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Changes in physico-chemical and sensory attributes of some wild fruits dried in indirect solar dryer

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Abstract
Studies were undertaken to evaluate the changes in physico-chemical and sensory characteristics of three major wild fruits i.e. wild ber (*Zizyphus mauritiana* L.), wild anola (*Phyllanthus emblica* L.) and wild bael (*Aegle marmelos* L. Corr.) dried in indirect solar drier. All the physico-chemical characteristics of dried fruits differ significantly (p<0.05) with those dried in open sun. Further, the pre-treated fruits dried in indirect solar dryer were rated best compared to untreated and sun dried samples on the basis of highest sensory scores of colour, texture, taste and overall acceptability even after 3 months of storage at ambient conditions. Hence, drying of such perishable crops in the indirect solar dryer could be a best option to prevent the postharvest losses and to extend the shelf life of these crops.

Keywords: Wild fruits, drying, solar dryer, physico-chemical and sensory quality

Introduction

Moisture removal from food products prevents the growth and reproduction of microorganisms, which cause decay (Chen *et al*., 2009) [1]. Drying is a popular and oldest preservation technique in which the moisture content is reduced to a level to keep the product at a relatively chemically stable state (Sharma *et al*., 2015; Ankush *et al*., 2018) [2, 3]. Although, open sun drying is the cheapest method, the dried products are of poor quality due to contamination by insects, pests, birds and dusts and attack by wild animals (Prakash *et al*., 2004) [4]. On the other hand, in solar drier product is kept inside a controlled environment, which reduces the probability of fungal and microbial growth and also, the food is less likely to be contaminated by animals, birds, insects and dust (Navalea *et al*., 2015) [5]. Solar drying results in quicker drying rates by achieving higher temperatures, lower humidity, and increased air movement (Muraleedharan *et al.*, 2013) [6]. Study has shown that solar drying improves the quality of a product with respect to colour, flavour, appearance and other organoleptic qualities, which enhances the marketability product (Ankush *et al*., 2018) [3]. Further, various pretreatments prior to drying like blanching, chemical treatments viz. sodium metabisulphite, citric acid, calcium chloride, ascorbic acid, osmotic solution etc. have been suggested for obtaining better quality characteristics of chillies (Doymaz and Pala 2002; Wiriya *et al*. 2009) [7, 8] and tomato (Bareh *et al*. 2012) [9].

Anola (*Phyllanthus emblica L.)* is one of the major wild fruit and probably the richest known source of ascorbic acid after Barbados cherry which contains various nutraceutical compounds making it antisorbutic, diuretic, laxative and antibiotic (Goyal *et al*. 2008; Thakur *et al*. 2018) [10, 11]. *Ziziphus mauritiana* L. (Ber), fruits are eaten fresh or can be made into a floury meal, butter, or a cheese like paste. The fruit is a good source of carotene, vitamins A and C, and fatty oils (Godi *et al*., 2016) [12]. *Aegle marmelos* L. Corr. (bael) is an indigenous fruit of India, highly nutritive with a great medicinal use and the richest source of riboflavin. Its medicinal properties have been described in the ancient medical treatise in Sanskrit in Charaka Samhita (Singh and Chaurasiya, 2014) [13]. During storage, the dried products may gain moisture and the quality parameters may also change, but these changes depend upon the mode of drying and the condition. Therefore, drying of these valuable crops was done in indirect solar drier and changes in their quality characteristics during storage were assessed in the present study.

Materials and Methods

Description of indirect solar dryer

There are two main components of solar dryer. One is solar collector and other is drying chamber (Figure 1.). Solar air collector is a rectangular box made of aluminum sheet with dimension of 1.52 × 1.21 × 0.12 m^3. It was inclined at an angle of 30.80 N latitude to receive maximum solar radiation. The glass of 4 mm thickness was fixed on the top of air collector for maximum transmission of solar radiation. Whereas, the drying chamber is a metallic box of dimension 1.52 × 1.21 × 1.21 m^3. There are four trays made of aluminum sheet in drying chamber to accommodate the material to be dried. The drying chamber is 0.60 m above the ground level (Ankush *et al*., 2018) [3]. There is a chimney at the top of the drying chamber for removal of moisture-laden air out of chamber. The solar drier works on natural convection.

