STM JOURNALS

International Journal of
Electrical Power and Machine Systems

Volume 3, Issue 1, 2025
January—June
DOI (Journal): 10.37591/IJEPMS

https://journals.stmjournals.com/ijepms

Review IJEPMS

# Optimization of Solar Drying Parameters for Turmeric and Papaya Leaves: Effects on Nutritional and Bioactive Compound Retention

Narendra Dnyanoba Dudhmal[1,*], Prashant Laximan Pandit[2], Nilesh Diwakar[3]

**Abstract**

*This study focuses on the optimization of solar drying parameters for turmeric and papaya leaves, based on their impact on retention of nutritional and bioactive compounds. One of the most crucial postharvest procedures is solar drying as it decreases the moisture content in plant materials, thereby increasing shelf life and preserving quality. This study considers traditional methods as open sun drying (OSD) and advanced solar dry techniques, including Hybrid Indirect Passive (HIP) and other innovative dryers. It stresses the role of drying conditions in retaining bioactive compounds like curcumin and flavonoids, which are very important for food and pharmaceutical applications. The study compares solar drying with conventional methods, emphasizing energy efficiency, environmental impact, and preservation of nutritional properties. The aim of the study is recommending sustainable and efficient drying technologies that can be applied in industrial practices.*

**Keywords:** Solar drying, turmeric, papaya leaves, bioactive compounds, nutritional retention, drying optimization

## INTRODUCTION

Drying, a crucial postharvest procedure that dehydrates plants by lowering their moisture content, aims to preserve these products and increase their shelf life by preventing microbial growth and enzymatic breakdown in addition to preserving the physicochemical qualities by preventing the oxidation of the chemical of the plants. Because it makes handling, transportation, and storage easier, drying is among the most popular processing methods for preserving the quality of food products [1]. It has been demonstrated that this method extends shelf life by reducing moisture content (MC) to a level where activity of the microbes is low. Fresh produce is traditionally dried in tropical climates using the open sun method, which can save a lot of money because it uses a free and renewable energy source. The quality of the finished product is decreased by this drying method's problems with contamination, infestation, microbial attacks, and other factors, as well as its extreme dependence on the weather [2]. India supplies more than 80% of the turmeric sold abroad. One of the countries that exports turmeric is Thailand, which will offer 2.8 million USD worth of turmeric products to the global market. Germany, Iran, Bangladesh, the United Kingdom, and the United States are the top importers of turmeric products. Turmeric is used as a spice, food supplement, dye, colouring agent (E100), and traditional medicine because of its

***Author for Correspondence**
Narendra Dnyanoba Dudhmal
E-mail: 1nddudhmal@gmail.com

[1]Assistant Professor, Department of Mechanical Engineering, Dr Sarvapalli, Radhakrishnan University, Bhopa, Madhya Pradesh, India
[2]Assistant Professor, Department of Mechanical Engineering, Dr Sarvapalli, Radhakrishnan University, Bhopal, Madhya Pradesh, India
[3]Professor, Department of Mechanical Engineering, Dr Sarvapalli, Radhakrishnan University, Bhopal, Madhya Pradesh, India

Received Date: March 05, 2025
Accepted Date: March 27, 2025
Published Date: April 08, 2025

**Citation:** Narendra Dnyanoba Dudhmal, Prashant Laximan Pandit, Nilesh Diwakar. Optimization of Solar Drying Parameters for Turmeric and Papaya Leaves: Effects on Nutritional and Bioactive Compound Retention. International Journal of Electrical Power and Machine Systems. 2025; 3(1): 29–37p.

characteristic orange-yellow colour, flavour, and pharmacological qualities. It has anti-inflammatory, anti-cancer, antioxidant, and antibacterial qualities, among other bioactivities. As people are getting more conscious towards their health the market of turmeric is touching hights. By combining its pharmaceutical and culinary uses, turmeric improves wellbeing and lowers risk factors for disease [3].

