

Post-harvest pre-treatments in vegetables to enhance shelf life- A review

Patel Manthan Chandrakant, Deven Verma*

Department of Horticulture, School of Agriculture, Lovely Professional University, Phaghwara, Punjab, India

Abstract

To suppress enzymatic activities, improve drying, and raise dried product quality, pretreatment is frequently employed before drying agro-products. The impact of several pretreatments on the qualities and drying traits of fruits and vegetables is compiled in the current work. They include thermal and non-thermal processes as physical treatments as well as different liquid and gas phases as chemical treatments. Traditional hot water blanching significantly reduces the number of unwanted enzymatic reactions, suppress and removal of bacterial growth, softens the texture, and speeds up the drying process. However, it causes items to lose desirable qualities like texture, soluble nutrition, color, aroma, fragrance and test as well. Modern techniques, like microwave, and ohmic heat for blanching (thermal treatments) and ultrasonic field and freezing as non-thermal treatments are effective and can lessen the loss of nutrients. Chemical pretreatments can significantly increase the rates of drying, but they also cause soluble nutrients to lose more of their nutrients and raise questions about the safety of the food that involve processing. To get around these issues, research on different types of pre-treatments should be done for better reduction in post-harvest losses and ensuring food security.

Keywords: pretreatment, drying, physical treatment, thermal blanching, dipping

Introduction

Vegetables are an essential part of the balanced diet of human being. They provide important nutrients in addition to giving diet a flavor, color, and diversity. They are a crucial source of antioxidants, compounds with anticancer properties, and complex dietary carbs which are vital for human health as well as well-being. Consumer purchase trends show a rising interest in fruits and vegetables, which provide health advantages in addition to their nutritional significance, as consumers become more conscious of the relationship between food and health. Additionally, infections, microbial toxins, and chemical residues-free items are in high demand from consumers.

Fresh produce storage is essential in India's current agriculture - based economy. Due to their vulnerability to fungal infection, tissue senescence, and transpiration, fruits and vegetables are very perishable. India loses over 20% of its fresh produce yield due to poor market accessibility, a lack of post-harvest infrastructure, and ignorance of proper farming methods. The horticulture sector is continuously looking for safer and better ways to preserve fresh food to increase shelf life, maintain disease resistance, and retain healthy phytochemicals.

A good post-harvest practices can significantly reduce the post-harvest losses. These practices are known as post-harvest treatments. It includes leaning, selecting, grading, and packing of fresh produce. Some crops, however, require unique care or treatments.

Drying is an important and popular technique for post-harvest preservation of agricultural produce. It involves lowering the water content of vegetables to a point where it stops microbial growth and reproduction as well as several moisture-dependent enzyme activities. Shelf life can be extended by this process in vegetable crops. (Wang *et al.*, 2014; Omolola *et al.*, 2017) [40, 28]. Vegetables benefit from drying since it significantly decreases their weight and volume while also lowering packaging, storage, and

transportation expenses (Kamilogul *et al.*, 2016). Additionally, drying agricultural items to less water content creates new product patterns with distinct physical and textural characteristics, such vegetable crisps.

Vegetables are frequently subjected to physical or chemical pretreatment prior to drying to hasten drying, consume less energy, and preserve product quality.

(Yu *et al.*, 2017) [43]. The pre-treatments are done prior to the drying which have a significant impact on the drying rate and quality of the goods (Fernandes and Rodrigues, 2008) [10, 11].

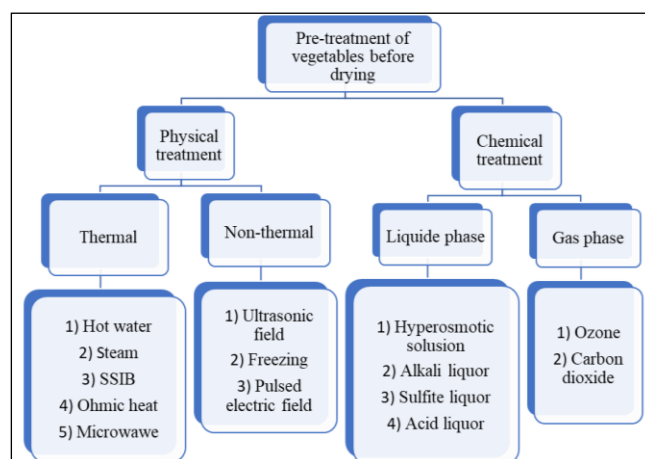


Fig 1: Pretreatment methods vegetables before thermal drying.

