Refractive window drying- A better approach to preserve the visual appearance of dried products

RUCHIKA ZALPOURI[1], PREETINDER KAUR[1] and MUKUL SAIN[2]

[1]*Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana- 141004 (Punjab),* [2]*Department of Agricultural Engineering, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib- 140407 (Punjab)*

ABSTRACT: The color is an influential parameter for deciding the quality of a product but it gets severely affected by heat treatment. While dehydration, the product is exposed to heat resulting in discoloration of the product. Drying of the liquids and purees can be done using a different kind of equipment viz. convective tray dryer, drum dryer, freeze dryer, and spray dryer. Due to different limitations in these drying methods, researchers have been continuously working to explore new innovative methods of drying that may help in reducing product quality losses due to direct heat application. Refractive window drying is one such technique that gained a lot of attention in recent years, owing to the numerous benefits it claims. The basic aim of this study was to explore the benefits of using refractive window drying for maintaining the color of the dried product.

Key words: Color, convective dryer, drum dryer, freeze dryer, refractive window dryer, spray dryer

The appearance of the product is the foremost quality attribute determining the quality of the product (Costa *et al.*, 2011).The color of the product acts as an influential parameter in determining the consumer's choice and preference (Francis and Clydesdale, 1975).The consumer tends to prefer products according to a specific color (Pathare *et al.*, 2013). The color helps in indicating the quality deterioration caused due to heat treatment (Shin and Bhowmik, 1995). Drying is one of the main unit operations in which the product is exposed to heat causing discoloration of the product. The main reasons for discoloration of a product occur due to non-enzymatic browning (Millard reaction) (Severini *et al.*, 2003).

Drying techniques are divided into four-generation *viz.* first, second, third, and fourth-generation (Raghavi *et al.*, 2018). The first generation technologies comprise of cabinet and bed type of dryers using hot air as a heating medium, used for drying food grains. While, second-generation technologies, consisting of drum and spray dryer are used for drying of paste, slurries, purees, etc.Third-generation technologies comprise freeze-drying and osmotic drying, used for drying fruits and vegetables (Vega-Mercado *et al.*, 2001). Other than these, the novel technologies like microwave drying, fluidized bed drying, radio-frequency drying, and refractive window drying come under fourth-generation technologies, used for drying heat sensitive produce (Chou and Chua, 2001).

Drying of liquids and purees can be done using a different kind of equipment *viz.* convective tray dryer, spray dryer, freeze dryer, and drum dryer. In convective tray dryer, the liquid product is in direct contact with hot air causing a change in color while drying (Maroulis *et al.*, 1988). While in drum dryer, drying temperature generally ranges between 120-170^{o}C, causing a serious quality loss in the product. During spray drying, raw material with high moisture content is required so that the feed could be atomized. The atomization and air temperature range from 150 to 300^{o}C.To attain this much high temperature, high capital investment is required (Nindo, 2008). During atomization, high shear action sometimes makes this approach inappropriate for products that are sensitive to mechanical damage. Freeze drying is reported as the best drying technique as it produces a high quality dried product having a good shape of crystal, color, and flavor as well as excellent rehydration ability but the cost of producing a freeze-dried product is almost 3-7 times costlier than air drying (Ratti, 2001).Another limitation of the freeze-drying method is that the dried products tend to have porous nature which might rehydrate quickly when exposed to the humid environment (Abascal *et al.*, 2005). The present study is focused on a better and economical drying method that retains better visual acceptability in terms of color.

Refractive window dryer: a novel approach

Researchers have been continuously working to explore new innovative methods of drying that may help in reducing quality losses, caused due to the direct heat application. The refractive window (RW) drying method is one such drying method in which the food product temperature is generally below 70^{o}C (Nindo and Tang, 2007). The refractive window dryer uses water as the heating medium and all modes of heat i.e. conduction, convection, and radiationremain active in this method (shown in Fig 1). Generally, heat transfer occurs due to conduction, and the other two modes of heat transfer depend on the resistance of water each mode offers (Ortiz-Jerez and Ochoa-Martínez, 2015).The loss of heat from the water to surrounding occurs either by conduction or evaporation, although radiation is an internal process (Baeghbali *et al.*, 2016).

