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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 2693-2696

www.thepharmajournal.com
Received: 15-06-2023
Accepted: 21-07-2023

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Advancements in microwave drying on quality improvement in spices: A review

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Abstract
Spices have a vital role in daily food consumption in many countries and around the world. Recently, spices have received increased attention as flavorings, preservatives and medicinal agents. The most popular technique to bring down moisture content and consequently, water activity to a secure level that expands longevity is dehydration. Therefore, drying must be done attentively in order to maintain the maximum amount of the plant's flavor, aroma, color, appearance, and nutritional content. However, the methods used in processing have a direct impact on the quality of spices. As a result, careful consideration should go into choosing processing methods to produce high-quality spices. This article examines current developments in important processing processes for spices, including innovative microwave drying techniques.

Keywords: Microwave drying, quality, spices, processing

Introduction

India is referred to as "The Land of Spices" around the world. India is the world's biggest producer, buyer, and exporter of spices, hence spice crops are a vital part of the agricultural systems of South Asian nations. The taste, aroma, and color of food can all be improved or changed with the use of spices. They are small-volume, highly profitable commodities that farmers typically raise as a crop for profit. They are a wonderful source of volatile oils, aromatic components, pharmaceutical and aesthetic also have significant demand (Surajit Mitra, 2021) [17]. Over 80 different types of spices are grown throughout the world, with 50 of them being grown in India and having various biological names. Herbs and spices are beneficial for our health as well as our taste buds. Depending on the harvest, location, wet or dry conditions, their historical background, etc., spice's qualities, such as color and constitution, might change. Spices can contribute to the economy both through export and import. Spices are the dried aromatic components of natural plants. The leaves, barks, buds, fruits, and other spice plant components are used as spices. The different separation and milling techniques used can also affect the quality of processed spices. For these reasons, it has been determined that it is necessary to set quality criteria and standards for spices (Balasubramanian, 2015) [2]. Currently, there is a greater demand from consumers for processed goods that retain the majority of the natural qualities of fresh plants. More attention should be paid to the essential processing procedures of spices in order to produce superior quality of spices while retaining their distinctive characteristics.

Drying to improve quality of spices

Drying is an important stage in preserving spices. The substantial moisture content increases the cost of shipping raw food ingredients and hinders preservation (microbial degradation). Traditional drying methods result in quality degradation and the loss of volatile compounds, which alters the flavor and nutritional value of spices and herbs (EG de Mejia, 2015) [5]. Spices can be dehydrated using a variety of processes, including microwave and combined microwave drying, infrared and combined infrared drying, and combined solar drying, all of which have significant advantages over conventional drying techniques, which include greater drying potency, low cost, and enhanced quality retention for better color, appearance, aroma, and nourishing qualities. (Zhang, 2006) [22].

The desire of consumers for processed goods that retain the majority of the original qualities of fresh plants has grown recently. To preserve as much of the flavor, perfume, color, look, and nutritional content of the plants as possible, drying must be done with care.

In addition to quality factors, drying efficiency which takes into account energy use, drying time, drying rate, and other factors is another important factor for assessing drying performance (Nani, 2002) [3].

Traditional "solo" drying methods including hot air, solar, and freeze drying hardly ever succeed in drying the specimens quickly enough without sacrificing their quality (Steinhaus, 2017) [15]. Combining (two or more) various drying processes can have a beneficial impact, giving rise to some unique drying processes which include things like microwave drying, infrared drying, and radio frequency drying which significantly shorten the dehydration time and energy consumption while retaining the highest quality attributes (Zhang, 2012) [7].