Physical treatment

Generally, two kinds of methods are used in physical treatments: Thermal and non-thermal treatments.

Thermal treatment

It is frequently used before drying. Its main objective is to inactivation of enzymes that cause fresh agricultural goods to decay. It also aims to lower the product's microbial

burden to improve preservation, soften tissues to speed up drying, and remove intracellular air to avoid oxidation.

1. Hot water blanching (Conventional method)

A general pre-treatment practice which is use before drying. It involves immersing fresh items in hot water at a temperature between 70 °C and 100 °C for a few minutes (Guida *et al.*, 2013) [13]. It is used to kill microorganisms and inactivation of enzymatic activities.

Because of its simple equipment and basic operation, conventional hot water blanching is currently the most widely used and commercially accepted procedure. It is frequently used as a preparation for agricultural goods to speed up drying and enhance product quality.

2. Steam blanching

Steam blanching systems have been created to replace hot water blanching treatment to reduce nutrients, particularly the water-soluble nutrients and solid content that dissolves in water, as well as to reduce effluent. Due to its minor leaching impact, steam blanching is important to help in retention of most minerals and water-soluble components as compared to hot water blanching.

However, because of the decrease in heat transmission, especially when the velocity of the steam is relatively low, softening of the tissue and unfavorable quality changes frequently arise from lengthy heating times. Because the product temperature is low than the steam during first stage of steam blanching, steam is condense on the surface of the goods, which may generate non-uniform blanching effects.

3. SSIB (Superheated steam impingement blanching)

To meet the rising demand for high-quality goods, which makes it crucial to reduce nutrient loss during the pretreatment, SSIB should use to replace stem blanching and hot water blanching. SSIB is recently developed thermal treatment. By immediately inactivating the enzyme oxidase and altering the skin and pulp tissue, SSIB has a great power to avoid browning and retain color.

Regarding cutting down on nutrient loss and oxidase inactivation time, SSIB technology excels. As a result, it will become more crucial in the processing of agricultural products. SSIB technology is still in its development, thus further research is required for large-scale industrial application.

4. Ohmic heat blanching

In ohmic heat blanching, heat is internally produced by the passage of alternating electrical current through a body, such as a food system that acts as an electrical resistance. Food product are put between two electrodes during ohmic heating, and the temperature of the product rises quickly. Ohmic heating has ability to significantly shorten the treatment time necessary to prevent causing severe thermal damage to labile material while yet delivering quick and generally uniform heating.

OH may be used as a different, quick blanching technique for fruits and vegetables (Icier *et al.*, 2006) [16], especially entire fruits and vegetables, where the procedure can be completed in a few seconds or less, independent of the product's size or form (Mizrahi, 1996) [26].

5. Microwave heating

Microwave heating occurs inside the wet biological materials, therefore in comparison with traditional heating method, microwave blanching has higher heating rate. This rate also rises with the amount of effective output power employed. Compared to standard procedures, MWB needs less processing time, have a greater heating capacity and retains more nutrients and can lower the drying time of agro-products (Krokida *et al.*, 2000).

But there are several limitations to MWB that prevent its implementation. On the one hand, it is exceedingly challenging to apply MW heating in a uniform manner; as a result, certain places receive insufficient heat and continue to be heated at lower temperatures than others.

