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Refractance window drying: Influence of drying parameters on drying characteristics and quality attributes of orange pestil

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Abstract

This study was focused on investigating drying traits and quality retention of orange pulp using Refractance Window Drying (RWD) method. The effect of RWD temperature (70, 80 and 90 °C) and orange pulp thickness (2mm and 3mm) on drying time, drying rate, moisture content, ascorbic acid and colour (L*, a*, b* and b*/a*) were studied. The moisture content of 15-25 % (wb) for intermediate moisture food like orange pestil was achieved within 50 minutes of drying. The moisture content of the final product was 18.5% (wb). The fastest and slowest drying rate was observed for the sample dried at 2mm thickness and 90°C (5.74 g/min) and the sample dried at 3mm thickness and 90°C (1.00g/min) respectively. The lowest ascorbic acid (57.15 mg/100g) was recorded for the sample dried at 2mm thickness and 70°C temperature and the highest ascorbic acid (62.05 mg/100g) was for the sample dried at 3mm thickness and 90°C temperature. The effect of pulp thickness (2mm and 3mm) and drying temperature had a considerable influence on the colour factors of orange pestil. The sample dried at 2mm thickness and 90°C has the least L* value of 57 and the samples appear brown or dark red dark in colour and sample dried at 3mm thickness and 90°C had a maximum L* value i.e., 62.96 with the bright yellow sample. Increased value of a* of orange pestil/sheet as compared to the a* value of orange pulp i.e., for orange sheet sample dried at 3mm and 90°C a* value was 10.69 showcasing an elevation in the level of redness of dried sample in comparison to the orange colour of orange puree. The b* value of dried orange pestil/sheet decreased maximum for sample dried at 3mm and 90°C i.e., 32.28. The findings revealed that RW drying is a suitable drying process that can be effectively used for the formulation of quality orange pestil preserving its nutritional as well as sensory attributes.

Keywords ascorbic acid, drying rate, drying time, refractance, sweet orange, window drying

Introduction

Citrus sinensis (Sweet orange), sometimes known as sweet orange, is a member of the citrus family and is well-known for its distinctive flavour, appealing colour, taste, and aroma, as well as its high content of nutrients like ascorbic acid, carotenoids, phenolic, and minerals [1]. Additionally, it is now recognised that other non-nutritional, bioactive compounds of citrus fruits, for instance, phytochemicals, antioxidants and insoluble and soluble dietary fibres, can help lower the risk of cancer and several chronic diseases, including arthritis, obesity, and coronary heart disease [2]. Fruit pestil are fruit sheets with modified structures manufactured from fresh fruit pulp or a blend of concentrated fruit juice and additional substances [3] which go through the process of drying. Fruit pestil, which has little fat content, and high dietary fibres, vitamins, carbs, minerals, and antioxidants, might be a healthier alternative to "junk food" and has superior health benefits [4]. It is also a practical and affordable fruit item that doesn't require refrigeration for storage or transportation [5]. Consuming fruit pestil is a cost-effective and practical value-added alternative to usual fruits as a way to get different kinds of nutrients. Additionally, compared to many other snacks, fruit sheets have a small amount of calories lower than 100 kcal per serving [3]. Refractance Window (RW) drying, also known as conductive hydro drying [6] or cast tape drying, is a drying technique of the fourth generation [7]. Water at a temperature below boiling point is utilised as a medium of heating in the RW drying process, held into a reservoir holding the flexible polyester film known as MylarTM sheet which is partly translucent to infrared emissions. As the heat from the hot water is transferred to the food through the polyester film, drying occurs through conduction and radiation. Additionally, the moisture (water vapour) extracted from the food matrix is carried away by air around the drying set-up [8]. The manufacturing of dehydrated fruit pestil and sheet is an area where RW drying is attracting a lot of interest. Based on studies done on the preparation of fruit pestil from pomegranate and mango [5], it has been indicated that RW is an upcoming and beneficial drying method because it uses less energy and costs less to make high-quality dried products (leather, powder, flakes) that have more nutrients and are popular with consumers to a greater extend. Therefore, the objective of the present study was to investigate the effect of drying factors on drying properties of sweet orange pestil dried using Refractance Window drying.

Methodology

Sweet Oranges (*Citrus sinensis*) were procured from the local market of Prayagraj, U.P., India. Firm oranges with thin and smooth skin were selected by visual inspection. The fruits were peeled and deseeded. Segments were processed in a blender for one minute to get a smooth pulp. The pulp was concentrated by putting the pulp in a sieve till the extra juice got collected in the bowl at the bottom and the resultant pulp was secured. Five per cent sugar powder was added to the pulp which made its final TSS to 25° Brix. The pulp was frozen for preservation. To ensure the best results, six experiments were run in triplicate.