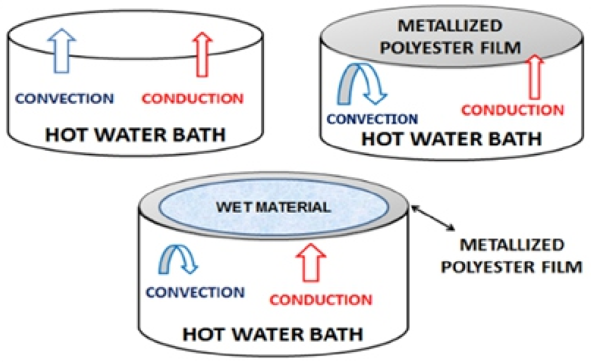

Fig 1: Theoretical concept of refraction window dryer (adapted from Zalpouri, 2018)

It is a relatively new drying method that uses circulating water at 95-98°C and at atmospheric pressure as a means of transporting thermal energy to materials that need to be dried. The pureed products are uniformly spread over the polyester conveyer belt, which passes over hot water trough. The unutilized heat is recycled in the hot water. As the dried product reaches the cold-water section,product gets harden which allows easy separation of the product from the belt utilizing a scraping instrument. The product dries quickly on the mobile belt as shown in Fig 2. This drying method has a similarity to drum drying where the product is dried in thin layers on the heated surface. The only difference between the two drying techniques is that the much lower temperature is maintained in the refraction based dryer than that in the case of a drum dryer (Abonyi *et al.*, 1999).Therefore, drum dryers are not suitable for heat sensitive products. This technology is comparatively inexpensive and the equipment is simple to use and maintain. MCD Technologies and Mt. Capra, Washington had already reported the commercial application of refractive window drying (Mt Capra, 2020).

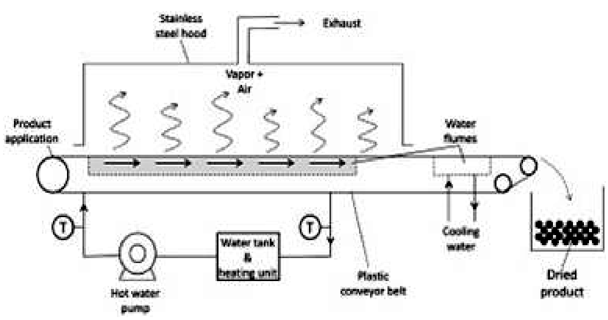

Fig 2: Schematic Diagram of a Refraction Window Dryer (Source: Raghavi *et al.*, 2018).

Effect of drying method on the color attribute of dried product

Strawberries have high ascorbic acid content and are highly perishable. When dried, it can be stored for a longer period. Strawberries being heat-sensitive tend to have a color loss due to heat. To overcome the associated problem, Abonyi *et al.* (2002) studied that refractive window dried and the freeze-dried strawberry puree was brighter in color. The color retention of dried strawberry puree by refractive window dryer was comparable to that of freeze-dried product.

When mango puree was dried in drum dryer, freeze dryer, refractive window dryer and spray dryer for obtaining mango powder. It was observed that the color of dried mango powder obtained by a refractive window dryer was comparable with the freeze-dried powder, but had a significant difference with that of drum dried and spray-dried powder. It was reported that refractive window dried products had similar color properties to raw product (Caparino *et al.,* 2012). In another study, Shende and Datta, 2019, dried mango puree using a refractive window dryer, oven dryer, and tray dryer to obtain mango powder. It was reported that refractive window dried mango powder had brighter color due to moderate time-temperature combination as compared to the other two drying methods. There was higher L* value, b* value, and lower a* value in refractive window dried mango powder, as there was low pigment degradation.

The anthocyanin pigment in pomegranate and cornelian cherry degrades due to the heating process, causing lower 'a' value (redness) of the sample. It was observed that pomegranate powder obtained from refractive window dryer and freeze dryer had no significant difference whereas spray dried product had lowest 'a' value showing greater loss of anthocyanin pigment (Baeghbali *et al.,* 2016).Similarly, cornelian cherry when dried in refractive window dryer had higher color (L value) and lower hue angle as compared with sample dried in a convective dryer. These results showed that the color of dried cornelian cherry powder of refractive window dryer was better than convective dried powder (Tontul *et al.,* 2018).

Guava is a good source of vitamin C and when dried tend to become darker when dried in hot air dryer due to non-enzymatic browning. Singh (2019) studied the effect of drying method on guava powder and observed that guava powder obtained by refractive window drying method had lower total color change (ΔE)value than the powder

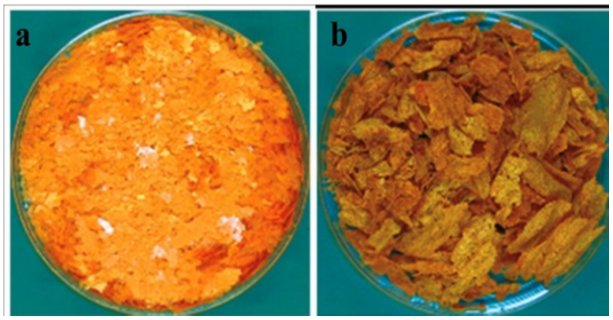

Fig 3: Carrot flakes produced by a) refractive window dryer and b) drum dryer (source: Shende and Datta, 2018)

obtained from convective tray dryer. Similarly, Kiwi dried in refractive window dryer had lower 'ΔE' than oven-dried. The lower 'ΔE' imposed lesser carotenoid decomposition and lesser formation of undesirable pigments (Jafari *et al.,* 2014).

