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Quality Traits of Some Vegetables as Affected by Pretreatments and Drying Methods

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Abstract: Carrots, sweet potatoes and eggplant are considered rich sources of fiber, vitamins, minerals and several of bioactive compounds that are able to get rid of free radicals and reduce the risk of degenerative diseases. This study was carried out to evaluate the effect of pre-treatments (soaking in 0.5% citric acid solution for 5 min and blanching in hot water at 90°C for 5 min) and drying methods (hot air oven and sun drying) on the drying characteristics, physicochemical, bioactive compounds and microbial load of carrot, sweet potato and eggplant slices. Ascorbic acid, total carotenoids, phenolic compounds, flavonoids and ascorbic acid content were 56.96 mg /100g, 55.28 mg/ 100g, 200.82 m GAE / 100g and 128.67 mg RE / 100g, respectively. The obtained results indicated that the untreated and sun-dried carrot, sweet potato and eggplant had greater moisture content (10.34%) than the chemically treated and oven-dried (8.71%). The oven dried samples had the lowest moisture. The tested vegetable slices treated with citric acid and dried in a hot air oven were found to have a high retention of ascorbic acid. The treated vegetable slices prepared by blanching in hot water and drying in the oven had higher total carotenoids than the treated citric acid solution and dried by sun dying. Whereas, total phenolic and flavonoids contents were high in slices treated with citric acid compared with control or blanching samples. Microbial analysis showed that hot air oven-dried carrots, sweet potatoes and eggplant had the lowest total viable count. While microbial load exhibited the highest bacteria, yeasts & mould counts for tested vegetable slices dried by sun drying. Thus, the obtained results suggest that hot air oven drying can be appropriately used to obtain vegetable powders with good functionality, microbial properties and chemical composition.

Key words: Carrots · Sweet Potato · Eggplant · Pretreatments · Drying Methods · Physicochemical Analysis · Bioactive Compounds · Microbiological Analysis

INTRODUCTION

Drying is one of the most widely used, natural and ancient methods of food preservation. It stops the biochemical changes in perishable plant materials by lessening the moisture content of the material [1]. Dehydrated products have a longer shelf life and a higher nutrient concentration than fresh vegetables [2]. Drying can be done using a number of conventional and advanced techniques. Cabinet dryer (oven) removes moisture by releasing a stream of hot air under controlled conditions, in the open sun, or solar drying methods. Heat applied in the drying process changes the nutritional and sensory attributes of the product [3].

Dehydration is considered an important process in the food processing industry since it helps preserve food and improves food quality and hygienic conditions. This means that specific fruits and vegetables can be consumed throughout the year and acute shortages caused by the shift in agricultural seasons can be avoided [4]. Such an approach has been used for centuries by means of traditional sun-drying techniques [5].

Open-air, uncontrolled solar drying is an uncontrolled process in which the produce is exposed to direct sunlight, rain and dust. Produce that is dried, using open-air uncontrolled solar drying is undesirable because the drying method causes variability in product quality [6, 7].

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Carrots (*Daucus carota* L.) are a widely grown root vegetable and were ranked the sixth most-produced vegetable globally in 2018 [8]. They are considered to be one of the healthiest vegetables as they are rich in bioactive compounds like carotenoids and dietary fibers and are also a good source of carbohydrates and minerals such as Ca, Fe, Na, K, Mg, Cu, Zn and vitamin C [9, 10]. However, due to their high-water content, carrots are susceptible to spoilage which leads to high post-harvest losses and quality degradation.

The sweet potato (*Ipomea batatas* L.) is a plant that belongs to the Convolvulaceae family. It is hearty vegetable that yield food in numerous nations, in including Egypt. Typical sweet potato yields in 2015 was 10.43 ton/feddan but in 2020 expanded to 10.45 ton/feddan. Sweet potato creation expanded in Egypt from 408280 tons to 450985 tons during 2015-2020. The region reaped additional expansion from 11933 to 13154 ha, separately [11].Sweet potatoes are an important staple crop that grows in many regions of the world and are known to be rich in dietary fiber, minerals, vitamins and antioxidants, including anthocyanins, phenolic acids, beta-carotene and tocopherol [12, 13]. Consumption of sweet potatoes can prevent the growth of human colon, leukemia, stomach cancer cells and ameliorate diabetes in humans [14, 15].

Eggplant (*Solanum melongena* L.), a member of the Solanaceae family, has a production value of 56.618.843 tons worldwide in 2020 [8]. Eggplant has a very limited shelf life for freshness and physiological and morphological changes occur after harvest. Its limited shelf life is one of the important restrictions in the trade of eggplant as a fresh product. Eggplant is primarily consumed as cooked vegetable and is commonly characterized by low calorie content and relatively high contents in fiber, K and as well as high antioxidant activity due to presence of high contents of phenolic compounds [16]. Drying of eggplants is important for ensuring easy shipment and yearlong use in regions such as the Middle East and for use as an ingredient in soups and sauces [17]. The consumers today are demanding the convenience health products that mimic the properties of fresh ones. It is a great challenge for food researchers and industry to produce such high quality dried products [18, 19].

Therefore, the objective of this study was to determine the effect of different pretreatments (dipping in citric acid solution and blanching in hot water) and drying techniques (oven drying and natural sun drying) on the drying properties, physicochemical, bioactive compounds and microbial aspects of carrot, sweet potato and eggplant slices.

