International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 449-453

Received: 22-03-2018
Accepted: 24-04-2018

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Comparison of different drying modes for drying of different forms of Asian carrot

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Abstract
Carrot (*Daucus carota* L) is a root vegetable which belongs to family Apiaceae is mainly consumed raw, converted to various products and cooked vegetable dish. Present studies were carried out to compare the drying modes for the drying of different forms of carrot like roundels, sticks and shreds. These forms were steam blanched followed by additive treatment and further dried under three modes like mechanical cabinet drier, solar tunnel drier and open sun till the constant weight is obtained. Quality evaluation of dried forms like roundels, sticks and shreds reflects that they could be dried to 10.68, 10.12 and 9.10 per cent moisture level within 9.25, 8.50 and 7.15 hours of drying, respectively in mechanical cabinet drier. Antioxidants like carotenoids, total phenols and other quality attributes like total solids, water activity, titratable acidity, sugars, rehydration ratio and sensory attributes etc. were retained better in this drying mode. So mechanical cabinet drier was observed as a best mode of drying of different forms of carrot followed by solar drier.

Keywords: Carrot (*Daucus carota* L), Apiaceae, Solar tunnel drier, Mechanical cabinet drier, Carotenoids

1. Introduction
Carrot (*Daucus carota* L) is a root vegetable originated in Central Asia and then spread to Asia, Europe, North Africa and the Mediterranean region (Kalra *et al.,* 1987 and Mazza, 1989) [10, 15]. It is grown throughout the world and China is the largest producer of carrots in the world. It is an annual or biennial herb with an erect or branched stem (30-120 cm) high arising from a thick fleshy root. Edible portion is the fleshy tap root composed of an outer cortex (phloem) and inner core (xylem). Harvesting of carrots is done when they have reached a diameter of 20 mm and more, still young and tender. It is a rich source of carotenoids both α and β carotene besides it contains high amount of vitamin B_1, B_2, B_6 and B_{12} (Manjunatha *et al.*, 2003) [14]. It also contains significant amount of calcium, potassium, phosphorus and higher amount of fibres (Bao and Chang, 1994) [5]. Consumption of carrot increases the quantity of urine and helps in elimination of uric acid. It also has cooling effects and is beneficial for people suffering from gall stones, constipation and heat troubles. It is also used for curing stomach problems and treat wounds, ulcers, liver and kidney ailments since ancient times by Greeks and Romans. The carrots are mainly consumed as raw, converted to juice beverages and cooked as vegetable dish. Solar tunnel drier is a natural energy based drying mode which is cheaper as compared to the mechanical cabinet drier and better in maintaining the product quality during the drying as compared to open sun drying mode. Although various works has been carried out throughout the world for drying of carrot roots with mechanical cabinet drier but not much efforts has been made in the world to compare these drying modes for the drying of carrot roots. Therefore the present investigations were aimed to standardize the drying technology for the pre-treated forms of carrots so as to utilize it as food item with the broad objective comparison of different drying modes for drying of different forms of Asian carrot.

Material and Methods
Procurement of raw material
Carrot roots of uniform shape, size, colour and maturity were procured from local market of Solan. Carrot roots were washed, peeled and divided into three lots. In first lot, they were cut

into one cm thick roundels, whereas, in the second lot, sticks of 2.5×1×1 cm size were made by hand operated finger chips (sticks) maker and in third lot, roots were grated into shreds by mechanical grater and were further steam blanched i.e. roundels and sticks for 3 min and shreds for 2.5 min and pretreated with 2000 ppm KMS (60 min) dipping. Then mechanical cabinet drier was further compared with other drying modes like open sun drying and solar tunnel drying for selection of best drying mode on the basis of physico-chemical and sensory characteristics score. Detail of different drying modes used is given below:

Drying Modes

Mechanical cabinet drying

The pre-treated forms of carrot (12 kg) were spread on the perforated aluminium trays of dimension 76 x 56 cm and dried at varying temperatures inside a mechanical cabinet drier having internal dimensions 78 x 58 x 128 cm upto a constant weight. The trays were shifted inside the drier by rotation to ensure uniform heat transmission to all the trays.