Table 1: Effect of thermal pre-treatment in vegetable crops

	Vegetables	Pre-treatment method	Drying process	Conclusion	Reference
Hot water blanching	Asparagus	Placed in water at 70 °C, 80 °C and 90 °C.	Hot air drying	The retention of ascorbic acid was lower than 2%.	Zheng and Lu, 2011
	Pumpkin	Immersed in water at 98.3 °C for 1 min.	Hot air drying	Evaporated water constant fluxes was increased up to 12.40% 23.76% but reduced total sugar content of 8.24%–14.86%.	Filho <i>et al.</i> , 2016
Steam blanching	Broccoli	Blanched for different time limit 30, 60, 90, 120 and 180 seconds.	Hot air-drying	Rapidly inactivation of peroxidase enzyme activity within 60 s, ascorbic acids losses was less compared to hot water blanching.	Roy <i>et al.</i> , 2009
	Cauliflower	A single layer of the cauliflower florets suspended above 400 g of boiling water for 10 min	Without drying	The least reductive effect on glucosinolates, total monomeric anthocyanins, total phenols and antioxidant capacity, compared to hot water blanching and boiling treatment.	Volden <i>et al.</i> , 2009
SSIB	Yam	Blanched at 120 °C and 35% RH for 3, 6, 9 and 12 min. respectively.	Drying with air impingement	Blanched for 6 min reduced the drying time up to 35%.	Xiao <i>et al.</i> , 2012
	Red pepper	Blanched in 110 °C for 1, 2 and 3	Drying with Air	Retention of red pigments	Wang <i>et al.</i> , 2017

		minutes.	impingement	and ascorbic acid. Reduction of drying time up to 4.0 h compared to untreated.	
Ohmic heat blanching	Artichoke	Field (electrical) strength of 14 V/cm, when the core reached to 80 ± 2 °C, samples were maintained for 0, 60, 120, 180, 240 and 300 seconds.	Without drying	Color, protein and polyphenol content of the product were well preserved. Inactivated both PPO and POD at shorter times than conventional blanching.	Guida <i>et al.</i> , 2013
Microwave heating	Carrot	Microwave power (360–900 W), blanching time (10–300 second) & blanching water (0–150 mL).	Without drying	MWB times of the 630 and 900 W were lower than conventional blanching (CB), and more effective than CB in inactivating pectin methylesterase.	Sezer & Demirdoven, 2015
	Sweet potato	Input power: 1200 W, output 700 W, at maximum power.	Microwave assisted spouted bed drying (MWSB)	Microwave blanching improved the drying process and reduced the drying time.	Liu <i>et al.</i> , 2015

Non-thermal treatments

The quality and qualities of fruits and vegetables have apparently been adversely affected by thermal pre-treatments, including tissue cell membrane disintegration, protein denaturation, thermal loss of phytonutrients, and a lack of firmness and crispness. (Lee *et al.*, 2006). Non-thermal process techniques are receiving more and more attention in the food business because of their significant superiority in reducing the quality deterioration of agro-products (Rastogi, 2011) [29].

1. Ultrasonic field

Interest in the study of ultrasonic pretreatment on agricultural products is growing. Ultrasound is now often applying as a pretreatment procedure to aid in the drying of agricultural goods. It has been demonstrated that ultrasound may speeding up drying by changing the microstructure of plant tissue, boost product quality by cutting drying time, and improve component extraction (Cakmak *et al.*, 2016).

Ultrasonic pretreatment has benefits in that it can speed up processing while, to some extent, retaining product quality. This technology is still in lab scale stage due to difficulties in scaling up to the industry level.

2. Freezing

Pre-treatment with freezing is mostly carried out at -20°C for a few hours, followed by thawing to room temperature. Large ice crystals are generated during freezing, which causes the cellular structure to break down and the porous structure to set (Sripinyowanich & Noomhorm, 2013) [36]. A pre-treatment of freezing can speed up drying while maintaining product quality. However, freezing as a pre-treatment has a very limited application because it can't inactivate the enzymatic activities that induce browning causing reactions and may result in nutrient loss upon thawing. Additionally, it has a high operating cost and is only appropriate for certain high-value items.

3. Pulsed electric field (PEF)

Pulsed electric field (PEF) technology applies higher voltage electronic pulses of short duration to food that is sandwiched between two electrodes, often in the range between 15 to 80 kV/cm. In order to suppression of bacteria and enzymes at adequate temperature without drastically altering the food's native colour, flavour, texture, or nutritional value. PEF is typically applied to liquid or semisolid foods. In recent years, it has been demonstrated that PEF increased tissue disintegration and cell membrane permeability in order to enhance the mass transfer of plant components (Knorr *et al.*, 2011) [20].

