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Solar Drying Technology for Northeast Region: Prospectus and Challenges

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Abstract

The production agricultural products and its preservation to fulfil the demand of increasing population is vital operation in agriculture sector. Solar drying technology provides the promising solution for preservation of agricultural products which reduces the reliance on fossil fuels and hygienic mode of drying over convention open sun drying. Northeast Indian states produce variety of agricultural crops including cash crops like large cardamom, ginger, chilli and turmeric. Northeast Indian states produce variety of agricultural crops including cash crops like large cardamom, ginger, chilli and turmeric which can be dried using solar dryer. Solar dryers can be adapted to assorted designs, sizes, and mode of operations depending on the requirement of the specific crop and area.

Introduction

Drying is important practice in preservation of agricultural produce as it helps to reduce moisture and increase the shelf life. Historically, drying was one of the methods used to preserve agricultural products, such as fruits, grains, vegetables, fish, meats, and wood. Dried product makes it difficult for enzymes, bacteria, yeasts, and molds to work and as a result, drying helps improve product quality and reduce waste. People have been using drying to preserve food and other things for a long time. Today, drying is still used for many agronomic products. The northeastern region (NER) which includes the states like Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, is the easternmost region of India. The agriculture sector is vibrant and growing Agriculture industry contribute significantly to economics of the states. The fertile land in NER is allowing farmers to variety of crops, including rice, tea, spices, fruits, Rubber, Jute and vegetables, making the region a significant source of agricultural produce. The cash crops like large cardamom, ginger, chilli and turmeric are also grown on wide range.

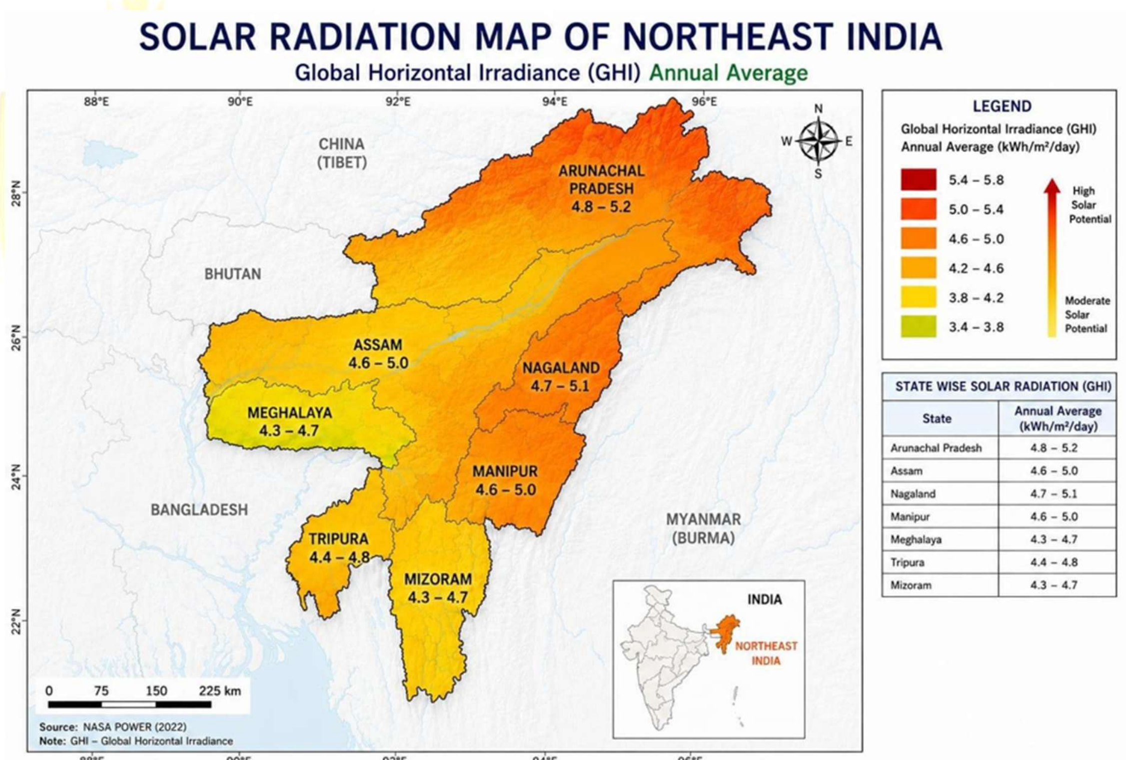

Figure 1. Solar Resource Map of Northeast India Based on Annual Average Global Horizontal Irradiance (GHI), NASA POWER (2022) data.