Solar tunnel drying

The pre-treated forms of carrot (12 kg) were spread on the aluminium tray and put on the stand for drying inside a solar tunnel drier of dimensions 297x204x207 cm. The structure of drier is covered with polyethylene sheet having 0.31 mm thickness. The temperature recorded in the solar tunnel drier during these studies was in the range of 40-45ºC. Pre-treated forms of carrot were dried in this drier till they attained the constant weight.

Sun drying

The pre-treated forms of carrot (12 kg) were spread on the aluminium trays and kept in the open sun in an inclined position for drying. The material was kept till the sunset before shifting it back in the laboratory for night. Carrot forms were dried in the sun till they attain a constant weight.

Physico-chemical and Sensory analysis

Among the different chemical characteristics of different forms of carrot moisture content of dried forms was estimated by drying the weighed samples to a constant weight in a hot air oven at 70±1 °C. Loss in weight of form after drying representing the moisture content and was expressed as per cent (W/W), whereas, total solids were estimated by subtracting moisture content from the fresh weight of the carrot forms. Water activity of the different dried forms of carrot was estimated by computer based digital water activity meter (HW3 model, Rotronic International, Switzerland), where direct measurements were taken at room temperature. The titratable acidity was determined by the method given by (AOAC, 1984) [4]. Sugars were estimated as per the standard procedure given by Lane and Eynon (1923) [12]. The pH of flour was determined by using a digital pH meter (CRISON Instrument, Ltd, Spain). Carotenoids in dried forms were determined by Ranganna (2009) [17]. Total fiber content was estimated by the method given by Gould (1978). The total phenolics content was determined by the Folin-Ciocalteu procedure given by Singleton and Rossi (1965). Ash content was determined by using muffle furnace at temperature of 550°C as given by Ranganna (2009) [17]. Rehydration ratio was determined by Ranganna (2009) [17]. Sensory analysis of dried forms was carried out by using 9 point hedonic scale as described by the Amerine *et al.* (1965) [3].

Statistical Analysis

The data pertaining to the sensory evaluation of dried forms of carrot replicated three times were analyzed by Randomized Block Design (RBD) as described by Mahony (1985) [13]. Whereas the data pertaining to the physico-chemical characteristics was replicated three times and analysed using Completely Randomized Design (CRD) (Cochran and Cox, 1967) [9].

Results and Discussion

Table 1: Physico-chemical characteristics of different forms of carrot in different drying modes

Drying modes / Physico-chemical characteristics	Roundels				Sticks				Shreds			
	D_1	D_2	D_3	CD (0.05)	D_1	D_2	D_3	CD (0.05)	D_1	D_2	D_3	CD (0.05)
Drying time (h)	9.25	40.00	55.00	1.62	8.50	35.00	49.00	1.42	7.15	27.00	40.00	1.22
Yield (%)	15.00	16.80	18.00	0.40	13.80	15.10	16.20	0.20	9.85	11.20	12.35	0.18
Moisture (%)	10.68	11.90	13.40	0.20	10.12	11.35	12.70	0.18	9.10	10.50	11.90	0.14
TS (%)	89.32	88.10	86.60	1.08	89.88	88.65	87.30	1.27	90.90	89.50	88.10	0.94
Water activity	0.278	0.371	0.395	0.06	0.231	0.301	0.356	0.09	0.169	0.252	0.307	0.10
Titratable acidity (%)	0.80	0.72	0.69	0.02	0.83	0.74	0.70	0.01	0.87	0.78	0.73	NS
Carotenoids (mg/100g)	30.10	28.50	26.90	1.62	31.70	28.40	27.70	1.42	32.50	28.20	26.70	1.01
Reducing sugars (%)	20.70	19.00	17.80	1.22	21.00	19.30	18.10	1.01	21.40	20.10	18.30	0.81
Total sugars (%)	34.80	32.30	31.60	2.05	35.20	33.20	32.10	2.09	35.90	33.70	32.30	2.05
pH	5.88	5.96	6.01	NS	5.80	5.91	5.98	NS	5.70	5.87	5.97	0.18
Phenols (mg/100g)	97.50	90.00	84.00	7.12	100.80	92.00	87.00	6.31	102.00	96.00	91.00	6.21
Rehydration ratio (%)	1:8.00	1:7.30	1:6.80	0.01	1:8.50	1:7.90	1:7.30	0.01	1:10.50	1:9.80	1:8.30	0.01
Ash content (%)	3.40	2.70	2.60	0.12	3.50	2.90	2.70	0.13	3.80	3.10	2.90	0.16
Fiber (%)	4.40	4.20	3.90	0.30	4.50	4.30	4.00	0.20	4.90	4.10	3.70	0.17