MATERIALS AND METHOS

Materials: Raw carrots (*Daucus carota* L.), orange sweet potato tubers (*Ipomoea batatas* L) and eggplant (*Solanum melongena* L.) were purchased from the local market (Tanta city, El-Gharbia governorate, Egypt).

Methods:

Pretreatments of Tested Vegetable Slices: All the vegetables were washed with clean tap water, drained and the inedible parts removed and peeled. Fresh vegetables are sliced to 5mm thickness using fruits slicer prior to pretreatment processes. The pretreatments were carried out as follows: C = control (untreated), CA = dipping in citric acid solution 0.5% for 5 min., B = blanching by hot water at 90°C for 5 min.

All treated vegetable slices were dried by two methods. An electrical oven air drier was used to spread the slices on the stainless steel in one layer and subjected to 55°C for 8-12 hr. to reach moisture content of about 14-16% [20]. The second method was sun drying under normal atmosphere conditions where one layer of slices was put on stainless steel trays, exposed to direct sun for 6 hours /day for 7 days at 28-30°C [21].

Analytical Methods: Moisture content, protein, ether extract, ash, crude fiber, total soluble solid (TSS), ascorbic acid, acidity as citric, pH value, total and reducing sugars were determined according to the methods described by A.O.A.C [22]. Total carbohydrates content was calculated by differences as followed:

Carbohydrate = 100 - (moisture + protein + fat + ash + Fiber).

Browning index of the alcoholic extracts for fresh and dried vegetables samples were determined according to the method of Ranganna [23] and total carotenoids were determined according to Askar and Treptow [24].

The total phenolic content as gallic acid (mg GAE/100g) was determined according to the Folin-Ciocalteau method as described by Gorinsten *et al*. [25]. Water activity measurement was determined according to method by Hasturk-Sahin and Ulger [26]. Antioxidant activity of vegetable slices in ethanolic extract was determined by DPPH radical (1,1-diphenyl 1-2 picrylhydrazyl) according to Singh *et al.* [27].

Microbiological Analysis: Total plate count, yeasts & moulds, and pathogenic bacteria including *E. coli*, *Staphylococcus* and *Salmonella* were determined as outlined by Oxoid [28].

Statistical Analysis: The data obtained were statistically analyzed by analysis of variances as described by SPSS, ver 16.0 [29]. Significant differences among individual means were analyzed by Duncan's multiple range tests [30].

RESULTS AND DISCUSSION

Physicochemical Composition of Fresh Carrots, Sweet Potatoes and Eggplant: The data in Table (1) revealed that the moisture content of tested vegetables ranged from 69.08 - 91.26% wet basis, with the highest being eggplant (91.26%) and lowest being sweet potato (69.08%), While protein content ranged from (5.25% to 28.08%). Also, the obtained results showed that, fresh sweet potatoes recorded higher values of in crude fiber, total sugar, reducing sugars, total carbohydrates and TSS (2.56, 10.29, 6.34, 25.76 and 26.89%) than carrots and eggplant. Protein recorded high in eggplant followed by sweet potato and carrot; it was 1.33 and 1.18 and 0.76%, respectively. The acidity measured as citric acid in carrot, sweet potato and eggplant was 0.12, 0.16 and 1.31%. In this regard, Assous *et al*. [31] reported that total acidity, total sugars, fat, protein, ash and crude fiber were 3.18, 53.85, 6.71, 8.28, 3.59 and 22.46% of fresh eggplant on dry weight basis, respectively.

The low carbohydrate level of fresh eggplant fruits, which recorded 3.95% makes them good for diabetic patients and individuals watching their weight. The total sugar content of fresh sweet potatoes reported by Zhang *et al*.[32] varied from 4.8% to 12.5% (dry weight basis) depending on varieties. Lai *et al*. [33] reported that the total sugar contents of seven fresh sweet potato cultivars were between 4.50 and 8.41% (dry weight basis). From the same table, it could be noticed that sweet potato had the highest value of carotenoids (40.70 mg/100g), followed by carrot (37.44 mg/100), whereas eggplant recorded the highest value of total phenolics (67.89 mg GAE /100g). There was reduction in ascorbic acid content after drying. All drying methods significantly cause loss of vitamin C [34] and this could be attributed to the fact that vitamin C is highly prone to oxidative destruction in the presence of heat, light, oxygen, enzymes, moisture and metal ions [35].