The red color of tomato puree is due to the presence of lycopene content and it gets degraded due to heating and drying under different processing conditions. The study showed that tomato powder produced by a refractive window dryer had the least color degradation showing lower lycopene decomposition in tomato powder (Castoldi *et al.,* 2015).

Asparagus puree dried in refractive window dryer, produced bright green color asparagus powder when compared with freeze-dried, combined microwave and spouted bed dried powder. This suggested that most of the chlorophyll content was retained during refractive window drying (Nindo *et al.,* 2003).
Carrots are a good source of β-carotene. When dried in convective oven and microwave oven, a considerable amount of loss is observed due to oxidation. Therefore, Abonyi *et al.* (2002) observed that the color of dried carrot puree in the refractive window dryer was comparable to fresh puree whereas the drum dried carrot sample showed pronounced color degradation (shown as Fig 3). In another study, Hernαndez-Santos *et al.* (2016) studied that carrot slices dried in a refractive window dryer prevented color destruction and intense reduction in orange color intensity than convective dried carrot slices. Hence, better color retention was observed in refractive window dried samples.

Paprika is a variety of red pepper used as a food colorant and when dried, tends to have color degradation due to non-enzymatic browning. Topuz *et al..,* 2009 studied the effect of drying methods on two cultivars of red pepper *viz.* Jalapeno and Anaheim. It was observed that Jalapeno cultivar had no significant difference in color when dried in freeze dryer and refractive window dryer but Anaheim cultivar dried in refractive window dryer had slightly lower L, a, b color values than dried in the freeze dryer. Whereas a notable decrease in color was observed for sample dried in oven dryer and natural convective dryer. Refractive dried and freeze-dried red pepper resulted in less color change.

The dehydrated potato products obtained using hot air dryers had a pronounced tendency to discolor to a grayish brown. Nayak *et al.* (2011) reported that dehydration of white and colored potato samples in refractive window dryers was significantly brighter than drum dried potato samples. Zalpouri (2018) studied that when potato puree was dried in a refractive widow dryer and convective tray dryer, potato flakes obtained from refractive window dryer had higher L value, b value, and lower a value than obtained from convective tray dryer shown in Fig 4. Therefore, showing the least tendency to browning when dried in refraction widow dryer.

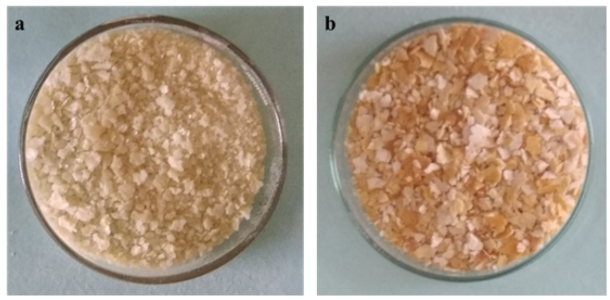

Fig 4: Potato flakes obtained from a) refractive window dryer and b) convective tray dryer (adapted from Zalpouri 2018)

CONCLUSION

Color is the foremost parameter determining the quality of the product. Degradation in color indicates the decomposition of bioactive compounds in the product. Heat treatment causes degradation of color and drying is one such unit operation in which product is directly in contact with heat treatment. Hence, refraction window drying is such a process in which the product is not in direct contact with the heating medium. The visual quality of the dried product is retained when dried in a refractive window dryer than that of a drum dryer, spray dryer, convective dryer. The freeze-dried product has an almost similar color attribute to that of refractive window dried product but freeze-drying is highly expensive and requires experienced labor, as well as the product formed, is highly porous. These limitations can be overawed using a refraction window dryer. The effectiveness of a refractive window dryer is because of rapid heat transfer. Thus, refractive window drying is a better drying method to retain the quality of the product than other prevailing methods for drying of purees and slurries.

Future Scope

Refraction window dryer is a gentle, simple, and low-cost drying technique that can be deployed at farm level to dry heat-sensitive fresh produce while persevering nutritive as well as the sensory quality of the dried product.The large capacity continuous dryer for industrial use can also be developed based on the same principle. High quality ready to use fruit and vegetable powder can be produced with high nutritive quality. Also, the technology should be scaled up. The present lockdown scenario due to coronavirus pandemic is the most suited example, which justifies the need for dried high shelf life products that can be stored for a long period. On the other hand, the developed refractive window dryers mainly use conventional energy resources for requisite water boiling operation, which must be replaced with renewable, inexhaustible resources of energy. In India, solar energy is the most promising source of energy, which can be used to fulfill a tremendous range of thermal heat requirements for processing operations (Sain *et al*., 2019a; Sain *et al*., 2019b). Also, portable biogas cylinders filled with purified biomethane (Sain *et al.,* 2018) can easily be used instead of conventional fuels to make the system ecofriendly.

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