Mechanical cabinet drier (D_1), Solar tunnel drier (D_2), Open Sun (D_3)

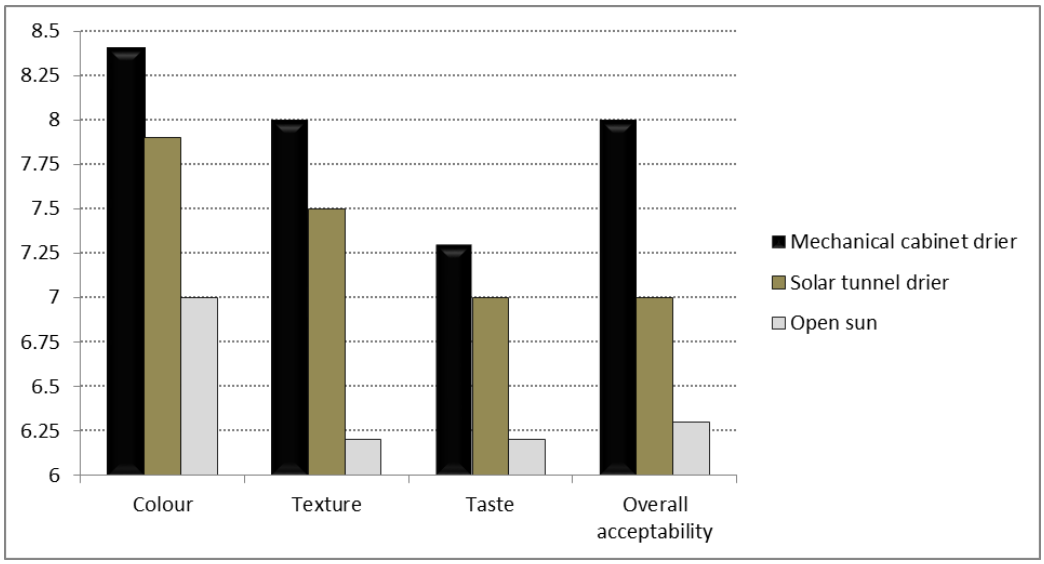

Fig 1: Sensory characteristics of dried carrot roundels in different drying modes