Table 1: Physicochemical properties (%) of fresh carrot, sweet potato and eggplant

	Tested vegetables		
Parameters (%)	Carrot	Sweet potato	Eggplant
Moisture	87.34±0.23^{b}	69.08±0.20^{c}	91.26±0.19^{a}
Protein	0.76±0.12^{b}	1.18±0.17^{a}	1.33±0.13^{a}
Ether extract	0.38±0.07^{a}	0.58±0.09^{b}	0.33±0.03^{a}
Ash	0.89±0.10^{b}	o.84±0.02^{b}	1.66±0.12^{a}
Crude fiber	1.43±0.09^{b}	2.56±0.12^{a}	1.47±0.15^{b}
Total sugars	5.32±0.11^{b}	10.29±0.10^{a}	4.29±0.09^{c}
Reducing sugar	3.26±0.20^{b}	6.34±0.13^{a}	2.34±0.14^{c}
Non reducing sugars	2.06±0.14^{b}	3.95±0.12^{a}	1.95±0.11^{c}
Total carbohydrates	10.09±0.12^{b}	25.76±0.06^{a}	3.95±0.15^{c}
TSS	11.42±0.22^{b}	26.89±0.19^{a}	5.46±0.12^{c}
Acidity (as citric acid %)	0.12±0.02^{b}	0.16±0.05^{b}	1.31±0.08^{a}
pH value	6.31±0.18^{a}	6.33±0.13^{a}	5.46±0.20^{b}
Ascorbic acid (mg/100g)	18.56±0.12^{c}	25.88±0.17^{b}	33.54±0.15^{a}
Phenolic compounds (mg GAE/100g)	21.35±0.14^{c}	27.47±0.11^{b}	67.89±0.13^{a}
Total carotenoids (mg/100g)	37.44±0.19^{b}	40.79±0.16^{a}	16.33±0.07^{c}
TS	13.66±0.10^{b}	30.92±0.13^{a}	8.74±0.09^{c}
Browning index (at 420nm)	0.042±0.03^{b}	0.034±0.02^{b}	0.132±0.07^{a}

Carbohydrates (%) = 100 - (% moisture + % ash + % fat + % protein + % crude fiber) (Rodriguez-Jimenez *et al*., 2018). Mean ± Standard deviation of three determinations Values with in a row followed by different letters are significantly differently at p=0.05 according to Danken's multiple range tests. The results represent the mean ± SD triplicate assay

Effect of Pretreatments and Drying Methods on the Drying Characteristics of Tested Vegetable Slices: The determination of the drying characteristics as a function of drying conditions could help in predicting suitable drying conditions [36]. The effect of different pretreatments such as dipping in citric acid solution and blanching in hot water on drying moisture content, drying time and drying rate of tested vegetable slices was studied and the obtained data are presented in Table (2). From the results it could be noticed that oven drying time was 7.52, 6.12 and5.24hrs in order to reach 8.23, 10.23 and 6.33% moisture content in the control carrot, sweet potato and eggplant samples, respectively at temperature of 55ºC, with a sharp decrease in the moisture content during the first 3 hours. Data shows also that the treated vegetables slices recorded higher drying time than the untreated ones (control). Blanched slices in hot water are higher than control and slices treated with citric acid (0.5%), because of blanching increased the initial moisture content of the carrots, sweet potato and eggplant from 87.34 % to 88.14 %, 69.08 to 71.32% and 91.26 to 92.66%, respectively. The use of blanching increased the drying time of tested vegetables. This increase in drying time due to pretreatment is reported for other fruits and vegetables including peach slices, apples and chili [37, 38].

Table 2: Drying characteristics of different drying methods on respective moisture content of dried vegetable samples

Drying methods	Treatments	Initial moisture content (%)	Final moisture content (%)	Drying time (hr.)	Rate of drying (moisture content%/hr.)
Hot air drying			**Carrots**		
	C	87.34	10.23	7.52	1.38
	CA	87.66	9.26	8.11	1.29
	HW	88.14	10.11	8.33	1.23
			Sweet potato		
	C	69.08	8.23	6.12	1.23
	CA	70.44	7.55	6.32	1.17
	HW	71.32	8.21	6.44	1.17
			Eggplant		
	C	91.26	6.33	5.24	1.32
	CA	91.42	5.52	5.26	1.27
	HW	92.66	5.42	5.31	1.30
Sun drying			**Carrots**		
	C	87.34	11.22	65.44	14.66
	CA	87.66	10.43	687.34	15.34
	HW	88.14	10.62	68.42	15.42
			Sweet Potato		
	C	69.08	10.22	72.18	13.78
	CA	70.44	9.45	74.22	13.45
	HW	71.32	9.62	74.15	12.89
			Eggplant		
	C	91.26	9.45	79.54	15.44
	CA	91.42	9.20	80.33	16.35
	HW	92.66	9.33	81.38	16.47

C = Control, CA = Dipping in citric acid, HW = Blanching in hot water

Effect of Pretreatments and Drying Methods on the Physicochemical Properties of Tested Vegetable Slices: The effects of pretreatments and drying methods on the physicochemical properties of tested vegetable slices were studied and the results are shown in Table (3). Data revealed that total soluble solids (TSS) in control slices were 11.34, 25.89 and 5.22% in carrot, sweet potato and eggplant slices dried in oven while they were recorded at 11.35, 26.14 and 5.52% in slices dried with sun drying, respectively. Slices treated by citric acid had the highest TSS content compared to slices treated with blanching or control. Data showed that slices dried in the oven had higher TSS than slices dried in the sun. This may be due to moisture content. A study by Shin and Lee [39] showed similar results as they found that the soluble solid content increased as the water content of the agricultural products decreased. TSS and reducing sugar increased significantly as the drying time increased. This was because the soluble solid content per unit weight had increased due to decreases in water content [40].