Microwave combined drying techniques

Microwaves are electromagnetic waves using wavelengths between 100 to 0.1 cm and electromagnetic wavelengths between 300 megahertz and 300 gigahertz that are produced by magnetic fields within the influence of magnetic field with 915 megahertz and electrical fields with 2450 MHz are two often employed microwave frequencies in the commercial food manufacturing bands. Since water serves as a common bipolar molecule, it rotates constantly under the influence of the electromagnetic field's rapidly changing polarity and generates heat volumetrically throughout the material as a result of friction among the molecules. As a result, moisture quickly vaporizes and travels to the surface of the substance (Wang, 2013) [19]. The findings demonstrate a variety of advantages of microwave drying over conventional dehydration techniques, including a rapid drying time, a high drying rate, and quality retention, which are believed to have paved the way for the widespread use of this relatively new strategy. As an innovative and potential drying method, microwave dehydration has previously been utilized to dehydrate a variety of spice crops, including ginger, garlic, etc. Considering the inconsistent heating, potential texture damage, the "puffing" phenomenon, and the microwave's limited penetration depth, there are still a number of advantages to single microwave drying. In order to overcome its limitations, microwave drying is perpetually paired with other dehydration methods (Shivanna, 2013) [14]. Cui *et al*., employed an approach consisting of microwave-vacuum drying (MVD) and air drying (AD) to cure garlic slices. Garlic slices were dried twice: once by MVD to a water content of 10% (w.b.), and once by air drying (45 °C) to a moisture content of less than 5% (w.b.). According to the results, dried commodities produced using the present method are almost equivalent as freeze-dried examples. According to reports, freeze drying can be utilized together with microwave drying to enhance the drying methodology's quality and effectiveness. Figiel *et al*., 2009 [6] assessed the effect from microwave power levels (240, 480, and 720 W) on the appearance of color and volatile oil content of garlic slices and cloves dried by Vacuum microwave drying. In comparison to convection drying, vacuum microwave drying specimens showed higher color preservation, and the greatest microwave power (720 W) resulted in the best volatile oil recovery for garlic slices. Mohanta *et al*., 2014 [12] estimated the level of microwave assisted convective dehydration (120 W, 50 °C) caused a reduction with dehydration time of 44% and 53% over "solo" hot air dehydration at 60 °C and 50 °C respectively, indicating that this was the ideal circumstance for producing oleoresin and volatile oil. Inconsistent heating is a critical problem in microwave drying that significantly affects the quality measures for the dried products. In order to mitigate the negative impacts of improper heating and to prevent the local overheating phenomena brought on by unstable electromagnetic energy intake, the food products are kept either continuously or sporadically under a spouting, rolling state. This dehydrating method is recognized as microwave fluidization drying. Kowalski *et al*., evaluated the impact of hybrid drying on drying kinetics, energy use, and product quality in green pepper. The ability to rehydrate, water activity, overall color change, and vitamin C retention were used to evaluate the dried bio product's quality. The trials showed that compared to pure convective drying, convective drying assisted with microwave and/or infrared radiation dramatically reduced drying time, permitted greater preservation of vitamin C content, enhanced product color, and consumed less energy. Lv *et al*., 2016 [10] examined the application of microwave fluidizing drying for uniform drying and higher-quality dried goods was investigated. Microwave fluidizing drying has been studied under several settings, including hot air drying (75 °C), microwaves at two different power densities with 0.4 s spouting, constant microwave at three distinct power densities (0.6, 1.2, and 1.8 W/g), and microwaves at two different power densities and it emerged that pulse spouting efficiently prevented excessive heat whereas the procedure of drying process might sharpen the flavor (gingerol) of ginger. Meetha *et al*., 2016 [11] carried out the dehydration process of nutmeg mace were enhanced by using pulsed microwave aided hot air drying (PMAHAD). They discovered that PMAHAD preserves the flavor and color of myristicin, making it an appropriate method for nutmeg mace dehydration. The dispersion of heat characteristic of microwave drying was successfully decreased by fluidization drying or pulse spouting, boosting the overall performance of dehydrated commodities and adding importance to dried spices. Vacuum-microwave drying (VMD), which integrates the benefits of vacuum and microwave drying, enhance the efficiency and product qualities. Koch *et al*., utilized the DPPH test to show how microwaves improved