RW Drying Apparatus

A domestic-level, batch-operated (type) Refractance Window drying arrangement was set up in the laboratory [9] to conduct all the experiments. A water bath with temperature control was used in this system to heat hot water to the necessary temperatures (70, 80, and 90°C). The temperature range was chosen based on reports in the literature[10-11] which suggest that water temperatures lower than 70°C can result in prolonged drying times and products with inferior quality, whereas higher temperatures (95°C) may produce agitation and effervescence in the hot water, hindering the transmission of heat across the plastic film [12]. To conduct tests in batch mode, a float made of Mylar sheet measuring 24 x15 x 3 cm was used. Uniform width of 2 and 3mm of orange pulp was smeared on the surface of the food grade Mylar sheet. At temperatures of 70, 80 and 90°C in the R W Dryer, batch Refractance Window drying was performed. On a sheet of food-grade mylar that was 0.25 mm thick, the prepared orange pulp was distributed at a thickness between 2 and 3mm, and the film was then left on the heating medium. As per the literature 0.25mm was suggested for RW drying from a thermal and mechanical characteristics point of view, so thickness was chosen based on such data [10-13].

Drying Characteristics

Determination of drying time

The sample was dried till a moisture content of 18% (wb) was attained. At this moisture content it was found that the sheet was easier to secure from mylar sheet after drying and the moisture content was under the permissible limit for orange pestil/sheet which is an Intermediate Moisture Food i.e., 15% to 25% [14].

Determination of drying rate

The drying rate is defined as the degree at which moisture inside the sample vaporises to the surroundings. Using equation (1), the sample's drying rate was calculated.

$$\text{Drying rate} = \frac{W_{t+dt} - Wt}{dt} \ldots\ldots\ldots\ldots (1)$$

where dt is the time elapsed between two measurements and W_t is the sample weight at time t (percent wb, wet basis).

Quality Evaluation

Determination of moisture content

To estimate the moisture content of orange pestil, Ranganna [15] standardized techniques were used. The sample was taken in a tared porcelain plate after being weighed (W_1g). A hot air oven set at 70±2°C was used to dry the sample till constant weight was achieved. The dish was weighed after cooling in desiccators. Heating, cooling down and weighing was repeated until there was no more than a 0.002g variation between two subsequent weighs. The observations were made as follows, Tare weight of dish (Wg.), Weight of dish with sample (W_1g), Weight of dish + sample after keeping in the oven (W_2g) and calculated using equation (2).

Calculation

$$\text{Percent moisture content (wet basis)} = \frac{\text{Loss in weight}}{\text{Initial weight of the sample}} \times 100$$

$$= \frac{W_1 - W_2}{W_1 - W} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Ascorbic acid

Ascorbic acid was determined using 2, 6-dichlorophenol-indophenol titration method recommended by AOAC [16]. The sample (10 g) was dissolved in metaphosphoric acid (3%) and strained through cheese cloth before being and distilled water was added to make up the volume to 100 ml. A delicate pink colour that lasts for no less than 15 seconds then appeared after a small amount (5 mL) was put into a 100 mL conical flask and titration was done against a dye. The amount of vitamin C was calculated using equation (3) and stated as a milligram of ascorbic acid per 100 g of the orange pestil as a sample.

$$\frac{\text{mg of ascorbic acid}}{100\text{g}} = \frac{\text{Titre} \times \text{Volume made up} \times 100}{\text{Aliquot extract taken} \times \text{weight of a sample}} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Colour measurement

A Colourimeter (Konica Minolta, CM-5) was used to measure the colour of each sample, and the results were reported as L*, a*, and b* values in the colour area. L* characterises the product's lightness or darkness; +a* for colour, +b* for hue, and b*/a* for darkness factor.