In the obtained results, it could be noticed that carrot, sweet potato and eggplant slices pretreated with citric acid had more acidity compared to the control or slices treated with blanching by hot water. The reduction in acidity may be due to leaching out acids from slices during blanching. The acidity was higher in tested vegetable slices dried in oven than dried with sun. The total acidity (TA) values of dried vegetable slices increased compared to the TA of control samples due to the organic acids in apples that become more concentrated as the temperature increases [41]. In this concern, Samia El-Safy [42] noticed a slight decrease in total acidity after dehydration of persimmon slices.

The untreated samples (control) had a pH level of 5.22, 5.51, 5.34 and 5.33, 5.72, 5.42 for carrot, sweet potato and eggplant which were dried by hot air oven and sun drying, respectively. A decrease in pH level was observed across the pretreatment concentration of citric acid which decreased from 5.22 to 4.68, 5.51 to 4.62 and 5.34 to 4.67, respectively, for carrot, sweet potato and eggplant slices treated with citric acid. Similar findings were obtained by Ngoma *et al*. [43] who reported that citric acid had a greater effect on the pH level of sweet potato flour compared to other treatments because of its high acidity. The pH and titratable acidity of tested vegetable slices, dried by the sun are low compared to dried slices in the oven.

From the same table, it could be observed that a_w was lower in slices treated by citric acid solution compared to control or blanching in hot air. Also, slices dried in a hot air oven had lower water activity values compared to those dried in the sun. The final water activity of the dried samples was around 0.389-472. This makes the tested vegetables slices more stable based on the inhibition of microbial growth ($\leq$0.60) and enzymatic activity ($\leq$0.75) [44, 45].

The highest browning index was found in control samples dried in the oven or in the sun. All studied vegetable samples treated with citric acid had lower browning compared to the blanching by hot water treated samples.

These results are agree with Bisnoi *et al*. [46] they found that the sun dried garlic powders had a higher values of browning index compared to powders were dried by other methods.

Effect of Pretreatments and Drying Methods on the Bioactive Compounds of Tested Vegetable Slices: Results in Table (4) indicate that pretreatments and drying methods had effect on ascorbic acid since a pronounced

Table 3: Physicochemical characteristics of tested vegetables slices dried by different drying methods

	Hot air oven drying			Sun drying		
Composition (%)	C	CA	B	C	CA	B
Carrot						
TSS	11.34±0.10[b]	11.39±0.08[a]	11.36±0.13[a]	11.35±0.12[ab]	11.37±0.05[a]	11.35±0.09[ab]
Acidity	0. 741±0.04[b]	1.192±0.01[a]	0.668±0.09[c]	0.787±0.10[bc]	1.21±0.03[a]	0.660±0.4[c]
pH	5.22±0.01[ab]	4.68±0.09[c]	5.13±0.02[b]	5.33±0.07[a]	4.82±0.11[c]	5.19±0.08[ab]
a_w	0.461±0.11[b]	0.420±0.12[c]	0.442±0.03[c]	0.472±0.02[a]	0.433±0.06[bc]	0.423±0.02[c]
Browning Index	0.455±0.09[b]	0.344±0.14[d]	0.346±0.07[d]	0.568±0.04[a]	0.438±0.03[c]	0.440±0.12[c]
Sweet potato						
TSS	25.89±0.05	29.78±0.04	28.69±0.09	26.14±0.03	26.23±0.02	26.41S±0.11
Acidity	0.542±0.13[c]	1.321±0.16[a]	0.422±0.14[c]	0.522±0.22[b]	1.66±0.23[a]	0.431±0.22[c]
pH	5.51±0.15[a]	4.62±0.15[b]	5.58±0.13[a]	5.72±0.32[a]	4.76±0.24[b]	5.78±0.19[a]
a_w	0.478±0.08[ab]	0.389±0.10[c]	0.397±0.08[c]	0.543±0.05[a]	0.432±0.10[bc]	0.449±0.07[b]
Browning Index	0.563±0.11[a]	0.487±0.04[c]	0.491±0.07[c]	0.575±0.11[a]	0.533±0.10[b]	0.538±0.03[b]
Eggplant						
TSS	5.22±0.12[a]	5.54±0.10[a]	5.33±0.12[ab]	5.52±0.13[a]	5.43±0.08[ab]	5.24±0.15[b]
Acidity	0.637±0.03[b]	1.965±0.12[a]	0.522±0.20[b]	0.628±0.04[b]	1.889±0.06[a]	0.515±0.12[b]
pH	5.34±0.11[a]	4.79±0.12[b]	5.45±0.19[a]	5.42±0.12[a]	4.67±0.08[b]	5.52±0.09[a]
a_w	0.422±0.05[a]	0.392±0.02[d]	0.416±0.04[b]	0.428±0.03[a]	0.402±0.06[c]	0.419±0.03[b]
Browning Index	1.254±0.16[a]	0.523±0.15[d]	0.433±0.12[e]	1.546±0.11[a]	0.612±0.17[c]	0.787±0.13[b]

Acidity expressed as % citric acid, Browning index at 420 nm, C = Control, CA = Citric acid, B = Blanching with hot water, Mean ± Standard deviation of three determinations, Values with in a row followed by different letters are significantly differently at $p \leq 0.05$ according to Danken's multiple range tests. The results represent the mean ± SD triplicate assay

Table 4: Effect of pretreatment and drying methods on the bioactive compounds and antioxidant activity of tested vegetable slices

