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Original Article

Modern Drying Techniques in Fruits and Vegetables to Reduce Postharvest Losses

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ABSTRACT

Fresh produce has a higher moisture content than frozen food, and if it is not stored properly, it will quickly decay. The cost of existing storage technologies like refrigeration and controlled environments is high because they require constant energy for system operation throughout the whole supply chain. Therefore, the adoption of drying processes is being promoted since it lowers post-harvest losses, enables ease of storage and transport, and ensures year-round product availability. Fruits and vegetables are slow to dry using traditional methods like sun or open air drying, and contamination can result in products of lower quality. Several cutting-edge drying techniques, including sun, microwave, vacuum, infrared, freeze, oven drying, and numerous hybrid drying technologies, have been created and are effectively employed for a variety of fruits and vegetables. The primary goal of this work is to analyse crop-specific operations and their effects on quality, efficacy, cost-effectiveness, and the capacity to retain nutrients.

INTRODUCTION

Fruits and vegetables are widely recognised for their high nutritional value, which includes key vitamins, minerals, and dietary fibres that are crucial for a balanced diet (Slavin & Lloyed, 2012). The suggested diet package lowers the likelihood of certain deficiencies and promotes healthy living. A variety of phytochemicals, such as phenolics, carotenoids, tocopherols, and flavonoids, which may be beneficial to human health singly or in combination, are also present in fruits and vegetables. The portion of these phytochemicals that is most readily accessible is phenolic compounds, which have an astounding 8,000 known forms (Luthria *et al.,* 2006). The main source of antioxidants in the human diet is phytochemicals, which are also crucial in fighting against the negative effects of stress and a number of chronic diseases like type II diabetes, dementia, and muscle degeneration. The prevention of many malignancies, cardiovascular, metabolic, and neurological disorders is another way that phenols support good health (Hughes *et al.,* 2010).

About 80% of the moisture in fresh fruits and vegetables. They are categorised as being very perishable and decay quickly (Sagar & Kumar, 2010). Poor pre- and post-harvest handling of the product as well as a lack of adequate infrastructure for marketing and processing all contribute to higher losses. Fruit and vegetable losses from the farm gate to the consumer level have been estimated to be between 30% and 50%. Unacceptably high levels of food insecurity are caused by losses worldwide (FAO, 2012). After harvest, post-storage measures are needed to keep the product fresh and preserve its nutritional content. Low temperatures are required by storage methods used all over the world to preserve goods (Sagar & Kumar, 2010); yet, their increased price and scarcity in many places are significant drawbacks. Hence, several drying procedures are viable choices to cut losses and preserve produce while maintaining quality. The current study discusses several drying methods and how drying affects the quality and preservation of specific fruits and vegetables.

MODERN DRYING TECHNIQUES

1. Solar drying

Renewable, affordable, and simple to use solar systems. For agricultural goods, a variety of sun dryers have been created with different designs, including chamber-based, rack/tray type, bin, and tunnel type (Fudholi et al., 2015). (Jayaraman *et al.,* 2000) reviewed some aspects of solar dehydration of FV and noted that a variety of fruits and vegetables, including potatoes, carrots, and French beans, are dried in small quantities using passive solar dryers, which are inexpensive, easily constructed, and have the ability to naturally heat air. To dry potatoes and compare their quality characteristics with a thin layer model dryer, a mixed mode solar tunnel dryer was recently designed. This dryer performs better in producing high-quality chips and is best suited for rural areas and small-scale companies (Eltawil *et al.,* 2018).

2. Microwave drying

Researchers have been motivated to create industry-based drying technologies as worries about product quality and product development expenses have grown. Using microwave technology, fruits and vegetables may be dried quickly, and electromagnetic radiations play a significant part in the heating of the product both within and outside. Microwave drying-related technologies are more beneficial independently or in combination (Li *et al.,* 2010) due to a quick drying duration, improved product quality, and having flexibility in drying of wide range of dried value-added goods. The disadvantage of conventional microwave drying is the uneven heating inside the goods. The usual usage of microwave-assisted procedures is much superior; in many circumstances, this is more advantageous for commodities with high sugar concentrations to increase quality (Zhang & Xu, 2003).

