Effect of Refractance Window Drying on Quality Characteristics of Food

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Abstract

Moisture content primarily impacts the shelf-life of food products. Two methods for reducing moisture content are converting the available free water in food into an unavailable form through cost-intensive procedures or drying. Drying, a unit operation that requires intensive energy is one of the most chosen methods in the food industry. It helps preserve food for a long time as dried food products are more stable regarding microbial contamination and other degenerating chemical reactions. This process mainly converts liquid and semi-liquid products into flakes, solids, or powders. Dried food products must retain their physiochemical properties, including texture, color, flavor, and nutritional content. The maintenance of these properties is not just a technical necessity but a crucial aspect of maintaining the quality and consumer appeal of the products, underscoring the significance of our work. Recent studies have shown that novel drying technology, such as Refractance Window Drying, can significantly improve drying efficiency by reducing energy consumption and enhancing food quality. It can be used to dry mango pulp, chickpea protein isolates, pumpkin seeds, etc., further discussed below in the article.

Drying technology is often classified based on generations, representing the evolution of drying techniques over time. The first generation includes traditional methods like sun drying, while the second generation involves the use of mechanical dryers like drum dryers (DD) and spray dryers (SD). Freeze dryers (FD) and osmotic dehydration belong to the third generation, which focuses on improving energy efficiency and product quality. The fourth generation, which includes Infrared, Radiofrequency, and Refractance Window drying, represents the latest advancements in drying technology.

Introduction

Refractance Window Drying is a popular non-thermal drying procedure that includes heat-sensitive purees and slices of vegetables and fruits. It is a low-temperature and short-time continuous procedure. Refractance Window drying has more ability to retain nutrition and physicochemical properties and characteristics. Recently, the potential of using RW drying for manufacturing meat powders has been raised. RW drying has multiple advantages. The direct drying technology of Refractive window drying has established many applications in the nutraceutical, pharmaceutical, algae, and pigment handling industries. The main advantage of RW dryers over traditional dryers (drum drying, spray drying, tray drying, freeze drying, etc.) is that they have lower cost, time, and energy consumption. In comparison, the thermal efficiency and product quality are higher.

The Refractance Window Dryer is a win-win equipment, delivering high-quality final products in terms of texture, color, nutrient retention, energy consumption, and drying time. Its thin film drying system and futuristically evolved drying procedure ensures fast and energy-efficient drying, resulting in high-quality products. The plus point is that the RW dryer application is used to dry food products and improve the gelling and emulsion properties and formation of edible and leather films. This technique can dry leafy vegetables, marine foods, and high-protein products without changing functional properties. Given all these upper-hand properties, Refractance Window drying has gained industrial and academic interest in recent years.

Principle of Refractance Window Technology

Refractance window drying uses circulating water at atmospheric pressure to carry heat to the desired product that needs drying. It consists of a plastic film known as Mylar. It is a polyethylene terephthalate (PET). The amount of energy conducted and radiated from this layer can change depending on the temperature of the heating source, thickness of the product, and humidity. As shown in Fig. 1., a two-end pulley supports the film and moves the film during drying. Under the film, a shallow water bath with hot water is placed that touches the film's bottom. Another cold water is kept beside to cool the products leaving after drying. A valve is used to pump water when the temperature drops than the required value. A moist product is applied on the upper surface of an infrared-transparent plastic conveyor belt, which will float on the

surface of the heated, circulating water. The product reheats and recirculates, and temperature is maintained as the heat energy transfers to the product. Stainless steel is used to exhaust the vapor that gets evaporated from the food product. (Mahanti et al., 2021)

Refractance window drying performs faster than other dryers and takes only 2 to 6 minutes to dry most products. Here, food is exposed to mild temperatures (below 99 degrees Celsius). In turn, the food products maintain a high level of sensory quality, such as flavor, color, nutritional content, and aroma. All of this takes place at lesser capital and energy costs. The heart of the novel drying technology is its contact film (Mylar).

