

The system generally consists of a transparent cover supported by a metal or bamboo frame structure, along with raised drying trays or mesh platforms that allow proper air circulation. Air inlet and outlet vents facilitate movement of air, and in some designs, optional fans are installed to enhance forced air circulation. The enclosed design protects coffee beans from rain, dust, insects, and animals while ensuring controlled and hygienic drying conditions.

#### Working principle

The operation of a solar tunnel dryer is based on the greenhouse effect. Solar radiation passes through the transparent cover and heats the air and coffee beans inside the tunnel. As the internal air temperature rises, it absorbs moisture from the beans. The warm, moisture-laden air moves upward due to natural convection and escapes through outlet vents, while fresh air enters through inlet openings. This continuous air exchange maintains steady drying. The temperature inside the solar tunnel is typically 10–20°C higher than the ambient temperature, significantly reducing drying time compared to conventional open sun drying methods.

#### Advantages of solar tunnel drying for coffee

Solar tunnel drying offers significant technical and economic advantages over traditional practices. The enclosed structure enables faster drying, thereby reducing exposure time and minimizing the risk of fungal contamination. Protection from unexpected rainfall and environmental contaminants improves the uniformity and colour of the beans. Controlled drying conditions help retain desirable aroma and flavour compounds, enhancing overall cup quality. The technology reduces post-harvest losses and lowers dependency on fuel-based mechanical dryers, making it an environmentally friendly and energy-efficient solution. Improved quality and reduced defects increase the export potential and market competitiveness of coffee beans.

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#### Introduction

Coffee is one of the most important commercial plantation crops cultivated in tropical and subtropical regions. The quality of coffee beans, particularly their aroma, flavour, colour, and overall market value, is highly influenced by post-harvest processing practices. Among these, drying is a critical step that determines the stability and quality of the final product. Traditional open sun drying methods are commonly practiced by farmers; however, they often result in inconsistent drying, contamination, fungal growth, and quality deterioration due to unpredictable weather conditions. Solar tunnel drying has emerged as an efficient, hygienic, and cost-effective alternative that enhances drying efficiency while preserving coffee quality. This improved technology utilizes solar energy within a controlled enclosure to ensure uniform and safe drying of coffee beans.

#### Importance of drying in coffee processing

Drying plays a crucial role in both dry (natural) and wet (washed) methods of coffee processing. Freshly harvested coffee cherries or parchment coffee contain a high moisture content ranging from approximately 45 to 60 percent. For safe storage and export, this moisture must be reduced to around 10–12 percent. Inadequate or improper drying can lead to fungal contamination and mycotoxin formation, uneven moisture distribution within the beans, poor flavour development, discoloration, and structural damage. Excess moisture also reduces shelf life and negatively affects cup quality. Therefore, efficient and controlled drying is essential to ensure better flavour retention, improved storage stability, and higher market price realization.

#### Concept of solar tunnel drying

Solar tunnel drying is an improved solar drying technology designed as a semi-cylindrical or tunnel-shaped structure covered with UV-stabilized transparent polyethylene sheets. The enclosed structure traps solar radiation and creates a greenhouse effect, raising the internal temperature and accelerating moisture removal from coffee beans.

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कोटा, राजस्थान



### Solar Tunnel Drying of Coffee

संकलन

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### Comparative performance of drying methods

When compared to open sun drying, solar tunnel drying demonstrates clear performance improvements. Open sun drying typically requires 12 to 20 days depending on weather conditions, whereas solar tunnel drying reduces the drying period to approximately 7 to 10 days. Open sun methods are highly dependent on weather and prone to contamination risks, while solar tunnel systems offer better protection and controlled drying. Uniform moisture reduction and improved quality retention are more consistently achieved under tunnel drying conditions.

### Construction and Design Considerations

The size and capacity of a solar tunnel dryer depend on the scale of production. Small-scale farmers can construct low-cost units using locally available materials such as bamboo frames and UV-stabilized plastic sheets. Proper ventilation design is essential to ensure effective removal of moisture-laden air. Raised drying platforms facilitate airflow from below and enhance uniform drying. Orientation of the structure in an east–west direction maximizes solar exposure throughout the day. The dryer should be installed in an open, unshaded area and constructed with adequate structural strength to withstand wind and heavy rainfall conditions.



Fig: Solar tunnel dryer

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### Economic Benefits for Coffee Growers

Adoption of solar tunnel drying reduces drying duration and minimizes post-harvest losses, leading to improved price realization. The system reduces operational costs associated with mechanical drying and lowers fuel consumption. By enhancing bean quality and reducing defects, farmers can access premium markets and achieve better export opportunities. This technology is particularly beneficial for small and medium-scale coffee growers located in hilly and high-rainfall regions where traditional sun drying is challenging.

### Challenges and Limitations

Despite its numerous advantages, solar tunnel drying has certain limitations. Initial installation requires investment, and performance depends on adequate sunlight availability. Regular monitoring of temperature and moisture levels is necessary to prevent over-drying or uneven drying. Additionally, the capacity of small-scale solar tunnels may be limited compared to large industrial mechanical dryers. However, proper design, management, and integration with simple monitoring systems can effectively address most of these challenges.

### Future Prospects

With increasing emphasis on sustainable agriculture and renewable energy utilization, solar tunnel drying technology holds strong future potential in coffee processing systems.

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Integration of temperature and humidity sensors, automated ventilation control, and hybrid solar-biomass systems can further enhance efficiency and reliability. Government support programs, subsidies, and farmer training initiatives can accelerate adoption, especially among smallholder coffee growers.

### CONCLUSION

Solar tunnel drying represents a sustainable, cost-effective, and quality-enhancing approach to coffee post-harvest processing. By providing a controlled and hygienic drying environment, it reduces contamination, improves moisture uniformity, shortens drying time, and enhances market value. Wider adoption of this technology can significantly contribute to improved income generation, better product quality, and environmentally sustainable coffee production systems.

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