Drying Kinetics and Quality Assessment of Curry Leaves in an Indirect Solar Dryer with Thermal Energy Storage

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Abstract: Drying culinary herbs is a fundamental practice for preserving their shelf life and enhancing their flavor, aroma, and overall quality. Among these herbs, curry leaves (Murraya koenigii. L. Spreng) are particularly significant due to their culinary, medicinal, and aromatic value. The choice of drying method significantly influences product quality and economic outcomes. While traditional sun drying is common, it faces challenges related to weather dependency and limited control over drying conditions. To meet international standards, efficient drying systems are imperative, incorporating precise control over temperature, airflow, and humidity. This study investigates the drying process of curry leaves in an indirect solar dryer, both with and without sensible heat storage material, and compares it to open sun drying. The results reveal that drying curry leaves in an indirect solar air heater without sensible heat storage material yields superior results, requiring less time compared to drying with heat storage material and open sun drying. Furthermore, this method retains the color and aroma of the leaves more effectively.

Keywords: Curry leaves, drying, indirect solar dryer, thermal energy storage

INTRODUCTION

India holds the distinguished title of being the world's leading producer of medicinal herbs, often referred to as the "botanical garden of the world" (Grover et al., 2002). These Indian herbs have garnered global recognition for their exceptional medicinal attributes. The moisture content of aromatic and medicinal plants plays a pivotal role in shaping their physical and chemical characteristics (Chasiotis et al., 2021). Among the various processes involved in post-harvest handling, drying emerges as a cornerstone procedure for medicinal plant processing. It is worth noting that the drying method employed significantly impacts the quality of the resulting herbal products, consequently influencing the economic returns (Halim & Maryani, 2022) (Mahapatra & Nguyen, 2007).

Aromatic and medicinal plant leaves are often subjected to drying prior to extraction to reduce their moisture content (Kaya & Aydin, 2009). Drying is a technique by which heat energy is used to reduce the moisture content of a product to a predetermined level (El-Sebaii & Shalaby, 2012). During drying process, a significant number of compounds, drawn to the leaf surface by the evaporating water, are lost. For many years, the conventional approach to drying leaves products involved exposure to direct sunlight. However, this method exhibited numerous shortcomings such as susceptibility to rain, dust, animals, wind, and insects. Additionally, open sun drying lacked control over essential drying parameters, including air flow rate, temperature, and moisture content (Yadav & Chandramohan, 2020) (Vengsungnle et al., 2020). Consequently, the quality of materials deteriorated during open sun drying, resulting in products that fell short of international standards in terms of both quality and cost-effectiveness. To address these issues and to meet the rigorous standards required for medicinal plants, there is a pressing need for efficient drying systems. These systems must utilize precise temperature, airflow velocity, and humidity control to rapidly reduce moisture content without compromising the quality of the active ingredients within medicinal plants (Rocha R. P., 2011).

The drying of culinary herbs is a fundamental practice that not only extends their shelf life but also crucially affects their flavor, aroma, and overall quality. Among these herbs, curry leaves (Murraya koenigii. L. Spreng) hold a special place, not only for their culinary importance but also for their medicinal and aromatic qualities.

Curry leaves, sourced from the aromatic Murraya koenigii shrub, are an essential ingredient in Indian cuisine and traditional medicine. Their rich mineral and vitamin content, coupled with valuable carbohydrates and proteins, make them a significant dietary addition. Moreover, they contain carbazole alkaloids and are renowned for their potential role in managing various health conditions. The curry leaf plant is renowned in South Asian cuisine for its distinct taste and aroma, making it a staple in various dishes. Additionally, it has a long history of being utilized as a home remedy. These fragrant leaves are commonly employed to enhance the flavor of curries, stimulating appetite and aiding digestion. Locally, they find application in the treatment of external injuries, burns, and even in neutralizing poison from the bites of venomous animals as well as addressing rheumatism. Traditional Ayurvedic medicine incorporates various parts of the curry leaf plant to treat conditions such as cough, hypertension, hepatitis, rheumatism, and hysteria. Additionally, in a traditional practice, curry leaves are boiled with coconut oil until reduced to a blanked residue, which is then employed as a hair tonic to maintain natural hair color and stimulate hair growth (Bhusal & Thakur, 2021). Through the process of transesterification, using curry leaf oil in the presence of a catalyst and alcohol, a renewable alternative fuel can be generated (Viswanathan et al., 2020).

