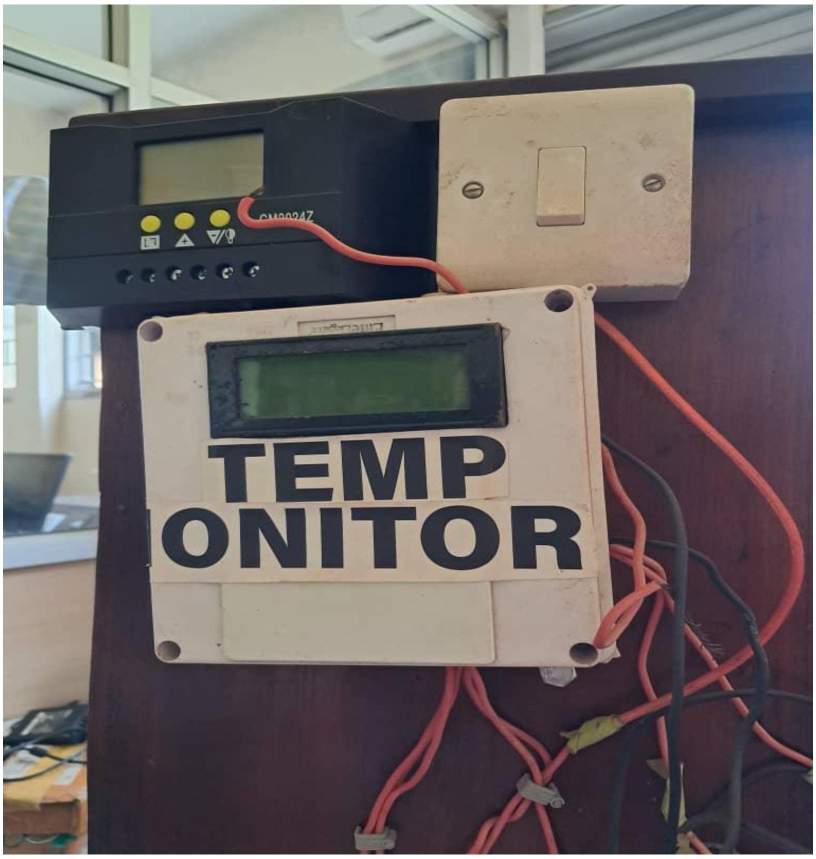
## APPENDICES

**Appendix 1: The Fish Trays Inside the Solar Dryer.**

**Appendix 2: Temperature Monitor and Charge Controller**



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**Appendix 3: The Finished Solar Fish Dryer with the Solar Panel at the Top.**