Air serves as the drying medium in convective drying techniques like solar drying, hot air, and ambient air, which remove water vapour from the dryer and evaporate water from a product at the same time. However, the evacuation of water is sometimes a slow process. Micronutrients and bioactive components in vegetables and dried fruits are significantly lost as a result of the long drying time and high temperature throughout the process of convective drying. The loss of these nutrients are typically far more than variations in the quality end of items dried with various drying techniques and processing parameters [4]. The most common method of food preservation is drying, which includes removing moisture from food items to increase their shelf life and assist stop enzymatic and microbiological deterioration. Due to their straightforward and affordable applications, sun and shade drying are the most widely used conventional drying processes globally.

The low drying efficiency, vulnerability to contamination, and reliance on weather conditions that have a substantial impact on the process are the drawbacks of the solar drying method. The most popular of these techniques, hot air convective drying, has a high drying temperature and a lengthy drying period that can seriously degrade product quality, changing its colour, flavour, surface properties, and nutritional value [5].

A drying chamber, air heater, and airflow system make up a conventional solar dryer, which is categorized based on the drying chamber type, air movement, and heat transfer method. Solar dryers are classified into two primary groups based on these categories: passive dryers, which use natural air circulation, and active dryers, which use forced air circulation. Both types of dryers can also use a combination of passive and active drying, known as mixed mode drying. In an indirect drying process, active dryers use a solar radiation collector to heat the surrounding air before transferring it to the drying chamber, whereas passive dryers transfer heat immediately. A collector warms the air before it enters the drying chamber in mixed mode dryers, and the items inside the drying chamber are also heated by the sun. In underdeveloped nations, solar drying offers food drying techniques that are inexpensive, operational, and energy efficient. To enhance the drying process, hybrid and/or forced convection solar dryers have become more and more popular [6].

The Figure 1 illustrates the classification of solar dryers, which are systems designed to dry materials using solar energy. Solar dryers are broadly divided into two categories: passive dryers and active dryers. Passive dryers rely solely on natural air circulation and sunlight, whereas active dryers use external energy sources, such as fans, to enhance the drying process. Within passive dryers, there are direct dryers, where materials are directly exposed to sunlight, and mixed-mode dryers, which combine direct and indirect heating methods, such as cabinet dryers. Active dryers, on the other hand, include indirect dryers, where the product is heated without direct exposure to sunlight, and tunnel dryers, which are more advanced systems designed for larger scale drying with forced airflow. One benefit of this approach is that it saves money and energy. However, because it relies on natural electricity, it is extremely susceptible to unpredictable weather variations. With at least 6 h of sunlight and 500–800 W/m² of radiation per hour, the sun-drying method is typically employed in tropical regions, resulting in isolation of 185 W/m² each day [7].

## TYPES OF DRY OPTIMIZATION PROCESS

### Drying Process Optimization

Foods containing functional or bioactive components, particularly those that are natural are in high demand since contemporary consumers are concerned about their health and wish to enhance their general wellbeing and nutritional value. Specifically, because of their many uses, there is an increasing need for healthful and nourishing oils in the food, pharmaceutical, and cosmetic sectors [8].

 