3. Vacuum drying

For very perishable goods, the vacuum drying method (VDT) is used to dehydrate the product (heat sensitive; Sagar & Kumar, 2010). It permits improved retention of product colour, flavour, and other contents like vitamins and volatile aromas while also having a higher rate of drying, lower temperature, better retention of rehydration capacity, and less energy consumption (Chen & Lamb, 2007). These characteristics contribute to an increase in the nutritional content and quality of the food. VDT can also be used to combat the oxidative issue since the system's lower pressure (vacuum) permits drying at low temperatures, which reduces the product's ultimate moisture content similarly to other drying methods. When used in conjunction with other drying techniques like microwave- and solar-assisted VDT, it works better (Rajkumar *et al.,* 2007).

4. Freeze-drying

A good method to dry a variety of fruits and vegetables is freeze-drying (FD). FD uses the sublimation of frozen goods, which stops all chemical and microbial reactions because of the low temperature, to produce high-quality products (Ratti, 2001).

5. **Infrared drying**

Infrared radiation drying of perishable goods has gained prominence as the best alternative drying method for a variety of agricultural items. The fundamental idea of an infrared drier is that radiations are utilised to heat and dry materials that contain moisture. The radiations enter exposed material and increase internal temperature. Compared to conventional dryers, it gives agricultural goods a major advantage. It may be regarded as having a high energy efficiency (lower energy consumption), a short drying time, consistent product temperatures, and good end product quality (Kocabiyik & Tezer, 2009).

6. **Oven drying**

Oven drying was a popular drying technique in the previous ten years due to its low cost, although it was inefficient in terms of energy usage. Oven drying is beneficial when combined with other drying methods, although research has shown that fluidized bed dryers and oven dryers perform better in terms of carotenoid and rehydration properties than solar dryers do in terms of internal qualities, such as carotenoid reduction during drying (Prakash *et al.,* 2004).

7. Hybrid drying

Feng *et al.,* (1999) examined drying methods that were created by combining two or more drying systems and reported on the advantages of both single-stage and multistage drying. Hybrid drying systems, which combine several drying methods, led to an improvement in the product's quality. The goal of developing a hybrid drying system was to improve product quality while lowering the likelihood of product deterioration. Similar to that, this system uses less energy, runs more quickly, is affordable, and is simple to use (Onwude *et al.,* 2017). Several combinations, including adding a microwave to a fluidized bed technique of drying to increase drying uniformity, were investigated. According to Onwude et al. (2017), convective hot-air drying with nonthermal source combinations is an equally effective instrument for processing (drying) as convective hot-air drying with pulse electric field assistance. A different type of hybrid solar dryer (HSD) described by Bhattacharya *et al.,* (2000) was useful for all end stockholders (growers and industrialists); it used a conventional solar dryer that was powered by the combustion of biomass and used during the day, cloudy weeks, and cool nights.

CONCLUSION AND FUTURE PERSPECTIVES

Because to their strong demand in the market and good nutritional content, dried FV products are now widely used. Commercially, a variety of drying techniques are used for fruits and vegetables; these techniques may all be grouped into several groups. Several of the innovative drying methods that have been developed globally, including solar drying, microwave drying, vacuum drying, infrared drying, and oven drying as well as hybrid drying, have been proven to be more effective in terms of time and energy utilisation than conventional drying methods (sun and open air). The food industry is where the aforementioned technologies are mostly applied and implemented. Industrialists, researchers, and other shareholders have recently focused on the creation of hybrid dryers because they improve both quality and cost-effectiveness. These cutting-edge methods, such as solar and microwave technologies (either basic or aided), are becoming more and more well-liked every day. Future crop-specific drying technologies must take into account a number of important criteria, including product quality, drying time reduction, energy efficiency, and overall cost effectiveness.

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