Results and Discussion

Drying Characteristics

Drying time

The effect of drying parameters (temperatures 70, 80 and 90°C) and thickness (2mm & 3mm) on drying characteristics were observed and presented in Figure 1. The longest drying time (70 minutes) was noticed for all the samples dehydrated at 70, 80 and 90°C for a pulp thickness of 3mm and the shortest drying time (60 minutes) was seen for all the samples dehydrated at 70, 80 and 90°C for a pulp thickness of 2mm. For 2mm sheets, drying time did not change when the heating medium's temperature was elevated from 70°C to 80°C, but it did decrease by 10 minutes when the temperature was raised to 90°C. When there was a temperature elevation of the heating medium from 70°C to 80°C for an orange sheet that was 3 mm thick, drying time did not change; however, when the temperature was raised to 90°C, drying time decreased by 10 minutes. This might be credited to the piece of evidence that thinner samples shorten the gap that molecules of water must travel across the fruit sheet to escape the drying product [17]. Since the time of drying changes in accordance with the amount of dehydrated solid, the product takes longer to dry when the sample thickness is increased from 2mm to 3mm [18]. By increasing the drying temperature (70, 80 and 90°C), the rate of water removal from the product's outer surface elevates rapidly, hastening the exclusion of water from the fruit tissues [19]. Consequently, by making progress towards achieving the desired moisture percentage, the time of drying of the product is dropped. The time of Refractance Window drying of orange puree was affected by the thickness of the puree sheet to a greater extent as compared to the drying temperature [10].

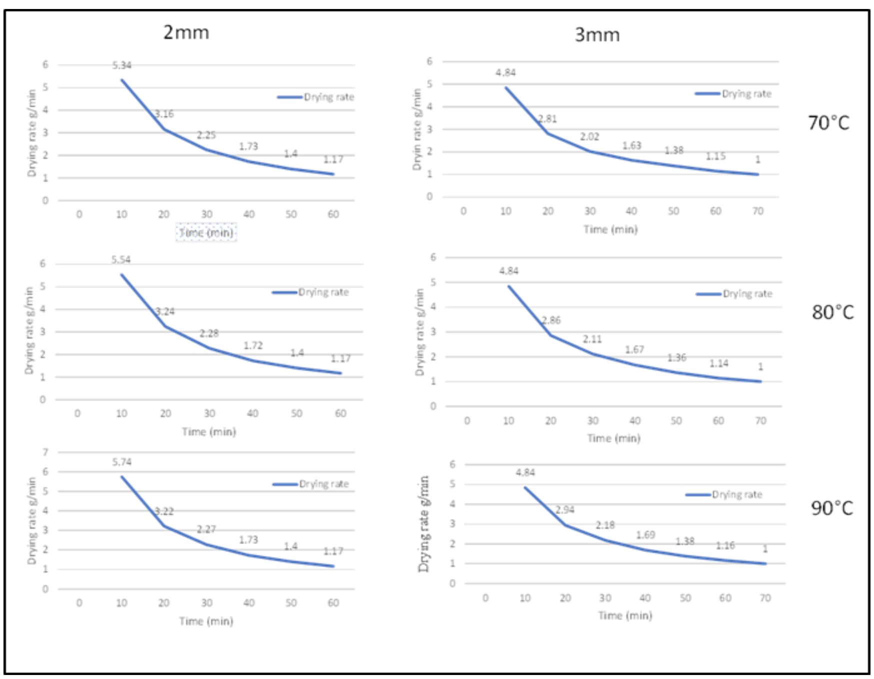

Figure 1. Effect of pulp thickness and temperature on drying rate of Refractance window drying of orange pestil

Drying rate

The influence of drying parameters (temperatures 70, 80 and 90°C) and thickness (2mm & 3mm) on the typical drying curve (moisture content vs time) was observed and presented in Figure 1. The orange pestil dried at 90°C and 2mm thickness has the maximum drying rate (5.74 g/min).

Orange sheets dried at 3mm thickness and 90°C showed the lowest drying rate (4.84g/min). It is clear that the time of drying increases as the thickness of the pulp increases, though drying rates for pulp with thicknesses of 2 and 3 mm were constant for all three heating temperatures. Orange pulp's relatively high-water content (88.5 percent on a wet basis) and thin dimensions of orange pulp sheet can be employed to explain this phenomenon. During such conditions, the dew point pressure (saturation pressure) for the duration of the drying and the pressure created by vapours at the surface of the sample are nearly equal and the inner barrier to mass transport is minimal. Assumptions can be made that the dehydration of film proceeds by traditional vaporisation and is governed by the heat transmission from the water if the external conditions have little effect on the rate of drying (convective drying does not have much significance here) [10]. The depth of the pulp layer significantly affected the RW drying of orange pulp. When the drying pulp's thickness was increased from 2mm to 3mm, the rate of drying during the constant rate period fell by no less than 40%. The rate of drying for 2mm R W dried samples was 4.9 times greater at 70°C, 5.5 times greater at 80°C and 6.6 times higher at 90°C as compared to drying rates obtained for 3mm thin pulp. Therefore, for thinly layered pulp, the drying rates are more affected by circulating water temperature.