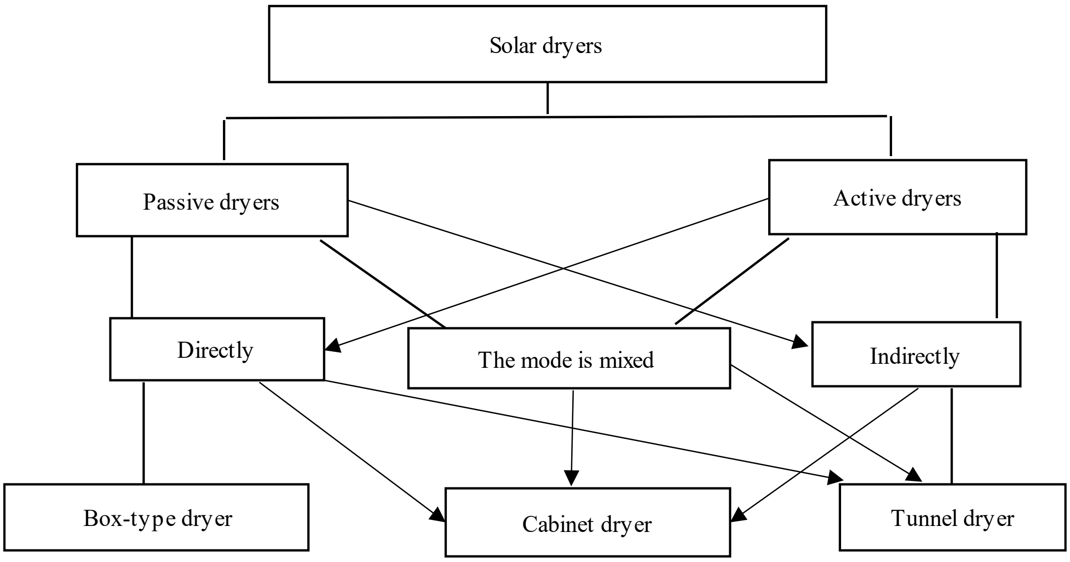


**Figure 1.** Solar dryer types.

Vegetable products can be dehydrated using numerous drying techniques that have been created over time. This section reviews and describes the most pertinent drying methods, including osmotic dehydration (OD), convective drying (CD), spray drying (SD), and freeze-drying (FD). These widely used techniques do have certain disadvantages, though, and much research has been done to reduce these factors as well as the overall energy usage. Energy-saving dryers that use heat pumps, combining current technologies to maximize the cost and quality of dried products, and any technique that improves control over process conditions and food quality are examples of drying technologies that the food industry may embrace [9].

**Heat Pump Drying (HP)**

The use of HP dryers is appropriate for high-value items, and research has shown that they can create regulated transient drying conditions with respect to temperature, humidity, and air velocity, which can enhance product quality and lower drying expenses. The performance of HP dryers and other dryers has been compared by several studies. Compared to traditional dryers running at the same temperature, HP dryers use 60–80% less energy. Compared to traditional hot air dryers, HP dryers used less energy and produced higher-quality onion slices [10]. As shown in Figure 2, the evaporator, condenser, compressor, and expansion valve are the same fundamental parts of a heat pump drying system. Depending on the drying conditions and surrounding temperature, the air passing through the exterior and inner condensers is either heated or cooled. There was more superheat as the drying temperature rose because it was harder for the condenser to discharge heat into the air and easier for the evaporator to absorb heat [11].

**Explosion Puffing Drying (EPD)**

About snack foods, EPD is a new method with numerous benefits. The most significant aspect is that it provides a crispy and porous structure. Other benefits of EPD include better snack food texture and rehydration capabilities, as well as the retention of colour and flavour. High pressure (0.1–0.4 MPa) and high temperature (about 80–100°C) are applied in the EPD system to increase the product's texture. To achieve a dry product with a porous structure, a sharp decrease in the pressure (vacuum) supplied after this procedure causes rapid water evaporation and product cooling [12].

**Low-Pressure Superheated Steam Drying (LPSSD)**

Low-pressure superheated steam drying (LPSSD) has been suggested as a substitute for dry goods like potatoes, peppers, and so forth because of its oxygen-free drying medium, low temperature, and high-water evaporation rate.

 