Table 2: Effect of non-thermal pre-treatment in vegetable crops

	Vegetables	Pre-treatment method	Drying process	Conclusion	Reference
Ultrasonic field	Melon	Immersed in distilled water and submitted to ultrasonic waves in 10, 20, & 30 minutes.	Hot air drying	Time of drying was reduced about 25%, caused a reduction of reducing sugars up to 52% after 30min of ultrasound.	Rodrigues & Fernandes, 2007
	Brussel sprout and cauliflower	Pretreatment with 20 kHz probe and 40 kHz bath for 3 and 10 minutes.	Freeze drying or conventional drying	Drying rate was enhanced, drying time was reduced and improved rehydration properties.	Jambrak <i>et al.</i> , 2007
Freezing	Carrot	Blast air freezer, maintained frozen samples at -20 °C for overnight.	vacuum frying	Helped in maintaining phenolic content and antioxidant of the samples. Increased in crispness values, and reduced absorption of oil.	Albertos <i>et al.</i> , 2016
	Potato	In freezing chamber at -18 °C for 24 hours.	Drying with fluidized bed	It gave good rehydration. Freezing gave result in highest	Eshtiaghi <i>et al.</i> , 1994

				drying rates.	
Pulsed electric field	Potato	Pulses ranged from 5 to 120 and the pulse width was set at 100 ms.	Convective air drying	The diffusion co-efficients of pre-treated samples increased by 40%.	Arevalo <i>et al.</i> , 2004
	Beetroot	Pulse duration 10 ms, pulse repetition time 200 ms, number of pulses are 5500, inter-train pause 60 second and number of trains was 1000.	Convective air drying	Increased in rehydration time, with preservation of colors.	Shynkaryk <i>et al.</i> , 2008

Chemical treatments

In chemical treatments, there are generally two ways: Liquide phase and gas phase.

Liquide Phase

1. Hyperosmotic solution

One of the most popular pretreatments used before drying to save energy and enhance food quality is osmotic dehydration.

It entails submerge the material for respective hours in a hypertonic solution, often made of sugar or salt dilution. Osmotic pre-treatment involves the transfer of moisture from the interior to the hypertonic solution while the solute flows into the products through the semi-permeable membrane that is formed by the plant's cells (Cierzynska *et al.*, 2016).

Osmotic dehydration is frequently regarded as suitable energy-saving technique for the partial, non-evaporative removal of water from foods, but as mentioned above, there are also limitation on its use. Changes linked to leaching from the product should not be disregarded.

2. Alkaline liquor

The alkaline solution dipping procedure is typically applied to whole berry fruit because their hydrophobic wax-coated outer skin. Because the coating of wax mostly consists oleanolic acid, it offers a drying challenge because it causes a slow rate of moisture evaporation (Serratosa *et al.*, 2008). Alkali liquor dipping pretreatment speeds up the drying process, cuts down on drying time, and slows down product quality deterioration. Only when a significant reduction in

drying time is required can alkaline liquor dipping technology be used.

3. Sulfite solution

Sulfuring techniques has long been used in the food processing business to lower drying-related darkening and guard against quality deterioration in processing and storage (Miranda *et al.*, 2009). Generally, sulfur dioxide gas or water-soluble sulfide compounds like sodium metabisulfite, potassium metabisulfite, and sodium hydrogen sulphite are used to complete it. The predominant form of SO₂ conversion into the fruit is the bisulphate ion. Using of sulfites at low concentrations inhibits microbial activity and both enzymatic and non-enzymatic browning (Joslyn & Braverman, 1954) [18].

4. Acid liquor

Acid pre-treatment is widely used to alter the texture of agricultural products and inactivate enzymes, which all work to improve product quality. When the media pH is dropped to 3.0, polyphenol oxidase activity can be suppressed because its optimal pH range is between 6.0 and 7.0, which results in a reduction in the rate of enzymatic browning (Langdon, 1987) [21].