Moisture content

Two process parameters were used for the RW drying process: three temperatures (70, 80 and 90°C), and two pulp thicknesses (2mm and 3mm). Figure 2, shows the product temperature during RW drying; for mylar sheet, this ranges between 59.8°C and 62.5°C. Because the mylar sheet is only a thin layer, it is noticeable that the temperature rises as the process of drying begin. Similar suggestions were made by Kaur et al., [14]. During the first 10 minutes of Refractance window drying, there was a noticeable loss of moisture, with the moisture content dropping by almost 60%. This could be because the air over the orange pestil exerts a (partial) pressure that decreases as the surrounding vapour pressure caused by evaporating moisture rises [20]. Orange pulp's initial moisture content (measured on a wet basis) was 88.5 percent, and it eventually dropped between 30 and 35 percent within the first twenty minutes. IMF (intermediate moisture foods) are recommended to have a moisture content between 15% and 25% (on a wet basis) or 17.65 to 33.33 percent (on a dry basis) to increase shelf life [14]. Within 50 minutes of Refractance Window drying in the current investigation, the anticipated moisture level recommended for the IMF food was reached (18 percent wet basis). These findings are consistent with the work of Muzaffar et al., [21], the greater the drying temperature, the greater would be the temperature difference between the water beneath the Mylar film and the fruit pulp being dried, leading to high water evaporation and decreased moisture content in the dried product.

Ascorbic acid content

Fresh orange pulp had an ascorbic acid level of 94.86 mg/100 g. Table 1 illustrate how the process parameters for RW drying affect the content of ascorbic acid in dried orange pestil. Because 2mm thick pulp had a higher surface area exposed to drying, which makes ascorbic acid more susceptible to oxidation, retention of ascorbic acid was maximum for pulp sheets of 3mm thickness (62.5 mg/100g), in contradiction to 2mm thick pulp sheets (57.15 mg/100g). Table 1 shows ascorbic acid retention rose significantly with the temperature of drying (from 70°C to 90°C), maybe because the sample was exposed to heat for a shorter period, reducing nutrient oxidation as a result [20]. Drying causes the ascorbic acid to degrade owing to oxidation due to high temperature and oxidation due to the presence of oxygen [22]. Illumination, heat, air, humidity, metallic ion catalysis, and time of processing are just a few of the internal and external elements that might affect how ascorbic and acid reacts [23]. The temperature of drying (70, 80 and 90°C) had a greater impact on the pulp's ascorbic acid content than did the thickness of the pulp (2mm and 3mm).

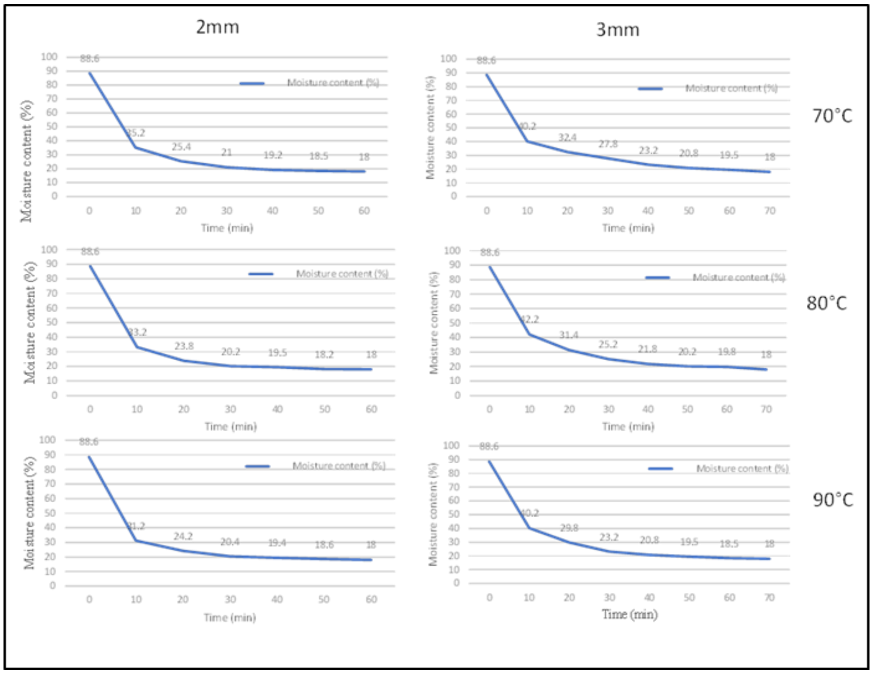

Figure 2. Effect of pulp thickness and temperature on moisture content and drying time on Refractance window drying of orange pestil