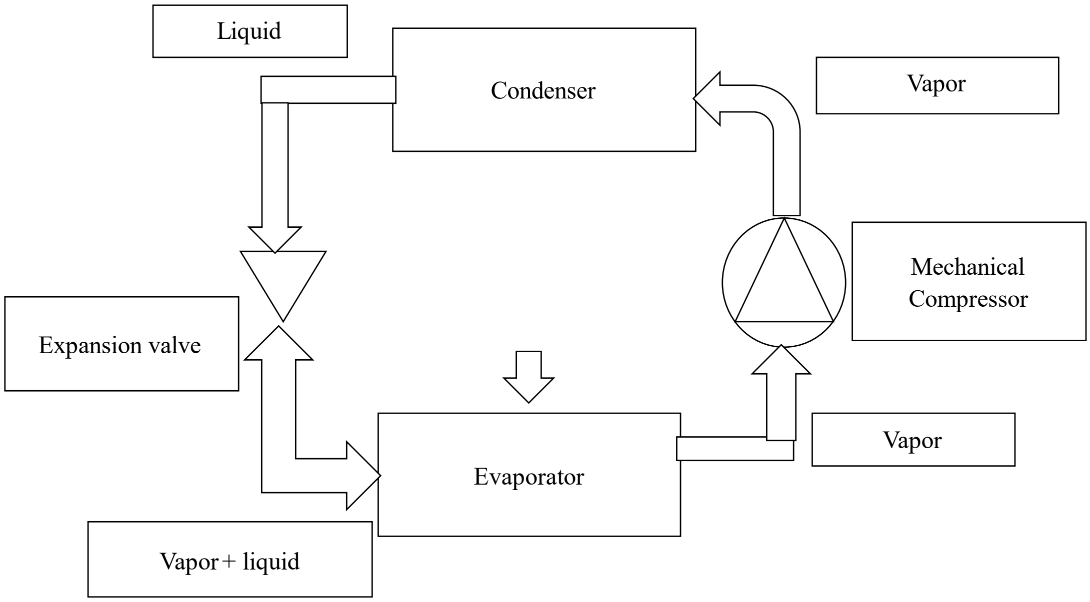


**Figure 2.** Schematic presentation of the heat pump.

When the food surface temperature reaches the steam saturation temperature, either normal or high pressure in the drying medium will cause melting, glass transition, or damage. As a result, thermosensitive materials that are dried using LPSSD are of higher quality than those that are dried using traditional methods. Low pressure lowers the saturation temperature of steam and causes water to evaporate at a lower temperature. This lowers the mass transfer resistance of water from food to a drying media while simultaneously preserving the quality of dried food. Some applications have led to the preliminary establishment and optimization of mathematical models of LPSSD [13].

## NUTRITIONAL AND BIOACTIVE COMPOUND RETENTION

Drying is a crucial procedure that can be used to stabilize or modify plant extracts into finished goods in addition to lowering their moisture content (Figure 3). The biological activity, shelf-life, and safety of final dried products are significantly impacted by the different features of drying processes, such as the physicochemical, organoleptic, and bioactive compound content. The market for plant-based bioactive chemicals and supplements is constantly growing, and it requires high-quality raw materials and finished goods. To preserve the quality of dried products and safeguard the bioactive components found in each plant matrix, it is imperative to select the ideal drying conditions. Additionally, the drying process accounts for 50% or even 90% of the entire processing expenses, which has a substantial economic impact on the costs associated with producing plant-based products. As a result, drying techniques ought to be both efficient and effective [14].

### Flavonoids

Flavonoids are phenolic compounds with a C6-C3-C6 skeleton that interact synergistically with carotenoids and chlorophylls, contributing to the colour and aroma of fruits and vegetables. They are classified such as flavones, flavanols, flavan-3-ols, flavanones, flavonoids, and anthocyanidins [14]. Flavonoids are found in foods like wine, tea, honey, nuts, and berries, as well as herbs like parsley and celery, and exhibit biological activities such as antioxidant, anti-inflammatory, antiviral, and anticancer effects. Despite their benefits, challenges such as low water solubility, chemical stability, and bioactivity variability (affected by factors like age, genotype, and food matrix) limit their application. Flavonoid glycosides are more water-soluble than aglycones, which are soluble in methanol and ethanol. Stabilization techniques like encapsulation and adsorption are being explored to enhance their solubility and stability, offering potential for developing new pharmaceutical drugs or high-value food industry ingredients [15].

 