Since some pigments, like chlorophylls and carotenoids, are acid-sensitive, employing an acidic solution may result in the breakdown and color change of those pigments. For instance, in an acidic environment, chlorophylls are more likely to form pheophytin, which causes a change in hue from green color to olive brown color (Ngamwonglumlert *et al.*, 2017) [27].

Table 3: Effect of chemical (liquid phase) on vegetable crops

	Vegetables	Pre-treatment method	Drying process	Conclusion	Reference
Hyperosmotic solution	Chayote	Dipped in 25% NaCl at 25 °C for 3 hours. solution to fruit mass ratio of 4:1 was maintained.	Hot air drying	Initial moisture content reduced by 17%, drying time decreased by 20–65%.	Ruiz-Lopez <i>et al.</i> , 2010
	Mellon	Dipped in 70 °Brix sucrose at 42.5 °C for 1 hours, solution to fruit mass ratio of 4:1 was maintained.	Hot air drying	Cells breakdown, drying time reduced by 20%.	Fernandes <i>et al.</i> , 2008
Alkaline liquor	Ginger	Immersed in 2% ethyl oleate with 5% K ₂ CO ₃ , for 1minute.	Hot air drying	The time of drying decreased, capacity of rehydration was enhanced.	Deshmukh, 2013
	Tomato	Submerged in 2% ethyl oleate + 3% K ₂ CO ₃ , for 1 minute.	Hot air drying	Reduction in time of drying, rehydration ratio increased.	Doymaz & Ozdemir, 2014
Sulfite solution	carrots	Immersing in 2% sodium bisulfite solution for 5 minutes.	Convective drying	Prevented browning reactions.	Krokida, <i>et al.</i> , 2000
	Sweet potato	Dipped in 1% (w/v) NaHSO ₃ at room temperature for 1 minutes.	Hot air drying, freeze drying	Maintained higher lightness, ascorbic acid, and beta- carotene	Ahmed <i>et al.</i> , 2010

				content.	
Acid liquor	Tomato	Pretreated with citric acid solution (1:25, w/w) at 20±1 °C for 1 minute.	Hot air drying	Reduced drying time, and improved rehydration ratio.	Doymaz & Ozdemir, 2014
	Carrot	Blanching in boiling 0.7% (w/v) citric acid solution (to achieve the pH of 4 or 5).	Hot air drying	Drying rate was enhanced and produced dried carrots with red color.	Hiranvarachat <i>et al.</i> , 2011

Gas phase

1. Ozone

Ozone (O₃) stands out because it has a greater oxidation potential. It can be used as bactericide or fungicide and it not leaving any trace and after use it decomposes into oxygen compound. Ozone is commonly used to inactivate a range of bacteria, including Gram-positive and Gram-negative vegetative and sporulated forms, as well as cell membrane components, spores, fungal, or viral capsids, at relatively low concentrations and short contact times.

Ozone has recently been used to lessen the pesticide residue on fruits and vegetables. Hwang *et al.* (2002) [15] ozone wash was shown to minimize mancozeb and ethylene-thiourea residues in fresh apples and their products. It is crucial to create effective food processing techniques that would allow for a reduction in the active component residues. Ozone can, however, have adverse effects. It can encourage the oxidative breakdown of chemical components, which can lead to colour loss, an alteration in aromaticity and a misrepresentation of the original quality of the food (Miller *et al.*, 2013) [24].

2. Carbon dioxide

Due to its quality, environmental friendliness, and food safety, carbon dioxide (CO₂) pre-treatment offers most advantages. This adaptation is reflected almost immediately inside plant materials by the shift from a respiratory to fermentative anaerobic metabolism. Its general application form is known as the carbonic maceration (CM) technique, invented by Michel Flanzly in 1934. It entails placing the samples into a closed tank with a carbon dioxide-rich atmosphere (Tesniere & Flanzly, 2011) [37].

