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A review-the impact of different drying method on bioactive compounds and antioxidant activity of fruits and vegetables

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Abstract
Fruits, vegetables and plant products are the richest sources of antioxidant compounds that play an important role for prevention of many chronic diseases such as various types of cancer, cardiovascular disorders. Suitable drying system should be adopted for prevention of degradation of phytochemicals, microbial contamination. Drying methods also effects the retention of nutritive value and their long-term stability. Literature revealed that there are different methods for drying *viz*., solar dying, sun drying, oven drying, freeze drying, vacuum drying and microwave drying etc. This review emphasis the effect of different drying processes on bioactive compounds of fruits and vegetables.

Keywords: drying techniques, fruits, vegetables, conventional drying process, antioxidant compounds

Introduction
Vegetables and fruit consumptions may reduce risk of chronic diseases such as cardiovascular diseases, arthritis, chronic inflammation and cancers as reported in literature [1]. It is ancient method for preservation of food and food products. The main aim of drying is to extend the shelf life of product by avoiding the growth of microorganism, to preserve the bioactive constituents of fruits and vegetables and their nutritive value [2]. There are numerous drying techniques offered to dehydrate different kinds of raw materials in order to obtain products of a high quality dependent on processing parameters [3]. There are numerous drying methods for drying of fruits, vegetables and other products *viz*., sun drying, solar drying, oven drying, freeze drying, vacuum drying and microwave drying etc. hot- air drying process is long term drying method. High temperature may cause degradation of bioactive constituents of fruits and vegetables [4]. Amongst these techniques, freeze drying technique considered to be best method for prevention of degradation of Phytoconstituents. Because of low temperature applied in freeze drying process which allow to higher retention of bioactive compounds. Change in phenolic compounds, flovanoid compounds and their antioxidant activity by two different drying methods- hot-air drying and freeze drying which is summarized in table-1. Carrot, taro, beet root, eggplant and tomato are good source of natural antioxidants. It have been found that the effect on total phenolic, flavonoid content and antioxidant activity in carrot, taro, beet root and eggplant were higher by freeze drying than hot air drying except in tomato[1, 5]. Freeze dried bitter gourd preserve antioxidant phytochemicals when compared to microwave and hot air oven drying method [6]. Fresh murtilla fruit showed lesser antioxidant activity (DPPH and ABTS) than lyophilized form of fruit. This decrease may be possible by variations in the composition of polyphenolic compounds, such gallic acid and catechin [7]. Strawberries are rich source of bioactive compounds and nutrients. Freeze dried strawberries retain their nutritional components, colour, odour and antioxidant activity as compare to hot drying method [8, 9]. Freeze dried chokeberries have been found higher phenolic compounds, flavonoid compounds and antioxidant activity when compared to sun dried and hot air dried chokeberries [10].

Table1: Changes in antioxidant activity, total phenolic content and total flavonoid content subjected to hot air drying and freeze drying.

Sr. no	Plant name	Total phenolic content(mg GAE/g sample)		Total flavonoid content (mg standard/100g)		DPPH radical scavenging % inhibition		FRAP (mg TE/g)		References
		Hot air dried	Freeze dried	Hot air dried	Freeze Dried	Hot air dried	Freeze dried	Hot air dried	Freeze dried	
1	Carrot and carrot peel (*Daucus carrota* L.)	33.1 ± 0.5(↓)	36.6 ± 0.5 (↑)	8.9 ± 0.2 (↓)	11.2 ± 0.2(↑)	6.7 ± 0.3(↓)	12.6 ± 0.3(↑)	16.20 ± 0.94(↓)	21.67 ± 1.18(↑)	[1, 5]
2	Taro (*Colocasiaesculenta*)	8.6 ± 0.5(↓)	93.5 ± 0.9(↑)	6.2 ± 0.3(↓)	7.1 ± 0.5(↑)	30.6 ± 1.3(↓)	48.5 ± 0.1(↑)	-	-	[1]
3	Tomato (*Lycopersicon esculentum Mill*)	21.6 ± 1.0(↓)	61.2 ± 0.7(↑)	15.1 ± 0.1(↑)	14.7 ± 0.2(↓)	24.0 ± 1.6(↓)	26.0 ± 0.3(↑)	-	-	[1, 11]
4	Beet root (*Beta vulgaris*)	31.4 ± 0.8(↓)	229.2 ± 1.6(↑)	9.1 ± 0.1(↓)	15.3 ± 0.9(↑)	46.1 ± 3.3(↓)	50 ± 2.7(↑)	-	-	[1]
5	Eggplant	49.2 ± 0.7(↓)	454.5 ± 0.5	38.8 ±	42.1 ± 0.2(↑)	86.9 ± 0.1(↓)	92.3 ± 0.5(↑)	-	-	[1]