		Oven drying			Sun drying		
	Fresh*	C	CA	B	C	CA	B
Carrot							
Ascorbic acid (mg/100g)	56.96±0.07[a]	31.45±0.10[c]	34.25±0.12[b]	32.33±0.14[c]	29.78±0.10[e]	30.66±0.09[d]	29.89±0.21[e]
Total carotenoids (mg/100g)	55.28±0.11[d]	132.55±0.15[b]	134.23±0.14[a]	136.43±0.13[a]	130.23±0.16[c]	131.51±0.15[bc]	132.22±0.10[b]
Total Phenolic (mg GAE/100g)	200.81±0.08	190.30±0.18	196.12±0.22	197.77±0.12	184.45±0.14	191.88±0.12	192.44±0.16
Total flavonoids (mg CE/100g)	128.67±0.12[c]	312.06±0.10[a]	310.44±0.14[a]	311.08±0.10[a]	309.27±0.09[b]	304.33±0.05[b]	302.45±0.17[b]
Antioxidant activity (%)	97.22±0.03[a]	73.50±0.12[c]	79.29±0.07[bc]	81.29±0.10[b]	70.36±0.08[d]	73.34±0.09[c]	69.58±0.12[d]
Sweet potato							
Ascorbic acid (mg/100g)	147.89±0.10[a]	109.11±0.19[b]	115.67±0.13[b]	99.79±0.09[c]	97.67±0.03[d]	100.45±0.02[c]	99.38±0.15[c]
Total carotenoids (mg/100g)	53.48±0.11[a]	118.22±0.12[d]	119.67±0.11[d]	120.13±0.13[c]	122.04±0.16[c]	124.33±0.10b[c]	128.45±0.11[b]
Total Phenolic (mg GAE/100g)	136.77±0.18[a]	91.23±0.01[c]	100.47±0.11[c]	114.33±0.07[b]	88.67±0.12[d]	96.37±0.05[d]	100.89±0.04[c]
Total flavonoids (mg CE/100g)	35.13±0.04[d]	65.12±0.08[a]	66.23±0.11[a]	63.33±0.10[ab]	62.89±0.09[ab]	63.77±0.17[ab]	59.34±0.05[c]
Antioxidant activity (%)	88.45±0.15[a]	81.23±0.18[c]	82.12±0.10[b]	81.33±0.12[c]	80.34±0.09[d]	81.41±0.08[c]	82.48±0.12[b]
Eggplant							
Ascorbic acid (mg/100g)	195.66±0.11[a]	130.16±0.09[c]	140.32±0.11[b]	95.67±0.10[e]	110.31±0.09[d]	117.28±0.02[d]	83.69±0.03[e]
Total carotenoids (mg/100g)	48.22±0.07[a]	20.45±0.03[c]	18.32±0.10[d]	21.65±0.06[b]	20.23±0.07[c]	17.39±0.12[d]	21.19±0.11[b]
Total Phenolic (mg GAE/100g)	227.24±0.11[b]	213.25±0.06[c]	224.11±0.04[a]	220.22±0.13[b]	210.890.17[d]	213.44±0.11[c]	211.07±0.19[d]
Total flavonoids (mg CE/100g	341.15±0.04[a]	312.34±0.16[c]	322.07±0.14[b]	314.37±0.03[b]	303.44±0.21[d]	310.47±0.18[c]	304.27±0.13[d]
Antioxidant activity (%)	78.56±0.19[a]	76.45±0.14[c]	77.68±0.12[b]	77.39±0.18[b]	68.55±0.22[e]	69.33±0.16[d]	68.92±0.14[e]

C= Control, CA= treated with Citric acid (0.5%), B= Blanching with hot water; Mean ± Standard deviation of three determinations; Values with in a row followed by different letters are significantly differently at p=0.05 according to Danken's multiple range tests. The results represent the mean ± SD triplicate assay

decrease in its content occurred in all cases of pretreatment for the tested vegetable slices. The initial ascorbic acid content was 56.96, 147.89 and 195.66 mg/100g (DW) of fresh carrot, sweet potato and eggplant, respectively. All tested vegetables slices treated by blanching in hot water recorded the highest decrease of ascorbic acid. The reason is that heating destroyed the cell structure, releasing a large amount of vitamin C from the cells, a part of which was oxidized by oxygen [47]. Results appear to indicate that the ascorbic acid content of tested vegetable decreased after drying process, and the decrement was higher in tested vegetable slices dried by sun drying comparing with hot air drying.

Tested vegetables slices pretreated with blanching in hot water showed higher values of total carotenoids than the control slices or slices dipping in citric acid solution,

Table 5: Microbiological aspects (× 10^2cfu/g) of fresh and dried carrot, sweet potato and eggplant slices

