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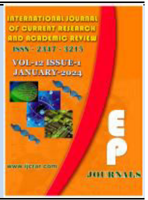

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Papaya Drying Methods and it's Nutritional Value

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Abstract

Papaya is one of the healthiest fruits, rich in antioxidants, polyphenols, and vitamins C and A. On the other hand, papayas are larger fruits that are more difficult to transport and are more perishable because of their high free water content and potential for microbial infection. To overcome this problem, various studies have been undertaken on different papaya drying processes. Therefore, this review aims to assess the research that has been conducted on drying methods and identify the best nutrient retention methods among driers. Drying methods such as solar (direct and indirect), oven (hot air), microwave, refraction window, and freeze dryers are the most common. Moreover, the nutritional quality of papaya depends not only on the drying methods but also on the thickness of the papaya slice or purée, the drying temperature, and the time. The most valuable nutrients of papaya, beta-carotene/provitamin A, lycopene, and vitamin C are better retained by a freeze dryer followed by a refractance window; hence, the nutrients are heat-liable. Instead, phenols and flavonoid nutrients are more retained by heat-driven dryers through the release of polyphenolic compounds from the food matrix during drying; hence, heat breaks down covalent bonds and facilitates the liberation of bio-compounds. The refractance window dryer is the most promising papaya drying technology over the freeze dryer because it uses less energy, is easier to use, is more environmentally friendly, and retains more nutrients than previous drying methods.

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Keywords

Nutritional content, Ripening stage, Drying methods, Nutrient retention.

Introduction

Fruits and vegetables are among the best food crops, and because of their high nutritional value and therapeutic characteristics, eating them is strongly associated with several health benefits (Ames *et al.,* 1993). Low fruit and vegetable consumption is listed as one of the 20 risk factors for world mortality, immediately after the most well-known killers like smoking and high cholesterol levels (Organization, 2005). Therefore, increasing fruit and vegetable consumption is necessary to improve human health (Lim *et al.,* 2007). These advantages of fruits and vegetables have generally been attributed to their antioxidant properties. Carotenoids (provitamin A), which are antioxidants, are the most intriguing and have received special attention in addition to their antioxidant characteristics because of their use as provitamin A (a source of vitamin A). According to a recent assessment, only 2.4% of adults consume the recommended five servings of fruits and/or vegetables daily, which increases their risk of developing chronic diseases and nutrient deficiencies (such as a lack of vitamin A). The highest number of years of life lost (YLLs) and disability-adjusted life years (DALYs) (11–12%) were associated with poor fruit consumption (Melaku *et al.,* 2016).

People in regions with widespread vitamin A deficiency consume provitamin A (carotenoids) almost exclusively (West, 1996). Provitamin A and preformed vitamin A both contribute 30% and 70% of the daily vitamin A requirements in developed nations, respectively.

In contrast, provitamin A carotenoids constitute 70% of the daily vitamin A intake in underdeveloped countries (Tang, 2010). The introduction of affordable, food-rich beta-carotene to combat widespread vitamin A deficiency is essential. Carotenoids, a type of provitamin A, are highly intriguing because they serve as both vitamin A and antioxidant sources. Furthermore, because they are only converted to vitamin A when the body requires them, it is crucial to avoid exposure to vitamin A toxicity (Dutta *et al.,* 2005). Therefore, besides health and nutritional benefits, the consumption of fruits and vegetables helps to prevent the prevalence of vitamin A deficiency, which plays a critical role, especially in developing countries because of the inaccessibility of livestock products.

Because of its high carotenoid content and pro-vitamin A-rich fruit, papaya fruit (*Carica papaya* L.) is a targeted crop for nutrient enrichment to be utilized in sustainable programs to combat vitamin A insufficiency in underdeveloped countries (Organization, 2007). According to Souza *et al.,* (2008), it is regarded as a source of vitamin A, calcium, and vitamin C (ascorbic acid), which is frequently utilized in diets.