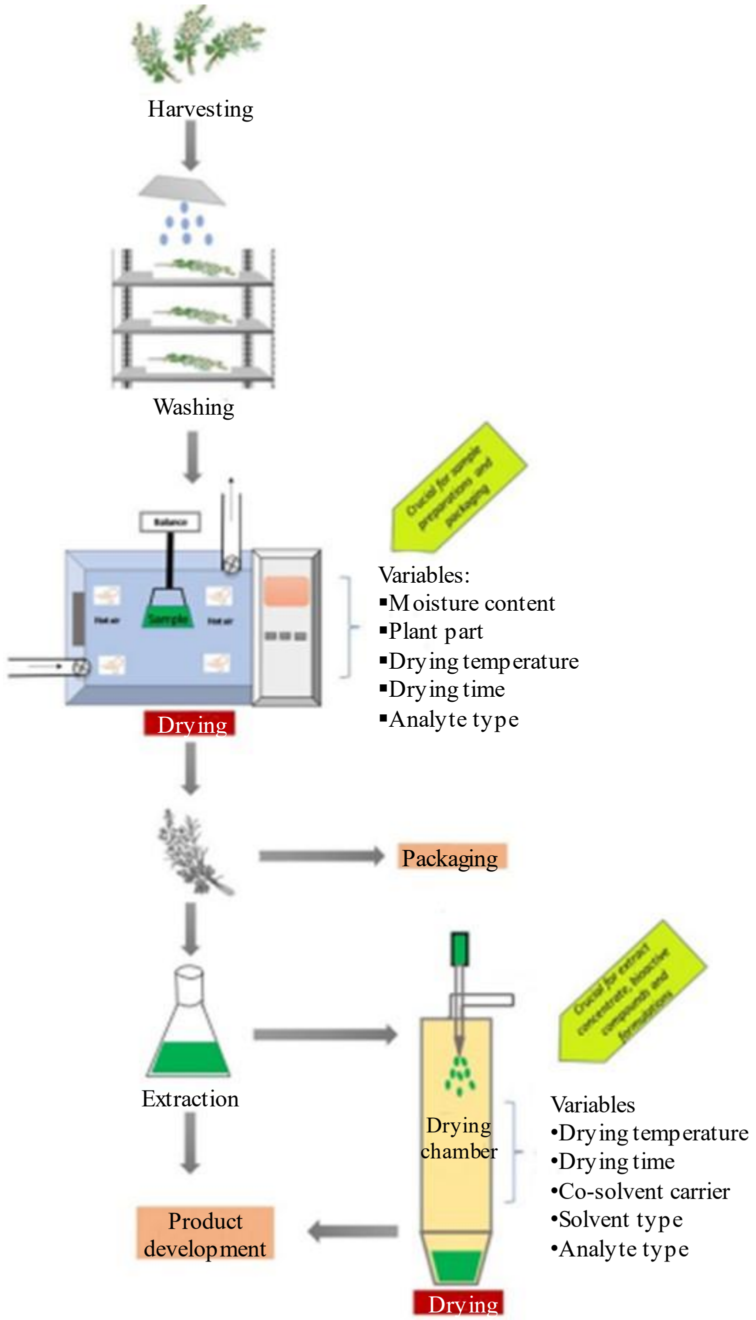


**Figure 3.** The use and significance of drying technology in the production of natural products derived from plants

**Curcumin**

Turmeric, the rhizome of *Curcuma longa* from the ginger family, is widely used in Indian cuisine for its golden colour and flavour, attributed to its oleoresins and essential oil. Its bioactive compounds, primarily curcuminoids like curcumin, are responsible for its yellow colour and exhibit notable biological activities [16]. Curcumin, a low molecular weight polyphenol, is highly valued in the food and pharmaceutical industries for its antimicrobial, anti-inflammatory, and anticancer properties. Studies highlight its effectiveness in reducing microbial growth in food, such as meat, fruits, and sausages, and its antifungal activity against pathogens like *Botrytis cinerea*. For instance, photodynamic inactivation using curcumin has been shown to significantly reduce harmful bacteria in various food samples, while coatings derived from turmeric residues can suppress microbial growth over extended storage periods. However, curcumin's lipophilic nature limits its bioavailability and absorption in the human body, restricting its practical applications. Encapsulation and adsorption techniques are being explored to overcome these limitations and expand its industrial applications. These advancements aim to enhance the solubility, stability, and usability of curcumin in diverse fields [17].

## COMPARATIVE ANALYSIS

The comparative analysis points out the advantages of solar drying techniques over the traditional ones (Table 1). For example, HIP dryers cut down the time to dry the product to almost half of the time taken in Open Sun Drying (18 h as compared to 30 h) and increase efficiency by 18%. Moreover, new solar drying technologies retain more nutrients, bioactive compounds, and sensory characteristics since the conditions are controlled. In contrast, the traditional method often results in uneven drying and degradation of quality. The environmental impact is also lower, such as carbon emissions and energy usage, compared to fired drying methods. These results point out the potential of solar drying as a sustainable and efficient alternative for preserving turmeric, papaya leaves, and other bioactive-rich materials [18].