Drying emerges as the most energy-intensive technique, accounting for around 20–30% of energy usage in agricultural and food processing. Consequently, there is an urgent requirement to explore diverse approaches to amplify the energy efficiency of the drying procedure, thereby decreasing energy consumption per unit of product moisture. The focal point should be on conceiving and producing innovative dryers that markedly curtail energy consumption. Given the prevailing energy limitations, multiple systems have been devised to trim both time and energy outlays.

Materials and Methods

The indirect type of solar dryer consist of evacuated tubes. Each tube is made up of two concentric borosilicate glass pipes, the vacuum between the two glass pipes minimises heat losses. The external tube is transparent, and the interior tube is coated with a (Al-N/Al) cover to increase the solar radiation absorption. The length, outer diameter of the external glass tube and diameter of the absorber tube is 1.8, 0.058, and 0.047 m respectively. The evacuated tubes are connected to the base of the drying chamber. The tube having surface area of 3.28 m^2 are closed from the bottom end and the upper end will open to the drying chamber as shown in figure 1.

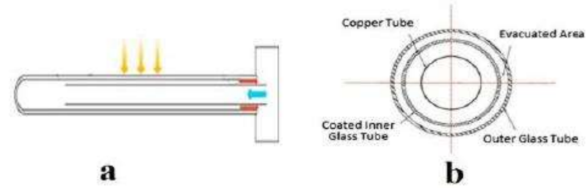

Figure 1: Cross section of the evacuated tube.

A blower having the motor of 0.5 HP is connected to an iron tube having the diameter of 0.075m and length of 1.8m with a flow control valve and the other end of the iron tube is closed. The iron tube is vertically connected with ten copper tubes. The copper tube has a diameter and length of 0.02 and 1.5 m, respectively. All the copper tubes are inserted inside the glass evacuated tubes. A blower is used to feed the evacuated tubes with air via the copper tubes. The inlet air flow was controlled by using a flow control valve connected between the air blower and glass evacuated tubes.

