Chapter 2

# LITERATURE REVIEW

## 2.1 Introduction

Cocoa drying is a vital post-harvest process that ensures the preservation of bean quality and flavor profile. While traditional sun drying is the most common method, it is weather-dependent, inconsistent, and can compromise bean quality through contamination and uneven drying. Solar -powered drying systems provide a more efficient, controlled, and sustainable alternative. This chapter reviews past and ongoing research into the design, materials, and performance evaluations of solar dryers for cocoa and other agricultural products.

## 2.2 Principles of Solar Drying Technology

Solar dryers operate by converting solar radiation into thermal energy, which removes moisture from agricultural products like cocoa beans. According to Nalubega (2015), indirect solar dryers are often preferred for cocoa as they minimize direct exposure to sunlight, which can degrade bean quality. Such dryers rely on a solar collector to heat air, which is then circulated through a drying chamber containing the beans

Design features include thermal energy storage systems to ensure continuous drying even during low sunlight periods. Commonly used materials include galvanized sheets, stainless steel, and insulated plywood, which enhance thermal retention while being cost-effective and durable.

## 2.3 Designs and Materials for Cocoa Solar Dryers

Several prototypes and configurations of cocoa solar dryers have been developed:

1. Flat-Plate Collectors: These are widely used due to their simplicity and effectiveness in converting solar radiation to heat. In a study by Madarang (2019), a flat-plate collector with black-painted galvanized iron was used to achieve uniform heat distribution and efficient drying. Insulating materials like plywood were also added to reduce thermal losses.

2. Rotating Screen Dryers: These incorporate mechanical components such as rolling screens to enhance airflow and ensure even drying. Evaluations of such designs have demonstrated their capability to reduce drying time to 9–10 hours at temperatures of 50–51°C while maintaining bean quality

3. Hybrid Systems: Hybrid designs combine solar energy with auxiliary heating sources, such as electrical heaters, to ensure uninterrupted drying during cloudy conditions. The incorporation of low-energy fans further improves airflow regulation, as highlighted by Nalubega (2015)

4. Localized Design Features: For smallholder cocoa farmers, localized materials and designs

have been prioritized. Nalubega's (2015) research emphasized the use of inexpensive, readily available materials like wood, mesh screens, and clear plastic covers to make the technology accessible to rural farmers

## 2.4 Performance Evaluations of Solar Dryers

Performance metrics for solar dryers include drying rate, moisture content reduction, energy efficiency, and product quality:

• Moisture Content Reduction:

Effective dryers should reduce moisture content to below 7%, ensuring proper fermentation and storage. Studies indicate that indirect dryers can achieve uniform drying without affecting bean flavor and appearance (Akinola et al., 2022; Kumar et al., 2021).

• Energy Efficiency:

The use of thermal energy storage systems ensures that solar dryers maintain optimal temperatures even during intermittent sunlight. Comparative studies have shown that hybrid systems with auxiliary heating are up to 30% more efficient than traditional methods (Adeoye & Olaniyi, 2020; Singh et al., 2021).

• Quality Assurance:

Solar drying minimizes microbial contamination and reduces the risk of bean discoloration, unlike open-sun drying (Obi & Ugwuishiwu, 2023; Chavan et al., 2022).

## 2.5 Advantages and Challenges of a Solar-powered cocoa Dryers

### 2.5.1 Advantages

• Environmental Sustainability:

Solar dryers significantly reduce the carbon footprint by eliminating the need for fossil fuels (Nair et al., 2020; Ali et al., 2021).

• Cost-Effectiveness:

Once installed, operational costs for solar dryers are minimal compared to mechanical dryers, making them more economical for long-term use (Chandra & Arora, 2019; Perez et al., 2022).

• Quality Enhancement:

Uniform drying achieved with solar-powered dryers helps preserve the nutritional and flavor profiles of cocoa beans (Nduka et al., 2021; Leong et al., 2020).

### 2.5.2 Challenges

• Initial Cost:

The capital cost for the fabrication and installation of solar dryers can be a barrier for small-scale farmers (Balde, 2021; Mohammed et al., 2022).

•Dependency on Weather:

Solar drying systems are highly dependent on weather conditions, and extended periods of cloudy or rainy weather require hybrid systems, increasing complexity and cost (Dutta & Singh, 2020; Nair et al., 2021).

• Maintenance:

Regular maintenance of components like fans and collectors may be necessary, impacting long-term usability (Akinmoladun et al., 2022; Patel et al., 2023).

## 2.6 The Impact of Automation in Cocoa Processing

Automation in cocoa drying has become a transformative technology aimed at improving efficiency and quality while reducing labor-intensive processes. Traditional methods rely heavily on manual oversight, leading to uneven drying and potential quality degradation. Automated systems address these challenges by integrating advanced sensors, controllers, and actuators to maintain optimal conditions.

Studies have shown that automation enhances drying consistency by maintaining precise temperature and humidity levels (Aremu et al., 2020). This ensures uniform drying, reduces post -harvest losses, and preserves the biochemical properties of cocoa seeds, such as their flavor precursors and fat content, critical for high-quality chocolate production (Fagunwa et al., 2019). Furthermore, automated systems reduce the dependency on human intervention, making the process more efficient and scalable.

## 2.7 Advances in Solar Drying Technologies

Solar drying has evolved from simple sun-drying techniques to sophisticated systems designed to maximize efficiency and minimize environmental impact. These advancements are particularly relevant in cocoa drying, where maintaining precise drying conditions is crucial.

1. Photovoltaic Integration

Modern solar dryers incorporate photovoltaic (PV) panels to convert sunlight into electricity, powering fans, sensors, and other essential components (Okoro et al., 2021). This innovation allows for continuous operation, even in low sunlight conditions, ensuring consistent drying cycles.

2. Thermal Energy Storage

Innovative solar drying systems now utilize thermal energy storage materials, such as phase change materials (PCMs), to retain heat for nighttime or cloudy-day operation (Ahmed et al., 2020). This ensures uninterrupted drying and enhances energy efficiency.

3. Hybrid Systems

Hybrid solar dryers, which combine solar energy with auxiliary power sources (e.g., biomass or electricity), have gained traction in regions with inconsistent sunlight. Such systems provide a reliable alternative to address weather variability (Agunbiade & Adebayo, 2022).

4. Smart Monitoring and IoT Integration

The integration of Internet of Things (IoT) technology in solar dryers allows for remote monitoring and control. Real-time data on drying conditions can be accessed via mobile devices, enabling farmers to make adjustments as needed (Eze et al., 2021).

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