Therefore, consuming papaya fruit can be a useful alternative strategy to lower the prevalence of vitamin A deficiency in underdeveloped nations. Papaya fruit (*Carica papaya* L.) is thought to be the most effective alternative way to reduce the prevalence of vitamin A deficiency (Organization, 2007) because (1) it is important as an economical and highly nutritious foodstuff, (2) it has a high content of beta carotenoid, (3) it is available all year (in the growing potential area), and (4) it is less expensive than other fruits with a higher beta-carotenoid source. However, (1) papaya fruit is highly perishable, with > 80% moisture content (Sagar and Suresh Kumar, 2010), (2) it is difficult to transport because of its enormous size (resulting in high transportation costs), (3) it is subject to substantial postharvest loss, and (4) it is not available in the requisite quantity for purchase. Therefore, to solve such problems, researchers have been trying to dry fruits using different drying technologies, and this review aims to assess the best papaya fruit drying method with minimal loss of nutrients.

Drying is the process of removing moisture from fruits to limit microbial activity and produce shelf-stable and easily handled products (Jangam *et al.,* 2010). Along with papaya preservation, dried items have lower weight and volume, as well as lower packing, handling, shipping expenses, and storage space (Demarchi *et al.,* 2013). Inadequate work has been recorded on the drying of papaya fruit using a different drying process, which is likely to be prohibitively expensive and inaccessible to LMICs. However, a complete comparison of sun drying technologies to more typical drying methods, such as oven and freeze-drying, is lacking, and this research study includes another locally adapted eco-friendly drying technology (refractance window).

Papaya fruit description

The fruit is prized for its sweetness and delicate pulp (Fabi *et al.,* 2007), and is frequently enjoyed when ripe. Although its origin is unknown, evidence shows that it originated in the American tropics (Garrett, 1995). Papaya is a year-round climacteric fruit with elongated berries of varying sizes, smooth thin skin, and a greenish-yellow tint (Fuggate *et al.,* 2010). It is typically 15–50 cm long, 10–20 cm wide, and weighs up to 9 kg (Ojike *et al.,* 2011). Papaya trees bear fruits for 5 months and can live for 4-5 years, the seeds are abundant, tiny, black, and covered in gelatinous aril (Orwa *et al.,* 2009). It has a high concentration of orange pulp and frequently has orange-red, yellow-green, and yellow-orange colors. Its flesh is thick and yellow to red in hue, with a pleasant, sweet, mellow flavor. The varied flesh colors of papaya are caused by carotenoids accumulating in fruit cell chromoplasts, primary lycopene in red flesh, and b-carotenoids in yellow flesh, which provide antioxidant activity and vitamin A nutrition, respectively. The climatic parameters for papaya growth in both tropical and subtropical climates are between 21 °C and 33 °C. It cannot handle cold temperatures below 15 °C; however, at an ideal storage temperature (°C) of 8-12, it has a maximum postharvest life (days)/shelf life of 7-21 days (Wakjira, 2010).

Papaya (*Carica papaya* L.) nutritional value

The nutritional value of papaya was rated as one of the highest among 38 common fruits, and each portion of the fruit had a different medical purpose (Silva *et al.,* 2010). It is a tropical and subtropical crop fruit recognized for its strong nutritional benefits, as well as its appeal due to its low-calorie content and high antioxidant content (Prajapati *et al.,* 2017).

The major carbohydrates present in the papaya fruit are glucose, sucrose, and fructose, with glucose being the most abundant carbohydrate present in the initial phases of development (Zhou and Paull, 2001); however, the sucrose content increases during ripening and can reach up to 80% of the total sugars, when the percentage of sugars varies between 10 and 13% (Nwofia *et al.,* 2012).

In general, the nutritional value of a fruit is determined by its variety, growing conditions, and ripeness at the time of eating, but the nutritional content of papaya fruit is highly associated with ripening (Chonhenchob and Singh, 2005). The ripening process is aided by respiration and is linked to the generation of ethylene. According to (Zuhair *et al.,* 2013), when papaya fruit ripens, it becomes more nutritious. It boosts physicochemical properties, antioxidant activity, and total phenolic and flavonoid content. There are five stages of papaya maturity based on peel color when stored at room temperature (24 ± 1 °C, 75 ± 5% RH).