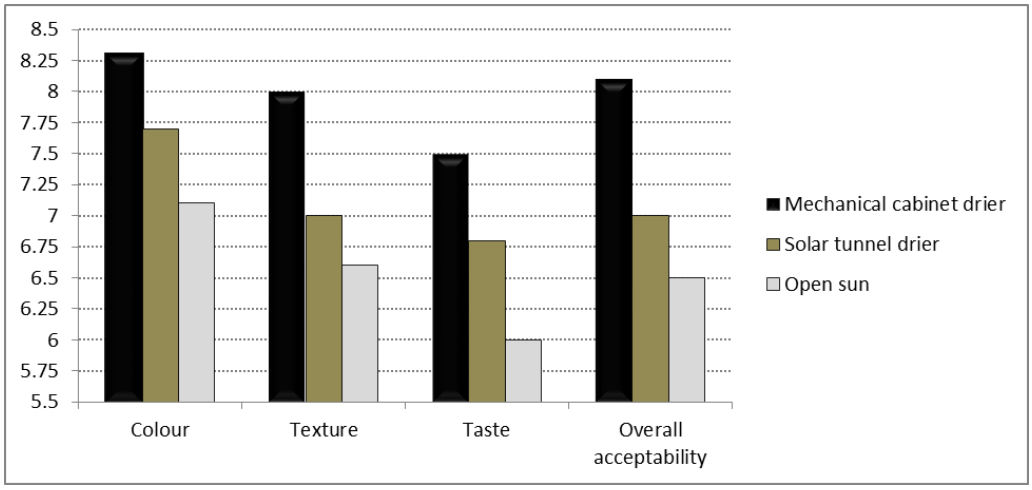

Fig 2: Sensory characteristics of dried carrot sticks in different drying modes

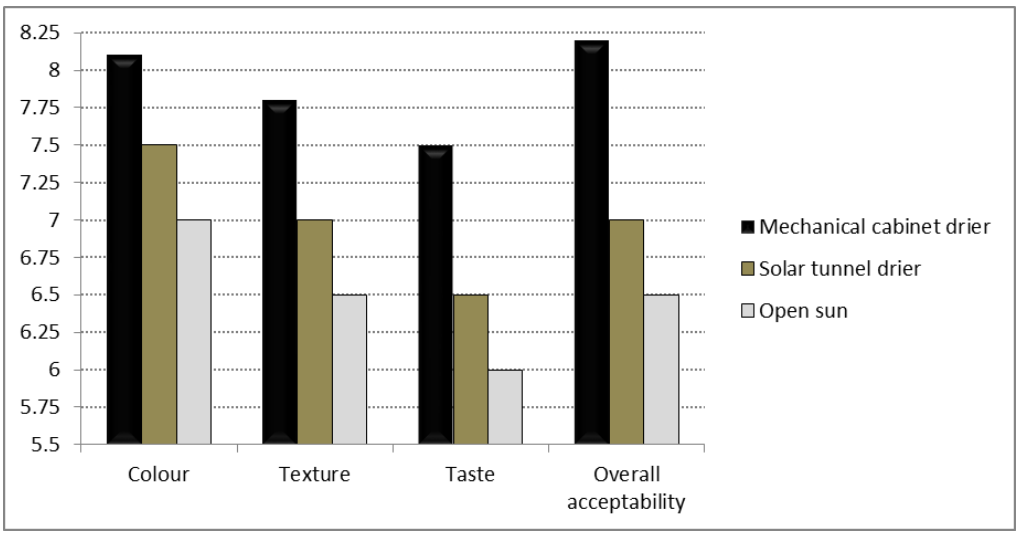

Fig 3: Sensory characteristics of dried carrot shreds in different drying modes

Physico-chemical characteristics

While comparing the different drying modes like mechanical cabinet drier (D_1), solar tunnel drier (D_2) and open sun (D_3) for drying of pre-treated forms of carrot i.e. roundels, sticks and shreds, mechanical cabinet drier was found to be the best on the basis of various physico-chemical and sensory characteristics. As table 1 revels that carrot forms i.e. roundels, sticks and shreds dried in mechanical cabinet drier (D_1) took least time to dry 9.25, 8.50 and 7.15 h, had lowest moisture 10.68, 10.12 and 9.10 per cent and water activity as 0.278, 0.231 and 0.169, respectively. Highest total solids as 89.32, 89.88 and 90.90 per cent and titratable acidity as 0.80, 0.83 and 0.87 per cent, respectively were also recorded in mechanical cabinet dried carrot forms. The minimum time for