Treatments	Total plate count	Moulds & Yeasts	*E. coli*	*Staphylococcus*	*Salmonella*
		Hot air oven			
		Carrot			
C	18.66±0.12^{d}	13.27±0.09^{c}	Nd	Nd	Nd
CA	14.89±0.14^{e}	12.56±0.04^{d}	Nd	Nd	Nd
B	12.56±0.10^{ef}	10.33±0.13^{f}	Nd	Nd	Nd
		Sweet potato			
C	21.26±0.16^{c}	14.23±0.15^{c}	Nd	Nd	Nd
CA	17.99±0.12^{d}	13.69±0.12^{d}	Nd	Nd	Nd
B	14.33±0.13^{e}	10.480.11^{f}	Nd	Nd	Nd
		Eggplant			
C	13.59±0.05^{ef}	10.77±0.03^{f}	Nd	Nd	Nd
CA	10.57±0.04^{f}	10.23±0.11^{f}	Nd	Nd	Nd
B	9.48±0.10^{g}	8.49±0.08	Nd	Nd	Nd
		Sun drying			
		Carrot			
C	26.33±0.23^{b}	20.12±0.24^{a}	Nd	Nd	Nd
CA	24.41±0.25^{bc}	19.58±0.21^{a}	Nd	Nd	Nd
B	22.35±0.21^{c}	11.47±0.23^{e}	Nd	Nd	Nd
		Sweet potato			
C	31.42±0.22^{a}	18.34±0.19^{b}	Nd	Nd	Nd
CA	25.67±0.27^{b}	16.45±0.18^{bc}	Nd	Nd	Nd
B	20.55±0.19^{c}	13.58±0.15^{c}	Nd	Nd	Nd
		Eggplant			
C	20.23±0.12^{c}	13.77±0.14^{c}	Nd	Nd	Nd
CA	16.17±0.15^{d}	12.18±0.11^{d}	Nd	Nd	Nd
B	14.28±0.10^{e}	9.89±0.06^{g}	Nd	Nd	Nd

All values are means ± SD; Nd = not detected; All values within the same column with different superscript letters are significantly different from each other at ($p<0.05$)

due to the stabilizing effect of blanching on carotenoids followed by treatment with citric acid. The present results agree with those obtained by Prakash *et al*. [48] who demonstrated that blanching as a heat treatment will inactivate the enzymes (peroxidases and lipoxygenases) which have a capacity in degrading β-carotene and β-carotene degradation is delayed. The highest concentration of carotenoids was found in sweet potato slices treated with balancing in hot water and dried by oven drying (128.45 mg/100g). The carotenoids content of dried sweet potatoes ranged between 118.22 to 128.45 mg/100g, while the corresponding values for dried eggplant slices were found in the range of 17.39 to 21.19 mg/100g. The highest value was recorded in fresh eggplant (48.22 mg/100g DW).The highest phenolic content was found in carrot, sweet potato and eggplant slices dried by hot air oven and treated with blanching by hot water (197.77, 114.33 and 220.22 mg GAE/100g, respectively) compared to slices dried by sun drying (which recorded 192.44, 100.89 and 211.07 mg GAE/100g, respectively). It is possibly due to the liberation of phenolic compounds from the matrix during process. These results are in agreement with Samia El-Safy [42] who showed that total phenolic content of persimmon slices increased when dried in the oven. Also, Lavelli *et al.* [49] stated that higher temperatures release more of the bound polyphenols due to breakdown of cell wall phenolic compounds. The same trends were observed in total flavonoids for the tested vegetable slices.

Effect of Pretreatments and Drying Methods on Microbial Aspects of Tested Vegetable Slices: The changes in microbial counts (total bacterial count, mould & yeasts, *E. coli*, *Staphylococcus* and *Salmonella*) of both vegetable samples as affected by pretreatment and drying processes were studied and the obtained results are given in Table (5). Pretreatments of slices evidently caused a great reduction in both total bacterial count and mould & yeasts count. It could be noticed that treating carrot, sweet potato and eggplant slices by blanching in hot water decrease the TPC than citric acid treatment, while all control samples recorded the highest number for both TPC and moulds & yeasts. Microbial analysis showed that hot air oven-dried carrot, sweet potato and eggplant slices had the lowest total viable count (12.56, 14.33 and 9.48×10^2g/CFU/g, respectively), compared to 22.35×10^2g/CFU/g, 20.55 and 14.28×10^2g/CFU/g, respectively, for slices dried by sun drying. Thus, the results suggest that hot air oven drying can be appropriately used to obtain vegetable slices with good sanitary or hygienic properties, microbial property and chemical composition. The lower levels of TPC and moulds & yeasts in tested vegetable slices that were dried by hot air oven could be attributed to the highest temperature applied by hot air drying. In this regard, Whitfield [50] showed that temperatures ranging from 37.2°C to 71°C were found to effectively kill bacteria.

No pathogenic bacteria such as *E. coli*, *Staphylococcus* and *Salmonella* were detected in the tested vegetable slices. This finding could be due to lower water activity, which leads to more stability of the food products, in addition to the presence of good sanitary conditions during different processing steps as well as packing and low moisture content of dehydrated carrot, sweet potato and eggplant samples.

CONCLUSION

In this work, the effects of pretreatments and drying methods such as sun drying and hot air oven drying on drying rate, drying time, chemical composition, physiochemical properties, bioactive compounds and microbiological aspects of dried vegetable slices are examined. Pretreatments improve the quality characteristics of the dried vegetables slices by hot air oven when when compared with the corresponding samples dried by natural sun drying.

Hot air oven drying also resulted in a decreased total viable and mould count, which could enhance the keeping quality of the products. The results obtained therefore show that hot air oven drying can be used to replace sun drying for the production of vegetable slices.