Furthermore, more ripe papaya fruits had higher redness and yellowness. A side from nutritional benefits, fruit hardness rapidly declines following separation from the tree during papaya ripening (Chonhenchob and Singh, 2005), indicating accelerated respiration/deterioration. Different physicochemical parameters of papaya fruit, including pH, titratable acidity, total soluble solids, moisture, and fruit color, were affected by ripening phases. Furthermore, sensory quality improves with ripening; therefore, it is dependent on color, flavor, sweetness, and sourness. Volatile chemicals (benzyl isothiocyanate, terpenes, hydrocarbons, esters, aldehydes, ketones, alcohols, and organic acids) (Fuggate *et al.,* 2010) contribute to papaya sensory properties (mostly taste and scent). Linalool is the most abundant volatile component in papaya and is responsible for its taste and scent (Flath and Forrey, 1977).

Research studies conducted by (Martins *et al.,* 2016) on Golden'and SunriseSolo papaya varieties at two different ripening stages found that Carotenoid levels increased with all-trans-lycopene varying from 0.73 to 1.58μg/g in the 'Golden' and from 0.68 to 1.67 μg/g in the 'SunriseSolo', and All-trans-β- cryptoxanthin content from 1.29- 3.0 μg/g in the 'Golden' and 0.28-5.13μg/g in the SunriseSolo'. Moreover, accordingly, (Bhaskarachary, 2008), in the study of papaya (Honey Dew) varieties at different ripening stages of light yellow and deep yellow, results of beta-carotenoid content (mg/100g) found 1.25 and 3.71 respectively. Furthermore, he also tried to see the differences after storing deep yellow ripe papaya fruits for 24 h and 72 h, and the result showed statistical variation. Fruit maturity studies stated that total carotenoid content was nearly doubled (22 mg/100 g), while β- -carotene content showed an increment of about three-fold through ripening when compared to contents of light-yellow ripe fruit. In 24-hour storage, the total carotenoid content did not change significantly ($p<0.001$). After 72 h, these two carotenoids, as well as the total carotenoid content of the fruit, diminished. Vitamin A activity was reduced as the storage time was extended from 24 to 72 hours (Duthie *et al.,* 1996).

Papaya is a rich source of antioxidants, such as vitamin A, E, and B complex and ascorbic acid, compared to carrots and oranges (Tietze, 2002). It is also the cheapest source of carotenoids, thiamine, riboflavin, niacin, vitamin B-6, and vitamin K (Bari *et al.,* 2006). Antioxidants, such as vitamins C, A, and E, as well as phenolics and carotenoids, diminish the oxidative stress caused by free radicals (Dosil-Díaz *et al.,* 2008). They are thought to control or reduce oxidative impairment in foods and biomolecules by suspending or inhibiting the oxidation process caused by reactive oxygen species, thereby improving product shelf-life and protecting biological systems (Duthie *et al.,* 1996). Antioxidant chemicals such as (B-carotene, ascorbic acid, and phenolics) are therapeutic and preventive against a variety of disorders, including aging, inflammation, and some malignancies (Vivekananthan *et al.,* 2003).

Carotenoids are the most fascinating antioxidants and have received special attention in addition to their antioxidant capabilities owing to their use as provitamin A (used as a source of Vitamin A) (Yahia *et al.,* 2017). Provitamin A carotenoids are extremely beneficial to our bodies in controlling Vitamin A toxicity since provitamins are converted to vitamin A when only the body is required.

Papaya varieties and their properties

There are two types of papaya based on their flesh color: red and yellow, which result from carotenoids accumulating in fruit cell chromoplasts. Red flesh papaya primarily contains lycopene, whereas yellow contains beta-carotenoids and -cryptoxanthin, which provide antioxidant activity and pro-vitamin A activity, respectively (Saengmanee *et al.,* 2018). Lycopene is responsible for the red flesh whereas β- carotene is responsible for the orange/yellow color (Blas *et al.,* 2010).