### Microbial and Shelf-Life Analysis

Since microbial cell viability is more robust when dry, dry heat is less effective than moist heat in microbial inactivation. In actuality, the microorganism's structure undergoes a number of changes throughout the drying process. Due to the fact that microbial cell viability is more robust when dry, dry heat is less effective than moist heat in microbial inactivation. The drying process substantially stops or slows the growth of microbes in food. However, because dry goods are hygroscopic and have varying moisture contents, the humidity in the storage air is essential. A favourable moisture environment is produced, specifically for the growth of mould, when the equilibrium between relative humidity and moisture content is upset. Health issues may arise because there may be sufficient bacteria and spore cells to cause the disease after drying, and they may even continue to exist for months [19]. Because SC-$CO_2$ has a lower $CO_2$ pressure (between 10 and 20 MPa) than HPP pressure (between 50 and 1000 MPa), it has been found to extend the shelf life of food products. Increased diffusivity, a faster mass transfer rate, less nutrient degradation, increased yield, and a shorter processing time all contribute to the preservation of key ingredients in food. The physicochemical properties are directly impacted using SC fluids. Liquids and gases undergo physicochemical changes beyond the supercritical state, such as low viscosity, high density, surface tension, and intermediate diffusivity. The pressure-dependent solvent that provides the SC fluid with great selectivity and solubility is linked to the high-density range.

**Table 1.** Comparison of solar drying vs. Traditional methods.

| Reference no. | Aspect | Solar drying methods | Traditional methods |
|---|---|---|---|
| 16 | Postharvest Loss Reduction | HIP and SPE dryers significantly reduce drying time (HIP: 18 h, SPE: 10 h) and increase efficiency (HIP: 18% higher). | Open Sun Drying (OSD) has longer drying times (30 h) and lower efficiency, leading to higher losses. |
| 9 | Product Quality Preservation | Novel solar techniques preserve more nutrients, colour, and phytochemicals due to controlled drying conditions. | Traditional methods often degrade quality due to uneven drying, overexposure, and contamination. |
| 17 | Environmental Impact | Solar-dried bricks significantly reduce $CO_2$ emissions. | Fired bricks consume more energy and emit higher $CO_2$, causing greater environmental harm. |
| 18 | Nutrient Retention in Seaweeds | HHGD retains nutrients and antioxidant activity similar to freeze-drying but at lower cost and higher capacity. | Freeze-drying ensures high quality but is costly and unsuitable for large-scale operations. |
| 19 | Drying Technology Versatility | Solar dryers (e.g., ITSD) are adaptable with different configurations, incorporating pre-treatments to improve outcomes. | Traditional methods lack customization and scalability, often producing inconsistent results. |

 

Furthermore, these fluids' low viscosity and intermediate diffusivity, along with the lack of surface tension, allow for rapid cell penetration and extraction [20].

## APPLICATIONS AND USES

The *Carica papaya*, sometimes called the papaya or papaw, is a well-known tropical and subtropical tree as all its parts are used. This tropical species grows steadily throughout the winter, but its growth slows, and its fruit production ceases during the cooler months. The fruit is used as a snack, appetizer, and nutritional supplement in cuisine, while the leaves are used as herbal medication for antimicrobials, antioxidants, antiviral, treating haematological disorders, and for anticancer purposes. Papaya seeds have been investigated for their potential to prevent diabetes; however, this effect is slight. In non-food and non-medical applications, papaya leaves are also utilized as larvicides, ectoparasite controls, bioherbicides, and to manage the onion pest *Spodoptera exigua*. Because the fruit is high in antioxidants, B vitamins, fibre, K, magnesium, folic acid, and pantothenic acid, it can be used as a nutritional supplement to detoxify, increase metabolism, and rejuvenate the body while preserving homeostasis. Specifically, B vitamins are co-enzymes in a wide range of enzymatic metabolic events. The creation of several neurotransmitters and signalling chemicals, energy production, DNA/RNA synthesis and repair, genomic and non-genomic methylation, and other aspects of brain function are expected to be affected by their combined impacts. Linalool and benzaldehyde were shown to be the most prevalent flavour-active chemicals in papaya when used as an appetizer [21].