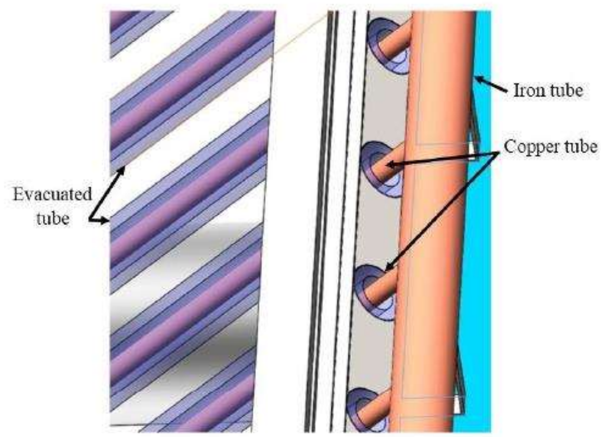

Figure 2: Connection of iron tube, copper tube and evacuated tube

The drying chamber have two perforated trays made of stainless steel, the bottom one for the thermal energy storage material for storing the heat in the day time and other one for the produce to be dried in the chamber. The dimension of the tray is 1500X900 mm^2. The inside wall of the drying chamber is made of stainless steel 304grade. The glass wool of 50mm thickness is applied on the SS304 sheet to insulate the chamber and aluminium foil is used to cover the glass wool insulation. A door is also provided for the loading and unloading of the trays. For discharging the air from the chamber, a chimney is provided. By using a blower and flow control valve, ambient air is feed to the evacuated tubes with the help of the iron tube and the copper tubes. Figure 4 represents the process of heating of ambient air in the evacuated tubes for the food dryer. In this process, the air flowed through the iron tube. This air flows through circular copper tubes inbuilt with an iron tube into the bottom of the evacuated tubes. Then, the air flows back over the circular copper tubes to the bottom of drying chamber. Therefore, the air gains heat while it is flowing inside the collector due to the solar radiation. The heated air due to the light weight comes with the contact with heat storage material on bottom tray to store the heat and then come with the contact of food products to be dried on upper tray. As the air heated, its moisture carrying capacity increases by reducing its relative humidity, resulting the air absorbs the moisture from the food products and escape to the surrounding from the chimney. At off sun shine hours, the stored heat in the heat storage material is used to heat the air for few hours.

Fresh samples of curry leaves were procured from the herbal garden of SKIT, Jaipur in the morning hours on the day of conducting the experiment. The undesirable, damaged and contaminated parts were removed manually. A sample of curry leaves were dried at different mass flow rate 0.01, 0.02 and 0.03 kg/s of air and drying time and quality of leaves were compared with the open sun drying.

Results and Discussion

Moisture Content

Drying at different mass flow rates significantly affected the moisture content. Higher mass flow rates resulted in taking more time to dry as compared with lower mass flow rates. Lower moisture content is desirable for preventing spoilage and preserving the leaves for an extended period.

The moisture content was reduced from approximately 75% in fresh leaves to 8% after drying in 16% shorter time at mass flow rate of 0.01 kg/s as compared to mass flow rate of 0.02 kg and 28% shorter as compared to mass flow rate of 0.03 kg/s. As compared to open sun drying, it was 33%.

Color

The retention of green color in dried curry leaves is crucial for aesthetic appeal and flavor preservation. Mass flow rates of 0.02 kg/s and 0.03 kg/s outperformed the 0.01 kg/s rate in maintaining the green color. The slower drying rate (0.01 kg/s) resulted in slightly browned leaves, indicating a possible longer exposure to drying conditions.

Flavor:

Flavor and aroma are key attributes of curry leaves in culinary applications. Drying at mass flow rates of 0.02 kg/s and 0.03 kg/s preserved the flavor and aroma effectively, making them more suitable for culinary use.

Upper Tray Lower Tray Open Sun

Figure 3: Drying of Curry leaves at mass flow rate of 0.01 kg/s

Upper Tray Lower Tray Open Sun

Figure 4: Drying of Curry leaves at mass flow rate of 0.02 kg/s

Upper Tray Lower Tray Open Sun

Figure 5: Drying of Curry leaves at mass flow rate of 0.03 kg/s

CONCLUSION

The drying of aromatic and medicinal plants, particularly curry leaves, is a critical step in preserving their valuable attributes for culinary, medicinal, and therapeutic applications. India's reputation as a leading producer of medicinal herbs underscores the importance of optimizing drying methods to maintain product quality and maximize economic returns.

Various drying techniques have been explored ranging from conventional methods like sun drying to innovative approaches such as fluidized bed drying and heat pump drying. Each method has its advantages and disadvantages, and the choice of drying technique should consider factors like moisture content, drying time, color retention, nutrient preservation, and sensory attributes.

The research highlighted that different drying methods yield varying results in terms of quality and nutritional content. For instance, microwave drying proved effective in preserving nutrients, while solar tunnel drying and mechanical drying exhibited favorable outcomes for maintaining the color and nutritional content of curry leaves.

Drying curry leaves at different mass flow rates had a significant impact on their quality. Mass flow rates of 0.02 kg/s and 0.03 kg/s outperformed 0.01 kg/s in terms of moisture removal, color retention, and flavor preservation. These findings emphasize the importance of selecting an appropriate drying rate to achieve the desired quality of dried curry leaves for culinary use.

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