the antioxidant activity of ginger rhizomes. The plant material used to make the extract gained strength the longer it was exposed to microwaves. The IC50 decreased from 210 g/mL (for fresh ginger) to 150 g/mL (for microwave-heated ginger), indicating a significant increase in the ginger rhizome's antioxidant capability after five minutes of microwave heating. Szadzińska *et al*., 2017 [18] estimated the level of drying rate, energy usage, and quality characteristics of green pepper were studied using a combination convective-microwave-ultrasound (CVMU) and convective (CV) dryer. According to experimental findings, microwave-enhanced convective drying can reduce drying time by up to 88%, although ultrasound enhancement can only do so by 39%. The microwave-enhanced convection drying process had the lowest energy consumption value (1.26 kWh), which represents an energy savings of about 84% compared to the convective drying process's energy usage of 7.97 kWh. It has been shown that convective-ultrasound drying preserves up to 70% of the vitamin C when considering the nutritional component. The best dried biological materials for color were produced by combining microwave, ultrasound and convection. Additionally, the dehydrated green pepper possessed a lower water activity and higher water replenishment capabilities as a result of the CVMU drying procedure. Sun *et al.*, carried out the research on ginger, which has been dried under using microwave vacuum drying method, which shows the quality and drying performance of ginger were greatly increased by microwave vacuum drying, which also drastically reduced the time required for dehydration. In order to achieve quick, efficient, and more uniform drying, microwave drying can be utilized in combination with other dehydration procedures such as hot air, vacuum drying and freeze, etc. Ginger was dried using hot air along with convective drying with microwave assistance. Zeng *et al*., reported the impact of hot air temperature and microwave power upon various physical and chemical characteristics of ginger dried via microwave hot-air rolling drying are examined. Results showed this process of drying was greatly hastened by the increase in both two conditions. The release of more starches and enhanced bioactive chemicals due to an upsurge in the microwave energy from 0.6 to 0.9 W/g resulted with greater microstructure damage and improves antioxidant activity. (Aslihan Yilmaz, 2023) [1] reported on coriander leaf samples were dried at 800 W produced the results that were most similar to newly collected specimens in terms of phosphate, zinc, potassium, and total protein. However, the calcium, magnesium, and iron contents of the samples dried at 800 and 200 W were the closest to those of fresh leaves. The maximum copper content was found by natural drying and microwave drying at 800 W after fresh samples. Despite the fact that the 200 W manganese levels were the closest to the fresh samples. The microwave drying method using 800 W in the experiment resulted in the best outcomes in terms of drying and quality metrics. Zeng *et al*., carried out the research work on ginger rhizomes were dried using the microwave infrared vibrating bed drying (MIVBD) method, and major product features, including ascorbic acid, drying characteristics, phenolic concentration, antioxidant capabilities, microstructure, sugar content, and flavonoid concentration were identified. Investigations have been carried out through the mechanism of sample turning brown during drying. Analysis showed that the higher microwave and infrared temperatures accelerated drying and harmed the samples' microstructures. The degree of browning increased as a result of the simultaneous degradation of the active components, promotion of the Maillard reaction among amino acids and reducing sugar might raise the level of 5-hydroxymethylfurfural. The amino acid and ascorbic acid reaction led to browning as well. Ascorbic acid and phenolics had a considerable impact on antioxidant activity ($r > 0.95$). By modulating infrared temperature and microwave power, MIVBD may successfully improve drying quality and efficiency while reducing discoloration in ginger rhizomes.

Conclusion

For improved quality and drying effectiveness, microwave dehydration has been widely used to dehydrate a variety of spices. It is a useful and potentially useful drying method for creating dehydrated foods. The main downside of microwave drying, overheating, prevents it from being widely used in the food business. Microwave drying is perpetually employed together with alternative dehydration techniques like vacuum, hot air, and freeze drying to prevent overheating, improve drying performance, and improve the end product's qualities. Recent studies on combination microwave drying technologies have shown promising results and considerable advancements. According to estimates, simultaneous microwave dehydration may become more significant in spices. However, further investigation and work are still required to develop microwave drying.

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