Table.1 Papaya major nutrient values

Nutrients	per 100-gram edible portion	Reference
Vitamin A	2000 IU	IU = international unit mg = milligram source; (Chaudhari *et al.,* 2000)
Vitamin C	46 IU	
Riboflavin	250 IU	
Niacin	200 IU	
Calcium	38 mg	
Phosphorus	1 mg	
Calcium	1.1 mg	
β- carotene	153-219 µg	(Pritwani & Mathur, 2017)

Table.2 Papaya maturity stage at room temperature storage

Maturity stage	Description
0	Completely developed fruit. 100% green skin color.
1	Yellow color does not cover more than 15% of the fruit surface.
2	1/4 mature. Fruit with up to 25% of the surface yellow, surrounded by a light green color.
3	1/2 mature. Fruit with up to 50% of the surface is yellow, surrounded by a light green color.
4	3/4 mature. Fruit with 50-75% of the surface yellow, surrounded by a light green color.
5	Mature. Fruit with 76-100% of the surface yellow. Only the area near the stem is green.

Source: *Export program for Brazilian papaya. Ministry of Agriculture, Livestock, and Environment.*

Table.3 Papaya nutrient retentions at different drying methods.

Research Conditions	Summary of findings	Reference
Effect of blanching, and temperature; Raw papaya was blanched in water with 0.2% Calcium lactate at different temperatures and times (100^{O}C, 5second; 95^{O}C, 10 seconds; 90^{O}C, 15 seconds; 85^{O}C, 20 seconds). Then treated samples were dried heat pump at 50^{O}C until 12% moisture.	Treated papaya at 95^{O}C for 10 seconds in the presence of Calcium lactate 0.2% and then dried by a heat pump dryer at 50^{O}C were the effective methods to retain more vitamin C and Beta-carotenoid.	(Minh *et al.,* 2019)
Drying effect Fresh ripe papaya fruits were sliced in different thicknesses (3mm, 5mm, and 7mm) respectively, for drying, then dried at 60° C in the oven and in lyophilized. The drying times were found as 7 to 9 h and 10-12 h for the oven and freeze-drying, respectively.	The drying time increased with the increase in sample thickness. Total carotenoid and ascorbic acid content in freeze-dried papaya powder was 15,535µg/100g and 54.07 mg/l00g, respectively whereas in oven-dried total carotenoid and ascorbic acid content was 1509 µg/100 g and 7.13 mg/l00g respectively. Freeze-dried has more retention of nutrients than oven dried. Sensory evaluation of papaya powder revealed that freeze-dried papaya powder had better quality than oven dried.	(Hemlata *et al.,* 2014)
Papaya fruit was cut into (2×2×2 cm^3) cubes and using freeze-drying frozen at −20± 1°C for 24h.	Beta-carotene (Fresh; 243.26 ±28; Freeze-dried; 223.42±24.08 (µg/100g); for Ascorbic acid (Fresh; 16.57 ± 0.36; Freeze-dried; 16.84±2.31 mg/100g). Freeze-drying did not exertany considerable effect on the β-caroteneand ascorbic acid concentration of	(Shofian *et al.,* 2011)