Because of its unique yellow colour, flavour, and antioxidant properties, turmeric has been used for a very long time as a spice and food ingredient to improve the palatability and shelf life of goods. The assessment of the organoleptic characteristics of the turmeric rhizomes showed that they are yellowish in colour, have a slightly bitter taste, and an aromatic odour [22]. Depending on the food category, curcumin is typically given at a dose of 5–500 mg/kg for nutritional purposes. It is primarily utilized in meat, fish, eggs, and bread goods, as well as dairy products, cereals, mustard, food concentrates, pickles, sausages, confections, and ice cream. It is also added to butter, mayonnaise sauces, and seasonal sauces when combined with annatto. Despite being referred to as "Indian saffron" in Europe, curcumin is a suitable and affordable substitute for saffron, but it cannot replace the flavour of saffron. Curcumin is stable as an addition in dry foods and when heated. While it may form salts with phthalates and citrates, it is comparatively inert to reactions with other components and inert to reactions with bicarbonates, phosphates, and chlorides [23]. There are various forms of turmeric, such as dry powders, liquid extracts, and capsules. The form and dose of turmeric might vary based on the individual's health and the intended application. An adult's daily intake of turmeric root might range from 1.5 to 3 g. As an alternative, 1–3 g of dried powdered turmeric root should be taken daily. It is recommended to take 400–600 mg doses of standard powder curcumin three times a day. Twice a day, 30 to 90 drops of a liquid turmeric extract (1:1) (1 part is 5 ml) should be taken in the morning and evening [24].

## CONCLUSION

The improved systems, such as the Hybrid Indirect Passive (HIP) solar dryer, offer significant advantages over traditional drying methods. They reduce drying time, enhance nutrient and bioactive compound retention, and improve product quality while addressing environmental concerns. The findings support the adoption of optimized solar drying methods for preserving turmeric and papaya leaves, ensuring economic and operational efficiency. Further studies into the stabilization methods like encapsulation improve bioavailability and industrial use of dried bioactive compounds. In conclusion, the utilization of advanced solar drying technologies throughout industries in place of the traditional methods for food as well as pharmaceutical is necessary for the conservation of sustainable environment.

## REFERENCES

1. ElGamal R, Song C, Rayan AM, Liu C, Al-Rejaie S, ElMasry G. Thermal degradation of bioactive compounds during drying process of horticultural and agronomic products: A comprehensive overview. Agronomy. 2023 Jun 11; 13(6): 1580.