Spatial distribution of annual average Global Horizontal Irradiance (GHI) across Northeast India, indicating moderate to high solar energy availability (4.3–5.2 kWh m^{-2} day^{-1}). The map demonstrates that the region possesses sufficient solar resources to support solar thermal technologies, particularly for post-harvest drying, agro-processing, and decentralized renewable energy applications. Higher solar radiation is observed in Arunachal Pradesh, Nagaland, Assam, and Manipur, whereas comparatively lower values occur in Meghalaya and Mizoram due to greater cloud cover and rainfall. Source: Adapted from NASA POWER database (0.25° × 0.25° spatial resolution).

Table 1. Important crops grown in Northeast states.

States	Major Crops
Arunachal Pradesh	Rice, maize, millet, wheat, pulses, ginger, and large cardamom.
Assam	Rice, tea (largest producer in the region), jute, mustard and sugarcane.
Manipur	Rice, maize, pulses, oilseeds, pineapples, and various seasonal vegetables.
Meghalaya	Rice, maize, potatoes, oranges, pineapples, turmeric, ginger, and sweet potatoes.
Mizoram	Rice, maize, pulses, ginger, turmeric, chili, sesame, and oil palms.
Nagaland	Rice, maize, millets, pulses, oilseeds, sugarcane, and potato.
Sikkim	Large Cardamom (primary global producer), rice, maize, buckwheat, ginger, and mandarin oranges.

Solar drying technology

Drying is an old way to keep agricultural products free from spoilage for long time. In open sun drying, the agricultural products are spread over the surfaces for drying but this method is susceptible to contamination by dirt, dust, insect infestation, birds, animal interfering and damage. It takes long time for drying with traditional method. The limitations of open sun drying method can be overcome by using the solar drying technology. Solar drying uses solar energy for drying the agriculture produce in a controlled environment in a system called as solar dryer. Solar driers can be used for drying of fruits, vegetables and crops for preservation and increasing shelf life.

Solar drying technology is sustainable and cost-effective alternative to remove the moisture, reducing post-harvest losses and enhancing the hygiene and quality of the dried products by improving the colour, taste and appearance. The closed environment reduces the risk of insect infestation and contamination. It reduces the dependence on the fossil fuels preserving the valuable commercial energy sources.

In solar dryer, incident solar radiations after passing through the transparent cover such as glass or plastic heats up the inside space by absorption. This absorption leads to an increase in temperature inside the chamber and above the crop. The air entering the chamber through air holes and escaping through an aperture at the top of the cabinet takes the moisture away from the crop (Fig.2).

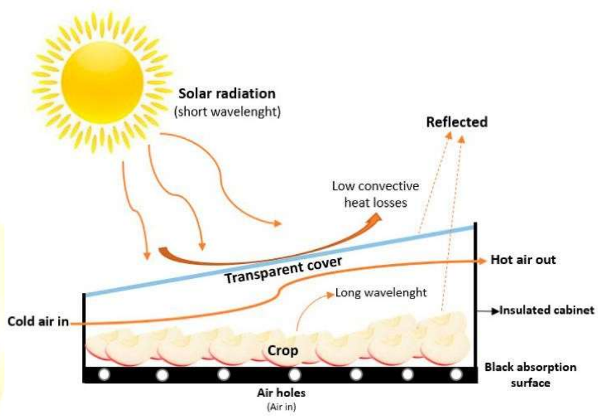

Figure 2. Working principle of solar dryer (Fernandes and Tavares, 2024)

Types of solar dryer

Solar energy dryers can be put into three groups: Direct Solar dryers, Indirect Solar dryers and Hybrid Solar dryers based on the incidence of the solar radiance. Direct solar dryers expose the drying product directly to the solar radiation where the product is heated releasing the moisture from the products. In indirect solar dryers, the air is heated separately in solar collector and then passed though the drying product in separate drying cabinet unit drying the material purely through convective heat transfer. Hybrid solar dryers combine solar energy with an auxiliary energy source, such as biomass burners, electric heaters, or solar thermal storage systems. This integration ensures a continuous, controlled drying process that can operate during cloudy days or throughout the night, drastically reducing drying times and minimizing post-harvest losses for high-value crops.