	papaya fruit.	
Fresh papaya with 11-12 ºBrix samples cut into cubes of 1.5 cm3. As an osmotic treatment solution (60%(w/w) sucrose, 0.1M CaCl$_2$, and 0.1M lactic acid), a fruit/solution ratio of 1:10 was used & immersed for 24 h. Hot air drying (HA) at 60 °C and air velocity at 1.5 m/s for 18 h (untreated) and for 32 h (osmotic treated) to achieve a moisture content of 17% dry basis.	Fresh papaya; 9.36±0.659(µg/100 g); Untreated papaya in(HA); 6.80±0.48(µg/100g); Osmotic treatment; 4.59±0.22 (µg/100 g); Osmotic treat-HA;3.87±0.19(µg/100g). In all treatments, the beta-carotenoid content is decreased.	(Siriamornpun *et al.,* 2015)
1. Subject to Sun drying at least 8 hours). A minimum temperature of 30 - 35 ºC is required with humidity below 60% 2. Samples were pre-frozen in a -70 °C freezer overnight. 3. Oven Dray method, 60 ºC for 24 hours to reach 10% moisture content 4. Deep Freeze method, at -70 and 80 °C for 24 hours.	Fresh; 5.84 mg/100g without drying; Freeze-dried; 8.80 mg/100g; Sun-dried; 2.96 mg/100g; Oven-dried; 3.44 mg/ 100g; Deep freeze; 4.56 mg/100g. The result showed that Freeze-Dried samples had the highest vitamin C levels (5.84 ± 0.83 mg/100g) while Sun-Dried had the lowest value of vitamin C (2.96 ± 0.47 mg/100g). In conclusion, the Freeze-Dried method resulted in the highest vitamin C retention. The highest retention of vitamin C will indicate the highest retention of other nutrients because vitamin C is easily lost.	(Mustapa & Ahmad, 2019)
Effect of drying/methods of drying	The beta-carotenoid contents of (µg/100 g); Freshly cut fruit cubes; 7616; Sun-drying; 1602; Solar cabinet drying 3130 whereas the total carotenoid content of (µg/100 g); Freshly cut fruit cubes; 27440; Sun-drying; 10373; Solar cabinet drying;13316. Papaya pulp dried in a solar cabinet drier retained carotenoids better than sun drying.	(Bhaskarachary, 2008)
Papaya fruits (cv. ''Sunrise Solo'') were collected, and then the pulp was obtained by manually peeling and removing the seeds. Pulp samples were stored at - 20 ^{o}C. Papaya pulp was dehydrated in a freeze-dryer at - 62 ^{o}C and 6.11 mbar for 48 h. For spray-drying, maltodextrin (14% DE concerning the weight of the fresh papaya pulp) was added directly to the papaya pulp and then dried with a spray dryer of 150 ^{o}C, air flow of 4.00 m3/min and air pressure of 3 kgf/cm^2.	Freeze- and spray-drying exhibited hopeful results in the detention of bioactive compounds and physicochemical proprieties of papaya pulp. Mostly the phenolic and flavonoid compounds were retained in both dried products. Ascorbic acid presented less retention (86.5%) in spray dried powder compared to freeze dried products. Freeze-drying resulted in lower retention of some prominent phenolic compounds than spray drier.	(Gomes *et al.,* 2018)
Chilean papayas (V. pubescens) of similar ripeness were selected to obtain samples of uniform shape, size, and ripening grade, based on skin color (80–90% of yellowness). The selected fruits were washed and peeled using a boiling solution of NaOH (10%) and fast peel additive and washed immediately with cold water to remove skin remains. The peeled fruits were cut into slices (9.0 × 1.5 cm) with 0.4 cm of thickness after the seeds and mucilage were	Papaya slices dried in a vacuum drier retained the highest amount of ascorbic acid (75%), antioxidant activity (43%), 39% of flavonoids, and 57% of β-carotene. On the other hand, solar drying caused the largest loss in phenolic compounds (8%), individual phenolic acids, antioxidant activity (68%), ascorbic acid (71%), and β-carotene (73%) due to the extended drying times and high-water content. The highest retention in flavonoids was observed for the infrared dried sample (58%) while the highest retention in β-carotene was observed for the	(Vega-Gálvez *et al.,* 2019)

removed.	convective dried sample (68%).	
Ripe yellow pulp papaya with 75% of skin color is yellow was used. The sample was peeled and sliced into cubes of a diameter of 5–6 mm and was divided into two portions, where half was treated by soaking in an ascorbic acid solution (34 g prepared in 1 L water), and the other half was left untreated.	The highest Total phenolic content, Total flavonoid content, total carotenoids, and ß- carotene were found in freeze-dried papaya samples, followed by refractance window, and solar glass house, and prominent statistical differences were observed b/n pretreated and untreated papaya in all drying technology. and the heist nutrient retentions were observed from ascorbic acid pretreated papaya fruit.	(Minuye *et al.,* 2020)