	(Solanum melongena)			0.1(↓)						
6	Bitter gourd (*Momordica charantia*)	1180.39 (↓)	13533.33(↑)	-	-	20.17(↓)	45.59(↑)	1749.80(↓)	20913.57(↑)	[6]
7	Murtilla fruit (*Ugni molinae Turcz*)	720.9 ± 41.1(↓)	2192.4 ± 181.9(↑)	-	-	3567.4 ± 47.0(↓)	3677.6 ± 27.0 (↑)	-	-	[7]
8	Strawberry fruit (*Fragaria × ananassa*)	1541.5(↓)	2411.5(↑)	-	-	20.22_1.19 (↓)	46.13_0.45(↑)	13.6(↓)	16.8(↑)	[8, 9]
9	Hawthorn fruit (*Crataegus*)	9.68(↓)	12.64(↑)	-	-	29.47(↓)	32.77(↑)	-	-	[12]
10	Apple (*Malus pumila*)	3.20(↓)	3.99(↑)	-	-	253(↓)	144(↑)	-	-	[13]
11	Red fleshy watermelon rind powder (*Citrullus lanatus*)	218.39 ± 0.34(↓)	180.58 ± 0.57(↑)	123.31± 0.52(↓)	193.43 ± 0.24(↑)	23.49 ± 0.10(↓)	25.81 ± 0.60(↑)	319.43 ± 062(↓)	348.70 ± 0.20(↑)	[14]
12	Chokeberries (*Aronia melanocarpa*)	792.3±6.8(↓)	919.7±6.9(↑)	58.5±4.3 (↓)	66.15±4.5(↑)	73.8 %(↓)	74.3 %(↑)	-	-	[10]

(↓) decrease, (↑) increase; - no data is reported

The effect of other drying techniques such as vacuuming, hot air, freeze and microwave drying effect on phytochemicals of plants like vitamin C, flavonoids, phenolic compounds, carotenoids is given in Table 2. Various factors are responsible for degradation of vitamin C such as longer drying time causes oxidation of vitamin C and it may cause loss of this vitamin [15]. Different drying techniques affect vitamin C in fruits and vegetables some examples- Hot air oven dried apples, apricots, sweet potatoes and carrots were found to have lower level of ascorbic acid. Increase level of vitamin C was found in freeze dried papaya, muskmelon and carrot as depicted in table 2. Carotenoids are the plant pigments which provide color to plants, fruits and flowers. They have health promoting effect. Degradation of carotenoids during drying it has been attributed to their high sensitivity to oxidation [16]. Microwave drying and steaming may decrease the carotenoid content in apricots, carrots and sweet potatoes but in freeze dried muskmelon, red guava and carrot were found no change the concentration of carotenoids was reported. Flavonoids contain a large number of polyphenol compounds which are found in flowers, fruits, stems, bark and root. Flavones, flavonones, flavanols, anthocyanidins, isoflavones and chalcones are subclasses of flavonoids. High temperature techniques leads to degradation of flavonoids, can cause breakdown of cell wall thus release out the flovanoids from cell wall, which may also end up with higher extractability of compounds from the samples [17, 18]. Hot air oven dried blueberries, raspberries, papaya and mangoes, vacuuming dried pomegranate, hot and vacuuming dried pear were found decrease the level of polyphenol compounds whereas freeze dried blueberries, red onions, were found to be no change in the level of total flovanoids.

Table 2: Effect of different drying techniques on Phytoconstituents of plants.

Sr. no	Plant name	Drying method	Effect on Phytoconstituents	References
1	Apple (*Malus pumila*)	Air drying (47°C)	Decrease Vitamin C	[19]
		Oven drying (70 °C)	Decrease Vitamin C	[20]
		Cold air drying	Decrease total phenolic content, decrease antioxidant capacity	[19]
2	Apricot (*Prunus armeniaca*)	Hot air drying	Decrease Ascorbic acid,	[21]
		Sulphating	Decrease ascorbic acid and total carotenoids	[22]
3	Blueberry (*Cyanococcu*)	Hot air drying (65°C)	Decrease Total phenolic, total antocyanins	[23]
4	Carrot (*D. c. subsp. sativus*)	Microwave drying(60°C),	Decrease α and β carotene	[24]
		Freezing	Increase vitamin C, α and β carotene	[25]
5	Mango (*Mangifera indica* L)	Cold air drying,	Decrease Total phenolic content, decrease total phenolic	[19]
		Hot air + drying vacuuming (240W)	Decrease total phenolic content	[19]
6	Blue berry (*Cyanococcus*)	Freezing(-60°C)	Increase total phenolic content but decrease anthocyanin	[19]
7	Muskmelon (*Cucumis melo*)	Freezing	Increase vitamin C and β carotene	[26]
8	Papaya (*Carica papaya*)	Freezing	Increase vitamin C, increase total antioxidant activity decrease total phenolic	[19]
		Hot air drying + vacuuming (360W)	Decrease total antioxidant activity, decrease total phenolic content	[19]
9	Red guava (*Psidium guajava*)	Freezing (-54°C)	Increase total carotenoids	[27]
10	Red onion (*Allium cepa*)	Freezing (-70°C)	Increase total flavonols, total anthocyanin, quercetin	[28]
11	Sweet potato (*Ipomoea batatas*)	Steaming (800W)	Decrease ascorbic acid and β carotene, increase total phenolic contents	[24]
		Microwave drying (5 KPa)	Decrease total anthocyanin	[29]
12	Pear (*Pyrus*)	Hot air + vacuuming (240W)	Decrease total phenolic	[19]
13	Pomegranate (*Punica granatum*)	Vacuuming (240-480W)	Decrease total phenolic contents	[30]
14	Sour cherry (*Prunus cerasus*)	Vacuuming (120-480W)	Increase quercetin, glucoside	[31]
15	Raspberry (*Rubus idaeus*)	Hot air drying (71.1°C)	Decrease kaemopferol and quercetin	[32]

Conclusion

Now-a-days increasing concern about food quality, lyophilization process could be considered as a valuable alternative to preserve the food. Freeze drying is considered as the best method because low-temperatures applied in this process allow the highest retention of bioactive compounds comparable with the raw material. It is concluded that freeze-drying technique is superior in comparison to the other drying methods, in terms of preserving the antioxidant compounds. Long term drying of fruits and vegetables may affect their colour, texture, phenolic and flavonoid content and antioxidant activity.

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