Sweet potato, tomato, and chilli have all been pretreated using the CM technique before drying, which significantly improved the drying process and dried product quality. Zhao *et al.* (2016) studied that the retention of phytochemicals and DPPH radical scavenging activity of CM pre-treatment samples were 13.83%-78.18% and 10.04%-14.09% greater than those samples which was untreated respectively.

However, CM preparation causes some anaerobic respiration, which affects the texture and smell of the products (Chen *et al.*, 2017). Tomato quarters dried more quickly with CM, but their water activity and titratable acidity were both significantly higher and their texture was poorer than the control sample (Turgut *et al.*, 2017).

The CM pre-treatment technique therefore offers considerable potential for speeding up the drying process, improving the quality of dried items, and removing residues from dangerous chemical reagents. However, because treatment typically lasts between 12 and 72 hours, the application of CM may be inhibited. While CM pretreatment is taking place, it's possible that the product's texture and flavor will deteriorate.

Conclusion

The drying rate is essential for preventing food quality deterioration and increasing energy efficiency in the manufacturing of dried foods. Pretreatment is a crucial procedure frequently used before to drying to speed up drying, preserve quality, and reduce product microbial burden. The various pretreatment methods discussed here each have advantages and disadvantages. The initial water content, drying time, and energy consumption were all decreased by osmotic dehydration, but the product quality was negatively impacted, such as the loss of minerals, vitamins, and colors due to their migration from tissue into the osmotic solution. The use of chemical additives in dipping procedures can improve the drying process and preserve food quality, but the residues they leave behind may compromise food safety. Traditional blanching techniques effectively deactivate a number of enzymes, soften the texture, and eradicate bacteria, improving the quality and speeding up the drying process. It was deemed negative, nevertheless, because it led to items losing their texture, soluble nutrients, color, and scent. Innovative blanching techniques include microwave, ohmic, and high-humidity hot air impingement blanching could minimize nutrition loss and outperform conventional methods. To solve the problems of heat-sensitive chemical degradation, emerging non-thermal technologies may be a better option than thermal blanching. Future research requirements are explored and determined to close the gap between laboratory research and industrial uses of various pretreatment technologies.

Reference

- Ahmed M., Sorifa AM, Eun JB. Effect of pretreatments and drying temperatures on sweet potato flour. *International Journal of Food Science & Technology*,2010;45(4):726-732.
- Albertos I, Martin-Diana AB, Sanz MA, Barat JM, Diez AM, Jaime I *et al.* Effect of high-pressure processing or freezing technologies as pretreatment in vacuum fried carrot snacks. *Innovative Food Science & Emerging Technologies*,2016;33:115-122.
- Arevalo P, Ngadi MO, Bazhal MI, Raghavan GSV. Impact of pulsed electric fields on the dehydration and physical properties of apple and potato slices. *Drying Technology*,2004;22(5):1233-1246.
- Çakmak RŞ, Tekeoğlu O, Bozkır H, Ergün AR, Baysal T. Effects of electrical and sonication pretreatments on the drying rate and quality of mushrooms. *LWT-Food Science and Technology*,2016;69:197-202.
- Chen K, Gao L, Li Q, Li HR, Zhang Y. Effects of CO₂ pretreatment on the volatile compounds of dried Chinese jujube (*Zizyphus jujuba* Miller). *Food Science and Technology*,2017;37:578-584.
- Ciurzyńska A, Kowalska H, Czajkowska K, Lenart A. Osmotic dehydration in production of sustainable and