Red flesh papaya softens faster and has a shorter shelf life; however, some consumers prefer it, which is commonly referred to as "strawberry papaya" on the market. The carotenoid alignments of red- and yellow-fleshed Hawaiian Solo papayas revealed a significant concentration of lycopene (about 63% of the total carotenoid content) in red-fleshed fruit but none in yellow-fleshed fruit (Yamamoto, 1964). Yellow-fleshed fruit carried up to 75% of the total carotenoid content in the form of β-cryptoxanthin and β-carotene derivatives, whereas red-fleshed fruit contained around half that proportion. During ripening, lycopene is rapidly transformed into β-carotene by the action of lycopene beta-cyclase, which is then turned into xanthophylls by β-carotene hydroxylase (Blas *et al.,* 2010).

In cultivars with red pulp, lycopene conversion to cyclic carotenoids is slowed or even blocked, resulting in lycopene build-up (Yan *et al.,* 2011). β-carotene can be found in green leafy vegetables and yellow-orange fruits and vegetables. Growing conditions, maturity index, post-harvest handling conditions, and variety or cultivar can all influence the β-carotene concentration of fruits (peach, papaya, apricot, and tangerine) (Mangels *et al.,* 1993).

Papaya drying

Drying is a traditional food preservation method that increases product shelf life at room temperature (Lau and Taip, 2011) and reduces weight, volume, packaging material, storage, and transportation costs (Doymaz, 2005). According to (Kaleem *et al.,* 2016), drying can remove between 80 and 90 percent of water from a fresh product while retaining a significant amount of nutrients. Although the drying of food products can be performed using different technologies, their dried food product quality is significantly different. Fruits that have been dried should be of the highest quality possible, so it is important to optimize new drying technologies that include proper pre-treatments and dehydration methods. Likewise, it is important to determine the appropriateness of a dryer in the drying of fruits as the physical properties of fruits may change when various drying practices are applied. If the correct drying technique cannot be used, the dried product may not be satisfactory in terms of acceptability and nutrient value for the consumer. Therefore, choosing appropriate/innovative drying technologies for fruits and vegetables should be a big priority. To maximize the marketability of the dried product, cutting-edge drier technology must be able to reduce changes in the physical characteristics of the fruit.

Papaya drying technology

Papaya nutrient retention is affected by different drying techniques. In addition, a few other variables affect the nutritional content and quality of dried papaya.

Papaya slice thickness or puree

The drying rate and moisture content decreased with the thickness of the slices or purée. However, thin slices or puree can also lead to more flavor, color, and vitamin C losses (Ocoro-Zamora and Ayala-Aponte, 2013; Zhang *et al.,* 2018).

Pre-treatment prior to drying

Pre-treatment of papaya might be applied by edible coating or ascorbic/citric acid treatment. Dried papaya can benefit from edible coverings and ascorbic acid pretreatment that increase retentions of carotenoid, beta-carotene, vitamin C, and anti-oxidants, stop oxidation, and enhance sensory aspects (Zhang *et al.,* 2018)

Drying temperature and time

Higher temperatures and longer drying times can reduce the drying time and energy consumption, but they can also cause more degradation of bioactive compounds, such as carotenoids, phenolics, and flavonoids (Raut *et al.,* 2021).

Drying method

Different drying methods have different effects on the quality and nutritional value of dried papaya. Some of the common drying methods are hot air drying, freeze drying, vacuum drying, microwave drying, and solar drying. Each method has advantages and disadvantages in terms of efficiency, cost, environmental impact, and product quality.