Table 1. Effect of pulp thickness and drying temperature on Ascorbic acid content (mg/100g) and colour parameters of Refractance Window Drieed orange pestil

Thickness (mm)	Temperature (°C)	Ascorbic acid (mg/100g)	Reference Colour			
			L*	a*	b*	b*/a*
2mm	70	57.15^{c}	62.44^{a}	10.50^{c}	31.65^{a}	3.014^{b}
	80	57.25^{b}	60.13^{b}	11.88^{b}	30.37^{b}	2.56^{b}
3mm	90	58.35^{a}	57.00^{c}	12.38^{a}	28.64^{c}	2.31^{ab}
	70	56.15^{c}	60.13^{c}	11.88^{c}	30.37^{a}	2.56^{ab}
	80	61.28^{b}	61.44^{b}	13.44^{b}	31.64^{a}	2.35^{a}
	90	62.50^{a}	62.96^{a}	15.61^{a}	32.28^{a}	2.06^{b}

Colour

When the colour parameters for orange pestil samples were determined, it was found that the pulp thickness (2mm and 3mm) and various temperatures for drying (70, 80 and 90°C) caused substantial differences, as shown in Table 1. It is evident that with drying time there is a change in the value of L* (which denotes lightness), the value of a* (which denotes red-green) and the value of b* (which denotes yellow-blue). As is obvious, the change in colour increases with drying time within 20 minutes of pestil drying. A drying temperature of 90°C and pulp thickness of 3mm obtained the maximum reading for L* i.e., 62.96, indicating the sample was bright yellow in colour, whereas the sample dried at 2mm thickness and 90°C had the minimum reading for L*, i.e., 57, revealing sample red with a darker shade or brown shade. The outcome demonstrates the lightness difference behaviour that many authors have used as an indication of browning for dried fruits [24]. In all drying cases, the pulp's L*value decreased; this could be the result of the colour darkening at high temperatures during the drying process [25]. Orange pestil/sheet's a* value increased in comparison to the orange pulp's a* value, i.e., for a sample dried at 3 mm and 90°C, orange pestil a* value was

10.69 and fresh orange pulp's a* value was 10.69, demonstrating how the dried sample's redness changed in comparison to orange puree's colour. The b* value of dried orange pestil/sheet decreased most for the sample dried at 3mm and 90°C i.e., 32.28, compared to b* value of orange pulp i.e., 28.26. The possible reason could be a change in the orange colour of the orange pulp to a dull and dark red colour of the orange sheet [26]. Ochoa-Martínez et al., [27] examined the effects of pulp thickness (2mm and 3mm), drying time, and their interactions on the colour characteristics of orange pestil dried by Refractance Window Drying (92°C). For both drying techniques, a* was significantly ($p<0.05$) influenced by the thickness of the sample. The thickness and temperature had a significant impact on RW drying methods, according to the ANOVA assessment ($p<0.05$). The ANOVA assessment showed a substantial (significant) relationship between temperature and thickness for parameter b for RW drying method. ANOVA assessment revealed a substantial impact on the thickness of the sample for the Refractance Window drying procedure for parameter L*. In Refractance Window dried sample, the pulp thickness, both individually and in combination with the length of the drying period, significantly affects b* and L* values. The variations are probably caused by the type of material as fibrous fruits can affect the colour values [27].

Conclusion

The effectiveness of Refractance Window Drying using Mylar sheet in hot water is demonstrated in this study. Industrial RW drying can produce orange pestil/sheet that is more nutritive and visibly more attractive. The RW dryer with Mylar sheet and 2 mm thick sheet at 90°C had the fastest drying rate, achieving the recommended moisture content for intermediate moisture food like orange pestil in 50 minutes. In comparison to 2mm thick pulp sheet (57.15mg/100g ascorbic acid), ascorbic acid retention was maximum in 3mm thick pulp sheet (62.5 mg/100g). It is evident that the product's L* value which denotes lightness, a* value which denotes red-green colour and b* value which denotes yellow-blue, change with drying time. In Refractance Window dried sample, the pulp thickness, both individually and in combination with the length of the drying period, significantly affects b* and L* values. Since fibrous fruit can affect the colour readings, the variations were probably caused by the fibrous material of orange pulp.

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