drying, low moisture, minimum water activity and high total solids recorded in the mechanical cabinet dried carrot forms might be due to the fast and efficient moisture removal because of the continuous air movement and controlled temperature conditions in the mechanical cabinet drier as compared to the solar tunnel drier (D_2) and open sun (D_3). The trend of results obtained for drying time, moisture and total solids in dried carrot forms is similar to the results reported for dried wild pomegranate arils by various workers (Pruthi and Saxena, 1984; Chandel *et al.*, 1989; Singh and Kingsley, 2008; Thakur *et al*., 2010) [16, 8, 19, 21]. The above results are also in conformity with the findings of Bhardwaj and Lal (1990) [6] in apple rings. Also sufficient amount of reducing sugars as 20.70, 21.00 and 21.40 per cent and total sugars as 34.80, 35.20 and 35.90 per cent and minimum pH as 5.88, 5.80 and 5.70 were recorded in dried carrot roundels, sticks and shreds, respectively. This might be due to the faster drying and lower moisture retention in these dried carrot forms. The above results are in conformity with the findings of Alam *et al*. (2013) [1] in dried carrot pomace, Bhardwaj and Lal (1990) [6] in dried apple rings, Sharma (2012) [18] in wild pomegranate arils and Kumar *et al.* (2017) [11] in horse chestnut flour. Maximum carotenoids as 30.10, 31.70 and 32.50 mg/100g and total phenols as 97.50, 100.80 and 102.00 mg/100g were found in mechanical cabinet dried roundels, sticks and shreds (D_1) might be due to better drying conditions in mechanical cabinet drier (D_1) lead to the minimum loss of carotenoids and phenols during drying as compared to other drying modes. The above results are in conformity with the findings of Al-Amin *et al.* (2015) [15] in carrot slices and Sharma (2012) [18] in wild pomegranate arils. The highest rehydration ratio as 1:8.00, 1:8.50 and 1:10.50 and ash content as 3.40, 3.50 and 3.80 per cent and fiber as 4.40, 4.50 and 4.90 were recorded in mechanical cabinet dried roundels, sticks and shreds, respectively might be due to minimum moisture content in it as compared to the other modes. The above results are in conformity with the findings of Alam *et al*. (2013) [1] in dried carrot pomace, Al-Amin *et al.* (2015) [15] in carrot slices and Kumar *et al.* (2017) [11] in horse chestnut flour.

Sensory characteristics

Higher sensory characteristics scores were recorded in the mechanical cabinet dried carrot forms as compared to other modes of drying. It is evident from the data in figures 1, 2 and 3 that maximum scores of colour as 8.40, 8.30 and 8.10 and texture as 8.00, 8.00 and 7.80 and taste as 7.30, 7.50 and 7.50 and overall acceptability as 8.00, 8.10 and 8.20 were awarded to the carrot roundels, sticks and shreds, respectively dried in mechanical cabinet drier (D_1). The reason of best score for colour might be due to less browning observed in the dried carrot forms, while the good texture of the dried carrot forms might be due to low moisture content in the carrot forms and quick drying of different carrot forms would have provided a good taste and texture to them thereby improving the overall acceptability. Consequently, the combined effect of the pre-treatments and drying under controlled conditions in mechanical cabinet drier reduced the drying time and therefore low moisture content of cabinet dried carrot forms prevented deteriorative chemical reactions like Maillard reaction and other associative reactions thus leading to the development of good dried carrot forms with the maximum overall acceptability scores. Similar trend of results have also been observed by Bhat (2007) [7] and Sharma (2012) [18] in wild pomegranate arils, Kumar *et al.* (2017) [11] in horse chestnut flour.

Conclusion

On the basis of various quality characteristics of dried forms of carrot prepared by using mechanical cabinet dryer (D_1) at temperature 60 ± 2 °C was found to be the best as compare to solar tunnel drier and open sun drying modes.

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