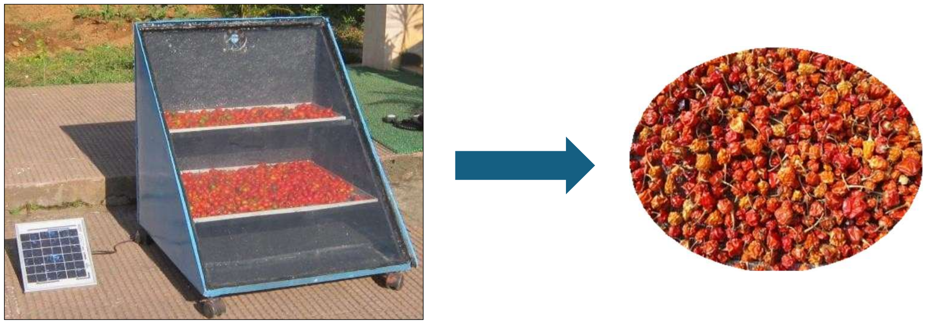

Figure 3. Portable PV powered forced convection solar dryer and dried dalle chilli developed by department of renewable energy engineering, caepht, ranipool

The Northeast produces some of the finest organic spices and fruits. However, their high initial moisture content makes them highly perishable. Solar drying changes the economic dynamic by enabling farm-gate processing. Large cardamom (Sikkim), Lakadong turmeric (Meghalaya), ginger, and bird's eye chilli benefit immensely. Solar drying preserves the high curcumin content in turmeric and volatile essential oils in ginger and cardamom far better than traditional wood-fired smoking or open sun drying. The region faces massive seasonal gluts of pineapple, jackfruit, mandarin oranges (Malta), and bamboo shoots. Solar tunnel dehydrators convert these into high-value, shelf-stable slices, candies, and powders. Drying orthodox tea leaves, medicinal and aromatic herbs, and coastal/riverine fish (in areas such as Tripura and Assam) creates stable off-season markets.

Prospectus of solar drying technology

1. Hygienic drying: Unlike open-air sun drying, solar drying completely takes place in an enclosed structure protecting the drying produce from dust, insects, birds, and harsh weather like sudden rain or heavy dew.
2. Faster drying: Solar dryers effectively trap the solar heat often achieving drying temperatures 60-70 ^{0}C. These decreases drying times by various days saving 50 to 60% of the drying time compared to open sun drying.
3. Quality and nutrition: The controlled, steady heat preserves the natural flavor, color, and nutritional content of fruits, vegetables, and herbs.
4. Low operational costs: Solar dryer run entirely on free, renewable solar energy, cutting out the electricity or fossil fuel costs of standard mechanical dehydrators.
5. Increased shelf life: The moisture of the products after drying reduced below 10% which enables products storage for long periods, vastly decreasing crop spoilage.

Challenges

Solar drying technology is highly relied on the ambient environment making it susceptible to intermittent nature of the solar energy availability. Solar dryers can work efficiently during clear sunshine day however, nighttime hours, cloudy weather, and sudden rains abruptly halt the drying process. In tropical or heavy-rainfall zones, the ambient relative humidity often exceeds 80%. If the temperature of solar dryer becomes low during cloudy conditions, evening time or during night, the air inside dryer can reach its dew point. This condition make highly hygroscopic crops like sliced ginger or turmeric can reabsorb moisture inside the chamber, creating a perfect microclimate for mold and microbial spoilage. Delicate agricultural produce can suffer structural degradation, case hardening (where the outer shell dries too fast and seals moisture inside), or may result in the loss of heat-sensitive nutrients and essential volatile oils. A robust, institutional-grade active solar tunnel or hybrid dryer stands for a steep upfront investment for smallholder farmers which makes and without government

subsidies, the cost-to-benefit ratio can seem prohibitive. A lack of field training often leads to over-drying or under-drying.

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