- healthy food. *Trends in Food Science & Technology*,2016:50:186-192.
7. Deshmukh AW, Varma MN, Yoo CK, Wasewar KL. Effect of ethyl oleate pretreatment on drying of ginger: characteristics and mathematical modelling. *Journal of Chemistry*, 2013, 1-6.
 8. Doymaz İ, Özdemir Ö. Effect of air temperature, slice thickness and pretreatment on drying and rehydration of tomato. *International Journal of Food Science & Technology*,2014:49(2):558-564.
 9. Eshtiaghi MN, Stute R, Knorr D. High-pressure and freezing pretreatment effects on drying, rehydration, texture and color of green beans, carrots and potatoes. *Journal of Food Science*,1994:59(6):1168-1170.
 10. Fernandes FA, Rodrigues S. Application of ultrasound and ultrasound-assisted osmotic dehydration in drying of fruits. *Drying Technology*,2008:26(12):1509-1516.
 11. Fernandes FA, Gallão MI, Rodrigues S. Effect of osmotic dehydration and ultrasound pre-treatment on cell structure: Melon dehydration. *LWT-Food Science and Technology*,2008:41(4):604-610.
 12. Filho LM, Frascareli EC, Mauro MA. Effect of an edible pectin coating and blanching pretreatments on the air-drying kinetics of pumpkin (*Cucurbita moschata*). *Food and Bioprocess Technology*,2016:9(2):859-871.
 13. Guida V, Ferrari G, Pataro G, Chambery A, Di Maro A, Parente A. The effects of ohmic and conventional blanching on the nutritional, bioactive compounds and quality parameters of artichoke heads. *LWT-Food Science and Technology*,2013:53(2):569-579.
 14. Hiranvarachat B, Devahastin S, Chiewchan N. Effects of acid pretreatments on some physicochemical properties of carrot undergoing hot air drying. *Food and Bioprocess Technology*,2011:89(2):116-127.
 15. Hwang ES, Cash JN, Zabik MJ. Degradation of mancozeb and ethylenethiourea in apples due to postharvest treatments and processing. *Journal of Food Science*,2002:67(9):3295-3300.
 16. Icier F, Yildiz H, Baysal T. Peroxidase inactivation and color changes during ohmic blanching of pea puree. *Journal of Food Engineering*,2006:74(3):424-429.
 17. Jambrak AR, Mason TJ, Paniwnyk L, Lelas V. Accelerated drying of button mushrooms, Brussels sprouts and cauliflower by applying power ultrasound and its rehydration properties. *Journal of Food Engineering*,2007:81(1):88-97.
 18. Joslyn MA, Braverman JBS. The chemistry and technology of the pretreatment and preservation of fruit and vegetable products with sulfur dioxide and sulfites. *Advances in Food Research*,1954:5:97-160.
 19. Kamiloglu S, Toydemir G, Boyacioglu D, Beekwilder J, Hall RD, Capanoglu E. A review on the effect of drying on antioxidant potential of fruits and vegetables. *Critical Reviews in Food Science and Nutrition*,2016:56:110-129.
 20. Knorr D, Froehling A, Jaeger H, Reineke K, Schlueter, O, Schoessler K. Emerging technologies in food processing. *Annual Review of Food Science and Technology*,2011:2(2):203-235.
 21. Langdon TT. Preventing of browning in fresh prepared potatoes without the use of sulfiting agents. *Food technology*,1987:41(5):64-67.
 22. Lee CY, Bourne MC, Van Buren JP. Effect of blanching treatments on the firmness of carrots. *Journal of Food Science*,1979:44(2):615-616.
 23. Liu P, Mujumdar AS, Zhang M, Jiang H. Comparison of three blanching treatments on the color and anthocyanin level of the microwave-assisted spouted bed drying of purple flesh sweet potato. *Drying Technology*,2015:33(1):66-71.
 24. Miller FA, Silva CL, Brandao TR. A review on ozone-based treatments for fruit and vegetables preservation. *Food Engineering Reviews*,2013:5(2):77-106.
 25. Miranda G, Berna À, Salazar D, Mulet A. Sulphur dioxide evolution during dried apricot storage. *LWT-Food Science and Technology*,2009:42(2):531-533.
 26. Mizrahi S. Leaching of soluble solids during blanching of vegetables by ohmic heating. *Journal of Food Engineering*,1996:29(2):153-166.
 27. Ngamwonglumlert L, Devahastin S, Chiewchan N. Natural colorants: Pigment stability and extraction yield enhancement via utilization of appropriate pretreatment and extraction methods. *Critical Reviews in Food Science and Nutrition*,2017:57(15):3243-3259.
 28. Omolola AO, Jideani AIO, Kapila PF. Quality properties of fruits as affected by drying operation. *Critical Reviews in Food Science and Nutrition*,2017:57(1):95-108.
 29. Rastogi NK. Opportunities and challenges in application of ultrasound in food processing. *Critical Reviews in Food Science and Nutrition*,2011:51(8):705-722.
 30. Rodrigues S, Fernandes FA. Dehydration of melons in a ternary system followed by air-drying. *Journal of Food Engineering*,2007:80(2):678-687.
 31. Roy MK, Juneja LR, Isobe S, Tsushida T. Steam processed broccoli (*Brassica oleracea*) has higher antioxidant activity in chemical and cellular assay systems. *Food Chemistry*,2009:114(1):263-269.
 32. Ruiz-López II, Huerta-Mora IR, Vivar-Vera MA, Martínez-Sánchez CE, Herman-Lara E. Effect of osmotic dehydration on air-drying characteristics of chayote. *Drying Technology*,2010:28(10):1201-1212.
 33. Serratos MP, Lopez-Toledano A, Medina M, Merida J. Drying of Pedro Ximenez grapes in chamber at controlled temperature and with dipping pretreatments. Changes in the color fraction. *Journal of Agricultural and Food Chemistry*,2008:56(22):10739-10746.
 34. Sezer DB, Demirdoven A. The effects of microwave blanching conditions on carrot slices: optimization and comparison. *Journal of Food Processing and Preservation*,2015:39(6):2188-2196.
 35. Shynkaryk MV, Lebovka NI, Vorobiev E. Pulsed electric fields and temperature effects on drying and rehydration of red beetroots. *Drying Technology*,2008:26(6):695-704.
 36. Sripinyowanich J, Noomhorm A. Effects of freezing pretreatment, microwave-assisted vibro-fluidized bed drying and drying temperature on instant rice production and quality. *Journal of Food Processing and Preservation*,2013:37(4):314-324.