Solar, oven, refractance window, freeze, and microwave drying of papaya pulp have been studied for their effects on the retention of nutritional compounds. These drying technologies display different drying rate patterns owing to differences in dryer designs, mechanisms of heat input, operating temperatures, and pressure conditions, among others. Solar drying can be carried out in various ways, including direct sun drying and indirect sun/solar drying (tray and glass hose dryer); however, they showed a different dried papaya quality even though they used the same solar energy. Direct sun exposure might lead to the loss of a major nutrient as it is in direct contact with the sun and the oxidation reaction is higher, but some methods of drying are better. Nevertheless, among the solar drying methods, glass-house drying mechanisms are the most preferable and maintain the quality of dried papaya products (Minuye *et al.,* 2021). The time was longer for sun/solar drying owing to the fluctuation of sunlight (ambient temperature) and laminar airflow over the product during the drying period (Babu *et al.,* 2018). However, the drying time for convective drying was considerably shorter when compared with the other drying technologies of solar and freeze drying. The continuous hot air circulation inside the oven rapidly removed the surface water from the product exposed with a large transfer area to hot dry air. This effect causes a rapid drying rate period, followed by a short falling rate period. A comparable activity was also noted by Lemus-Mondaca *et al.,* (2013) in papaya slices dried by convective drying under similar conditions.

Nonetheless, Vega-Gálvez *et al.,* (2019) discovered that papaya slices were dried with ultrasound or vacuum at a higher rate than convective drying. On the other hand, refractance window drying technology is the most suitable drying technology for fruit and vegetables. Drying principles are based on heat transmittance from boiling water, and it is a modern non thermal method for drying products (Forero *et al.,* 2015). The refractance window drying technology drying rate depends on slicing, load, and design; as a result, the drying time varies but is not longer than 2 h.

Nutrients found in fruits and vegetables are critical for human health, but they are sensitive to heat, and their retention during drying is determined by the type of pretreatment, drying time, and drying technology (Minuye *et al.,* 2021). Osmotic dehydration with ultrasound pretreatment followed by vacuum drying showed the highest retention of phenols and antioxidants compared to other drying techniques (Chandra *et al.,* 2021). Tray drying at 70 °C resulted in decreased moisture content, water activity, and shrinkage of the dried papaya, while higher osmotic solution concentration and lower process temperature retained maximum bioactive compounds (Mukherjee *et al.,* 2022). Furthermore, both freeze and spray drying are viable options for drying papaya pulp, with spray drying showing higher retention of phenolic and flavonoid compounds (Islam *et al.,* 2019). Osmotic pretreatment combined with freeze-drying at different working pressures affects the microstructure, color, and functional properties of papayas, with higher working pressures conserving bioactive compounds and minimizing structural deformation (Gomes *et al.,* 2018). Solar drying, which includes open-air, tray drying, and glasshouse methods, has been found to result in lower retention of total polyphenol content, total carotenoids, and beta-carotene, especially when compared to freeze-drying (Pham and Karim, 2022). Refractance window drying and freeze-drying were found to retain high levels of bioactive compounds, and ascorbic acid, as well as preserve quality attributes color, and flavor (Zalpouri *et al.,* 2020).

Here are some of the research findings of dried papaya, that are dried under different drying methods as shown in Table 2.

The nutritional value, variety type, ripening stage, and effects of different drying techniques on nutrient retention of papayas were evaluated in the current review. Papayas with yellow pulp have more provitamin/beta-carotene than those with red pulp, however, both types of pulp can help lower the prevalence of vitamin A insufficiency. The nutritional value of papaya increased significantly as the ripening stage increased. Various drying methods have their effect on papaya nutrient retention; however, other important elements that affect nutrient retention include temperature, slice/pure load, pretreatment before drying, and drying duration. Carotenoids, provitamins, and vitamin C are heat-sensitive components found in papayas that are better preserved in freeze and spray dryers than in other drying methods; moreover;

refractance window driers also maintain these nutrients better. Instead, due to the release of polyphenolic compounds from the food matrix during drying, which results in increased quantification of flavonoids and phenolic, the phenolic and flavonoid contents are higher for heat-induced dryers. In general, following freeze drying, refractance window is a prominent promising drying method for papaya. Promoting drying of papaya using eco-friendly techniques such as solar-glass houses and refractance windows can prolong the fruit's shelf life and preserve its nutrients, perhaps leading to an increase in fruit supply and accessibility. Products made from dried papaya may easily be included in meals and significantly help fulfill vitamin A needs.

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