REFERENCES

1. Raja, K.S., F.S. Taip, M.M.Z. Azmi and M.R.I. Shishir, 2017. Effect of pre-treatment and different drying methods on the physicochemical properties of *Carica papaya* L. leaf powder. Journal of the Saudi Society of Agricultural Sciences. Advance online publication.
2. Chauhan, S. K. and C.R. Sharma,1993. Development of instant dehydrated sag. Beverage and Foods World, 20 (4): 25-26.
3. Khan, M.J., F. Yeasmin, M.N. Islam, R. Ahmmed, P.C. Das and M.H. Ali, 2019. Effect of pretreatments on drying behavior of eggplant. Journal of Bangladesh Agricultural University, 17(1): 105-109.
4. Akeredolu, A.A. and L.O. Adebajo, 2013. Microflora of three dehydrated vegetables, British Microbiology Research Journal, 3(3): 295-308.
5. Sagar, V.R. and P.K. Suresh Kumar, 2010. Recent advances in drying and dehydration of fruits and vegetables: A review. J. Food Sci. Technol., 47: 15-26.
6. Madhlopa, A., S.A. Jones and J.D. Kalenga, 2002. A solar air heater with composite absorber systems for food dehydration. Journal of Renewable Energy, 27: 27-37.
7. Sagar, V.R. and S.P. Kumar, 2010. Recent advances in drying and dehydration of fruits and vegetables: A review. Journal of Food Engineering, 47(1): 15-26.
8. FAOSTAT, 2020. Comparison of World crops production quantities 2018. Food and Agriculture Organization Corporate Statistical Database. Available online at http://www.fao.org/faostat/en/# compare, updated on 2/18/2020, checked on 5/18/2020.
9. Frias, J., E. Peñas, M. Ullate and C. Vidal-Valverde, 2010. Influence of drying by convective air dryer or power ultrasound on the vitamin C and β-carotene content of carrots. Journal of Agricultural and Food Chem., 58(19): 10539-10544.
10. Velescu, I.D., I. Tenu, P. Carlescu and V. Dobre, 2013. Convective air drying characteristics for thin layer carrots. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Food Science and Technology. https://doi.org/10. 15835/buasvmcn-fst: 9619.
11. FAO, 2021. Statistics Division. https://www.fao.org/ faostat/en/#data/QC
12. Van Jaarsveld, P.J., D.W. Marais, E. Harmsea, S.M. Laurie, P. Nestel and D.B. Rodriguez-Amaya, 2006. Retention of β-carotene in boiled, mashed orange fleshed sweet-potato. Journal of Food Composition and Analyses, 19(4): 321-29.
13. Yildirim, Z., O. Tokusoglu and G. Ozturk, 2011. Determination of sweet potato (*Ipomoea batatas* L.) genotypes suitable to the Aegean Region of Turkey. Turkish Journal of Field Crops, 16: 48-52.
14. Kurata, R., M. Adachi, O. Yamakawa and M. Yoshimoto, 2007. Growth suppression of human cancer cells by polyphenolics from sweet potato (*Ipomoea batatas* L.) leaves. Journal of Agricultural and Food Chemistry, 55: 185-190.
15. Ludvik, B., M. Hanefeld and M. Pacini, 2008. Improved metabolic control by *Ipomoea batatas* (Caiapo) is associated with increased adiponectin

and decreased fibrinogen levels in type 2 diabetic subjects. Diabetes, Obesity and Metabolism, 10: 586-592.