2. Boateng ID. A review of solar and solar-assisted drying of fresh produce: state of the art, drying kinetics, and product qualities. J Sci Food Agric. 2023 Oct; 103(13): 6137–49.
3. Komonsing N, Mahayothee B. Influence of drying conditions on degradation of curcuminoids and bioactive compounds in turmeric (Curcuma longa L.) Doctoral dissertation. Bangkok: Silpakorn University; 2021.
4. Onwude DI, Iranshahi K, Rubinetti D, Schudel S, Schemminger J, Martynenko A, Defraeye T. How much do process parameters affect the residual quality attributes of dried fruits and vegetables for convective drying? Food Bioprod Process. 2022 Jan 1; 131: 176–90.
5. Ozcelik MM, Aydin S, Aydin E, Ozkan G. Preserving nutrient content in red cabbage juice powder via foam-mat hybrid microwave drying: application in fortified functional pancakes. Food Sci Nutr. 2024 Feb; 12(2): 1340–55.
6. Skåra T, Løvdal T, Skipnes D, Nwabisa Mehlomakulu N, Mapengo CR, Otema Baah R, Emmambux MN. Drying of vegetable and root crops by solar, infrared, microwave, and radio frequency as energy efficient methods: a review. Food Rev Int. 2023 Oct 3; 39(9): 7197–217.
7. Citra F, Aulia G, Indiarto R, Asyifaa AF, Achmad S. Conventional and Advanced Food-Drying Technology: A Current Review Article. Int J Sci Technol Res. 2021; 10(1): 99–107.
8. Mohammed NK, Tan CP, Manap YA, Muhialdin BJ, Hussin AS. Spray drying for the encapsulation of oils—A review. Molecules. 2020 Aug 26; 25(17): 3873.
9. Calín-Sánchez Á, Lipan L, Cano-Lamadrid M, Kharaghani A, Masztalerz K, Carbonell-Barrachina ÁA, Figiel A. Comparison of traditional and novel drying techniques and its effect on quality of fruits, vegetables and aromatic herbs. Foods. 2020 Sep 9; 9(9): 1261.
10. Salehi F. Recent applications of heat pump dryer for drying of fruit crops: A review. Int J Fruit Sci. 2021 Jan 1; 21(1): 546–55.
11. Deymi-Dashtebayaz M, Mostafa A, Asadi M, Hosseinzadeh D, Khutornaya J, Sergienko O. Recent developments in heat pump dryers focusing on methods of supplying and reducing their energy consumption. J Therm Anal Calorim. 2024 Sep; 149(17): 9751–75.
12. Köprüalan Ö, Elmas F, Bodruk A, Arıkaya Ş, Koc M, Koca N, Kaymak-Ertekin F. Impact of pre-drying on the textural, chemical, color, and sensory properties of explosive puffing dried white cheese snacks. LWT. 2022 Jan 15; 154: 112665.
13. Yao Y, Lu Z, Gong Y, Guo S, Xiao C, Hu W. Drying Characteristics of a Combined Drying System of Low-Pressure Superheated Steam and Heat Pump. Processes. 2022 Jul 19; 10(7): 1402.
14. Belwal T, Cravotto C, Prieto MA, Venskutonis PR, Daglia M, Devkota HP, Baldi A, Ezzat SM, Gómez-Gómez L, Salama MM, Campone L. Effects of different drying techniques on the quality and bioactive compounds of plant-based products: A critical review on current trends. Dry Technol. 2022 Jun 15; 40(8): 1539–61.
15. Koop BL, da Silva MN, da Silva FD, dos Santos Lima KT, Soares LS, de Andrade CJ, Valencia GA, Monteiro AR. Flavonoids, anthocyanins, betalains, curcumin, and carotenoids: Sources, classification and enhanced stabilization by encapsulation and adsorption. Food Res Int. 2022 Mar 1; 153: 110929.
16. Ssemwanga M, Makule E, Kayondo SI. Performance analysis of an improved solar dryer integrated with multiple metallic solar concentrators for drying fruits. Sol Energy. 2020 Jul 1; 204: 419–28.
17. Dabaieh M, Heinonen J, El-Mahdy D, Hassan DM. A comparative study of life cycle carbon emissions and embodied energy between sun-dried bricks and fired clay bricks. J Clean Prod. 2020 Dec 1; 275: 122998.
18. Nagahawatta DP, Asanka Sanjeewa KK, Jayawardena TU, Kim HS, Yang HW, Jiang Y, Je JG, Lee TK, Jeon YJ. Drying seaweeds using hybrid hot water Goodle dryer (HHGD): Comparison with freeze-dryer in chemical composition and antioxidant activity. Fish Aquat Sci. 2021; 24(1): 19–31.
19. Lingayat AB, Chandramohan VP, Raju VR, Meda V. A review on indirect type solar dryers for agricultural crops–Dryer setup, its performance, energy storage and important highlights. Appl Energy. 2020 Jan 15; 258: 114005.
20. Alp D, Bulantekin Ö. The microbiological quality of various foods dried by applying different drying methods: a review. Eur Food Res Technol. 2021 Jun; 247(6): 1333–43.


 

21. Allai FM, Azad ZA, Mir NA, Gul K. Recent advances in non-thermal processing technologies for enhancing shelf life and improving food safety. Appl Food Res. 2023 Jun 1; 3(1): 100258.
22. Hariono M, Julianus J, Djunarko I, Hidayat I, Adelya L, Indayani F, Auw Z, Namba G, Hariyono P. The future of Carica papaya leaf extract as an herbal medicine product. Molecules. 2021 Nov 17; 26(22): 6922.
23. Sharifi-Rad J, Rayess YE, Rizk AA, Sadaka C, Zgheib R, Zam W, Sestito S, Rapposelli S, Neffe-Skocińska K, Zielińska D. Turmeric and its major compound curcumin on health: bioactive effects and safety profiles for food, pharmaceutical, biotechnological and medicinal applications. Front Pharmacol. 2020 Sep 15; 11: 01021.
24. Kumar H, Dhalaria R, Guleria S, Sharma R, Cimler R, Dhanjal DS, Chopra C, Kumar V, Manickam S, Siddiqui SA, Kaur T. Advances in the concept of functional foods and feeds: applications of cinnamon and turmeric as functional enrichment ingredients. Crit Rev Food Sci Nutr. 2025 Feb 25; 65(6): 1144–62.

 