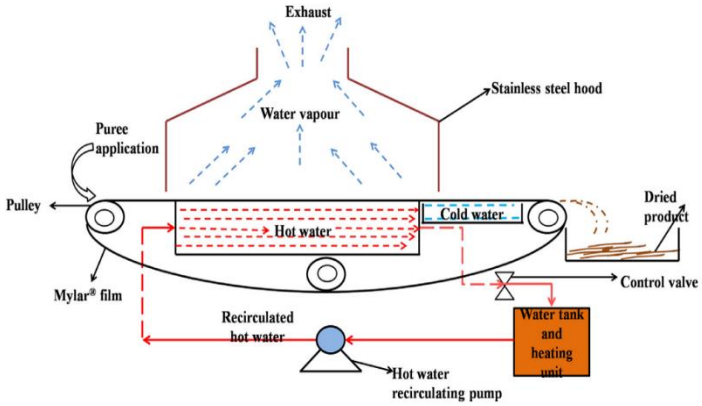

Fig. 1. The working setup of refractance window drying system for past and purees (Nindo et al., 2003a &2003b; Nindo & Tang, 2007; Caparino et al., 2012).

RW drying depends on several process parameters, including water bath temperature, loading rate, mylar film thickness, sample thickness, air velocity, and relative humidity. The air velocity, film thickness, and temperature are controllable primary parameters. The secondary parameters are loading rate and sample thickness.

Besides, the shorter the food product is exposed to heat, the fewer color changes occur. The aroma, flavor, and nutritional value of the product are retained. Bioactive compounds like minerals, vitamins, and phenolic compounds are also better preserved, along with better inhibition of microbial growth during the drying process. For example, the RW drying can dry raspberry puree from 92% moisture to 2 to 4% moisture in just five minutes. The rapid yet gentle drying will minimize the product degradation caused by heat and oxidation and increase the retention of flavor, color, and aroma. There is no need for additives like sulfites. The dried product shall have high bulk density.

According to another study by (Ssenyimba et al., 2022), a lab-scale Refractance Window dryer can be helpful as a small-medium scale fruit and vegetable processor. It is small, built with a static Mylar belt with two rollers, and needs less water for heating. The primary object of the lab-scale RW dryer is to accommodate up to 2kg of the wet product only before drying. Fruits or vegetable pulp can be of thickness up to 5mm only. It is built using materials found locally and is functional for a reasonable period. Built-in a smaller size, it is economically viable, energy efficient, and cheap for small-scale bio-product drying.

Applications of Refractance Window Technology

1. **Impact of RWD on mango pulp:**

Refractance Window Drying has been used to dehydrate mango pulp to make leather, effectively preserving taste and nutrition in the off-season. Previously, fruit leather was prepared at home, but now, its industrial products are gaining popularity among a vast population. Saying this, previously, the drying processes mainly involved solar drying, cabinet drying, drum drying, and tray drying at low production costs. However, more convenient and modern drying methods have emerged with recent discoveries.

This study is on Langra variety ripe mangoes obtained from the locals of Kharagpur, West Bengal, India. (Shende & Datta, 2020)Thirteen experiments were conducted in triplicates to ensure optimum drying conditions, with a 95 degrees Celsius drying temperature and a pulp thickness of 2.49 mm with a 0.969 desirability function. The results demonstrated that only in 22.31 minutes of drying, the 2.49 mm thick pulp gave good retention in ascorbic acid, 7.72 mg GAE/g DW, and TPC, 62.33 mg/100 g DW, respectively.

The Refractance Window Drying was compared with conventional and traditional methods, such as oven drying and tray drying at 95 degrees Celsius using 2.5 mm mango pulp thickness. RW dryer takes much less time, and the mango leather obtained was better quality and retained more nutrients than traditional drying. The mango powder had undergone SEM microstructure analysis (Fig. 2.), where it was found that the powder produced through RW drying is of irregular shape, smooth surface, and uniform thickness. However, powder particles from the tray and oven drying were irregular and corrugated, with uneven surfaces and thickness.