37. Tesniere C, Flanzy C. Carbonic maceration wines: Characteristics and winemaking process. *Advances in Food and Nutrition Research*,2011:63:1-15.
38. Turgut SS, Küçüköner E, Karacabey E. Improvements in drying characteristics and quality parameters of tomato by carbonic maceration pretreatment. *Journal of Food Processing and Preservation*,2018:42(2):13282.
39. Volden J, Borge GIA, Hansen M, Wicklund T, Bengtsson GB. Processing (blanching, boiling, steaming) effects on the content of glucosinolates and antioxidant-related parameters in cauliflower (*Brassica oleracea* L. ssp. botrytis). *LWT-Food Science and Technology*,2009:42(1):63-73.
40. Wang H, Zhang M, Mujumdar AS. Comparison of three new drying methods for drying characteristics and quality of shiitake mushroom (*Lentinus edodes*). *Drying Technology*,2014:32(15):1791-1802.
41. Wang J, Fang XM, Mujumdar AS, Qian JY, Zhang Q, Yang X *et al.* Effect of high-humidity hot air impingement blanching (HHAIB) on drying and quality of red pepper (*Capsicum annuum* L.). *Food Chemistry*,2017:220:145-152.
42. Xiao HW, Yao XD, Lin H, Yang WX, Meng JS, Gao ZJ. Effect of SSB (superheated steam blanching) time and drying temperature on hot air impingement drying kinetics and quality attributes of yam slices. *Journal of Food Process Engineering*,2012:35(3):370-390.
43. Yu Y, Jin TZ, Xiao G. Effects of pulsed electric fields pretreatment and drying method on drying characteristics and nutritive quality of blueberries. *Journal of Food Processing and Preservation*,2017:41(6):1-9.
44. Zhao D, Wang Y, Zhu Y, Ni Y. Effect of carbonic maceration pre-treatment on the drying behavior and physicochemical compositions of sweet potato dried with intermittent or continuous microwave. *Drying Technology*,2016:34(13):1604-1612.
45. Zheng H, Lu H. Effect of microwave pretreatment on the kinetics of ascorbic acid degradation and peroxidase inactivation in different parts of green asparagus (*Asparagus officinalis* L.) during water blanching. *Food chemistry*,2011:128(4):1087-1093.