16. Jose, R.S., M.C. Sanchez-Mata, M. Camara and J. Prohens, 2014. Eggplant fruit composition as affected by the cultivation environment and genetic constitution. J. Sci. Food Agric., 94(13): 2774-2784.
17. Santacatalina, J.V., C. Ozuna, J.A. Carcel, J.V. Garcia-Perez and A. Mulet, 2011. Quality assessment of dried eggplant using different drying methods: hot air drying, vacuum freeze drying and atmospheric freeze drying, in Proceedings of the 11th International Congress on Engineering and Food, Athens, Greece, May 2011.
18. Sablani, S.S., 2006. Drying of fruits and vegetables: Retention of nutritional/functional quality. Dry Technol., 24: 123-135.
19. Mujumdar, A.S. and L.X. Huang, 2007. Global r&d needs in drying. Dry. Technol., 25: 647-658.
20. Akyidiz, A., S. Aksay, H. Benli, F. Kiroglu and H. Fenercioglu, 2004. Determination of changes in some characteristics of persimmon during dehydration at different temperatures. J. Food Eng., 65: 95-99.
21. Asgar, M.A., R. Yamauchi and K. Kato, 2003. Structural features of pectins from fresh and sun dried Japanese persimmon fruit. Food Chem., 87: 247-251.
22. AOAC., 2012. Offcial Methods of Analysis of the Association of Offcial Analytical Chemists, 20th ed., 2012.
23. Ranganna, S., 1986. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd ed.; Tata McGraw Hill Pub. Comp. LTd.; New Delhi, India.
24. Askar, A. and H. Treptow, 1993. Quality assurance in tropical fruit processing. Springer-Verlag, Berlin, Heidelberg, Germany.
25. Gorinstein, S., M. Zemser, M. Weitz, S. Halevy, J. Deutsch and K. Tilis, 1994. Fluorometric analysis of phenolics in persimmons. Biosci. Biotech. Bioch., 58: 1087-1092.
26. Hastürk-Şahin F. and P. Ülger, 2010. Comparison of different methods of tomato drying. Doctoral thesis Namýk Kemal University, Tekirdag.
27. Singh, R.P., M. Chidamdara and G.K. Jayaprakasha, 2002. Studies on the antioxidant activity of pomegranate (*Punica granatum*) peel and seed extracts using *in vitro* models J. Agric. Food Chem., 50: 81-86.
28. Oxoid, M., 1992. The oxoid manual of culture media and other laboratory services. 5th Edition Basingstock: oxid Hd.
29. SPSS, 1997. SPss uses Gide statistics version 8. Copy right SPss Inc., USA, Washington, D.C., USA.
30. Duncan's, D., 1955. Multiple range and multiple F test. Biometric., 11: 1-42. Edition ASSOC, Office. Anal. Chem. Arlington.
31. Assous, M.T.M., A.T.M. El-Kady and A.S. Dyab, 2014. Effect of Pretreatments on Controlling Enzymatic Browning before Drying of Eggplant Slices. Alex. J. Food Sci., 11(1): 21-29.
32. Zhang, Z., C.C. Wheatley and H. Corke, 2002. Biochemical changes during storage of sweet potato roots differing in dry matter content. Postharvest Biol. Tech., 24: 317-325.
33. Lai, Y.C., C.L. Huang, C.F. Ching, C.C. Lien and W.C. Liab, 2013. Studies of sugar composition and starch morphology of baked sweet potatoes (*Ipomoea batatas* (L.) Lam. J. Food Sci. Technol., 50(6): 1193-1199.
34. Kiremire, B.T., E. Musinguzi, J.K. Kikafunda and F.B. Lukwago, 2010. Effects of vegetable drying techniques on nutrient content: a case study of south-western Uganda. African Journal of Food, Agriculture, Nutrition and Development, 10(5).
35. Russell, L. and R.L. MacDowell, 1989. Vitamins in animal nutrition; comparative aspects to human nutrition. Academic press Inc.
36. Hamdami, N., M. Sayyad and A. Oladegaragoze, 2006. Mathematical modeling of Thin Layer Drying Kinetics of Apples Slices. In 13th World Congress of Food Science and Technology 2006 (324-324).
37. Hossain, M.A. and B.K. Bala, 2007. Drying of hot chilli using solar tunnel drier. Solar Energy, 81(1): 85-92.
38. Doymaz, I., 2010. Effect of citric acid and blanching pretreatments on drying and rehydration of Amasya red apples. Food and Bio-products Processing, 88(2-3): 124-132.
39. Shin, M.Y. and W.Y. Lee, 2011. Physical properties and preference of a steamed sweet potato slab after mild hot air drying. Korean Journal of Food and Cookery Science, 27: 73-81.
40. Heo, S., J.Y. Choi, J. Kim and K.D. Moon, 2021. Prediction of moisture content in steamed and dried purple sweet potato using hyper spectral imaging analysis. Food Science and Biotechnology, 30: 783-791.

41. Owusu, J., Z. Wang and A. Amissah, 2012. Effect of drying methods on physicochemical properties of pretreated tomato (*Lycopersicon esculentum*) slices. Croatian J. Food Technol. Biotech., 7(1-2): 106 - 111.
42. Samia El-Safy, 2009. Effect of different drying methods on quality characteristics of persimmon slices. J. Adv. Agric. Res. (Fac. Ag. Saba Basha) 14(3): 705-719.
43. Ngoma, K., M.E. Mashau and H. Silungwe, 2019. Physicochemical and functional properties of chemically pretreated ndou sweet potato flour. Inter. J. Food Sci., 2019, Article ID 4158213, 9 pages, 2019.
44. Prabhakar, K. and E.N. Mallika, 2014. Dried foods.In C. A. Batt (Ed.), Encyclopedia of Food Microbiology, (2nd ed, pp: 574-576). Academic Press.
45. Tapia, M.S., S.M. Alzamora and J. Chirife, 2020. Effects of water activity (a_w) on microbial stability as a hurdle in food preservation. In G.V. Barbosa-Cánovas, J. Anthony, J. Fontana, S. J. Schmidt, & T.P. Labuza (Eds.), Water activity in foods: Fundamentals and applications, (pp: 323-355). Wiley.
46. Bisnoi, N., P. Kumari and Y.K. Yadav, 2008. Study of dehydration characteristics of garlic. J. Dairy Foods, 27: 238-240.
47. Sun, X., X. Jin, N. Fu and X. Chen, 2020. Effects of different pretreatment methods on the drying characteristics and quality of potatoes. Food Sci. Nutr., 8: 5767-5775.
48. Prekash, S., S.K. Jha and N. Datta, 2004. Performance evaluation of blanched carrots dried by three different driers. J. Food Eng., 62(3): 305-313.
49. Lavelli, V., S. Hippeli, C. Peri and E.F. Elstner, 1999. Evaluation of radical scavenging activity of fresh and air-dried tomatoes by three model reactions. J. Agric. Food Chem., 47: 3826-3831.
50. Whitfied, D.E., 2000. Solar drying. Inter. Conference on Solar cooking, Kimerly-South Africa. 26-29th November, 2000.