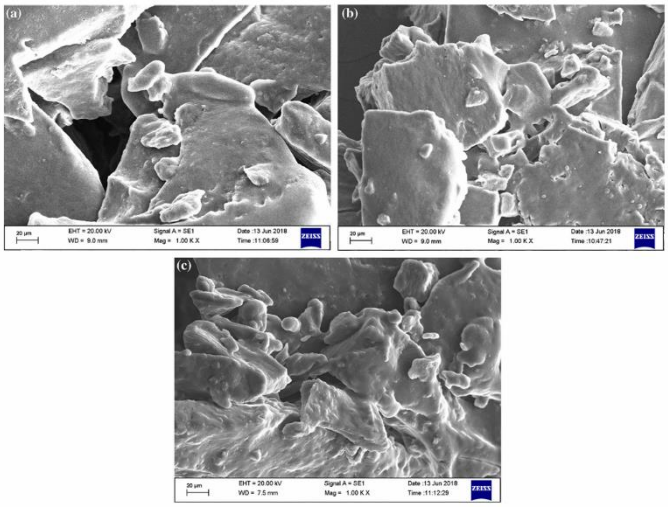

Fig. 2. SEM image of the mango powder a) RW dried, b) tray dried, and c) oven dried (Shende & Datta, 2020)

2. Changes in Functional Properties of Chickpea Protein Isolates Post-Refractance Window Drying:

According to (Tontul et al., 2018)The effect of RW drying on chickpea protein isolates' functional properties was studied, and the effect was compared with freeze drying at different pH levels. Functional properties include water and oil holding capacity, protein solubility, emulsifying properties, flocculation and coalescence indices foaming properties, and textural properties. The freeze-dried samples' foam stability and gel-forming properties were higher than those of RW-dried protein isolates. Meanwhile, RW-dried protein isolates had higher oil-holding and water-holding capacities and emulsion stabilization properties than freeze-dried samples. Thus, the protein isolates obtained from this drying method are better for producing high-fat emulsion products.

However, the texture profile analysis shows that the freeze-dried samples exhibited higher gelation ability. This indicates that Refractance Window drying techniques affect the functional properties differently.

3. Refractance Window Drying of Dehydrated Pumpkin Seeds:

In a study by (Ortiz-Jerez et al., 2022), refractance window drying of dehydrated pumpkin seeds was carried out in a non-commercial lab-scale hydro-dryer (in a 5 L thermostatic bath), keeping the water temperature constant at 80 degrees Celsius. The drying chamber was covered with a transparent plastic sheet for infrared testing, and the sample was evenly placed for tests.

The texture obtained after RW drying was considered the best, but the aroma was rated the worst. The final product of dehydrated pumpkin seeds obtained is best suited for direct consumption (snack kind). The benefits of using RW drying for food drying in terms of sensory aspects have been explained in a study by (Puente-Díaz et al., 2020). It was concluded that RW drying could be considered to fetch ready-to-eat dehydrated pumpkin seeds.

Future Prospect

Refractance Window Drying can better protect all thermal-labile compounds, such as vitamins, phytochemicals, and color, than many other drying procedures. This is because its forced air convection feature decreases the product temperature and moisture rate accordingly. Most recent studies on RWD have focused on drying purees and juices of fruits and vegetables. Hence, further research is essential to utilize RWD for solid foods, nuts, meat, etc., while retaining their color, texture, and nutritional value. Besides, the chemical behavior of structurally strong products like tubers or nuts shall be researched further. Presently, RWD is combined with novel processing technologies like ultrasound, microwave, etc. This is considered a pre-treatment and requires more research to increase drying efficiency and for heat-sensitive high-moisture foods. (Mahanti et al., 2021).

Conclusion

The United Nations Framework Convention on Climate Change (UNFCCC) reported an urgent need for new drying equipment and techniques to improve thermal and energy efficiency, enhance food quality, and reduce operational costs. Therefore, elevated drying techniques have become crucial for food products and fresh produce. This, in turn, can expand the product availability and markets. Refractance Window Drying is the fourth-generation novel drying technology in the limelight because of its numerous advantages in the food industry. It can even dry heat-sensitive products, juices, and purees, retaining their color, aroma, nutritional properties, and antioxidant compounds.(Mahanti et al., 2021)Therefore, to achieve higher quality food products with more energy efficiency and low-cost equipment, Refractance Window Drying can be considered one of the best modern drying methods.

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