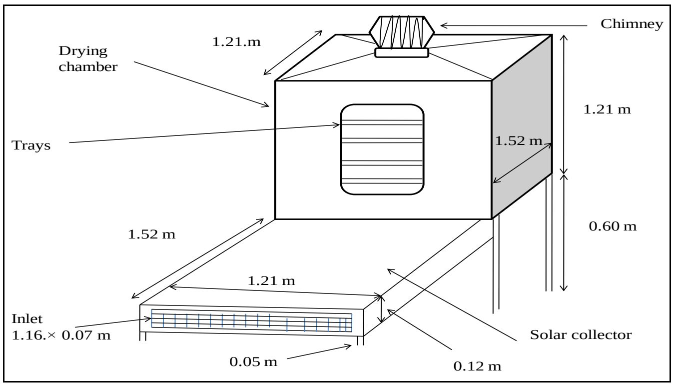

Fig 1: Indirect solar dryer

Raw material

Wild ber, wild aonla and wild bael were pre-treated prior to drying with different modes. Wild ber fruits were pre-treated by immersing in 0.30 % sodium hydroxide (NaOH) solution at 100 ºC for 60 seconds i.e. lye peeling followed by washing in distilled water at 25 ºC for 5 minutes (Elsheshetawy and Faid, 2015) [14]. Wild anola of uniform shape and size were sliced to make flakes of thickness from 2 to 3 mm and soaked in 0.10 % KMS (potassium metabisulphite) solution for 5 minutes (Verma and Gupta, 2004) [15] and mature green bael were, washed and cut in to 1-1.5cm thick slices after removing its hard shell. The slices of fruit were fumigated with SO_2 for one hour (Singh and Chaurasiya, 2014) [16]. The fruits were dried in different modes of drying as: C_{1} = treated fruits dried in indirect solar dryer and C_2= untreated fruits dried in open sun. Tray loads for wild ber fruits was 0.50 kg, whereas 1.0 kg for wild aonla flakes and wild bael slices. The best dried fruits were packed in polyethylene pouches and stored at ambient temperature up to a period of three months for storage studies. The observation for different quality parameters was recorded at 0, 1 and 3 months interval of storage.

Analyses

Various physico-chemical parameters like moisture content (W/W), titratable acidity (%), pH, total soluble solids (ºB), total sugars (%), reducing sugars (%) and non-reducing sugars were analyzed as per standard methods (Ranganna, 2009) [17]. The sensory evaluation of prepared dried fruit samples was carried out by hedonic rating test as given by Amerine *et al.* (1965) [18]. The prepared samples were evaluated for sensory qualities on the basis of colour, texture, taste and overall acceptability on a 9-point hedonic scale. The data pertaining to Physio-chemical characteristics of dried fruits before and during storage were analyzed by CRD (factorial) and data pertaining to the sensory characteristics was analyzed by RBD (Cochran and Cox, 1957) [19]. The experiments were replicated three times.

Results and Discussion

Change in physico-chemical and sensory characteristics of dried wild fruits during the storage

The samples dried in solar dryer (C_1) were evaluated for changes in physico-chemical and sensory characteristics during storage at ambient temperature and compared with untreated control samples dried in open sun (C_2).

Moisture content

There was a slight increase in moisture content of wild ber, wild aonla flakes and wild bael slices during storage interval. The moisture content of wild ber dried in solar dryer (C_1) increased from initial value 15.36 to 15.99 per cent (C_1) and from 18.53 to 19.30 per cent in control (C_2) during storage. In case of aonla flakes slices it increased from 11.07 to 11.53 per cent (C_1) and 12.63 to 13.17 per cent in control (C_2) whereas, in bael slices it increased from 12.28 to 12.78 per cent (C_1) and 14.19 to 14.78 per cent in control (C_2) during storage. A general increase of moisture in the dried fruit observed during storage might be due to the hygroscopic nature of the dried product. Similar trend of increase in dried carrot slices and wild pomegranate arils during storage has also been observed by Mansoor *et al.* (2013) [20] and Bhatt *et al.* (2014) [21]. Increase in moisture content of wild ber, wild aonla flakes and wild bael slices during storage interval has been presented in Figure 2.

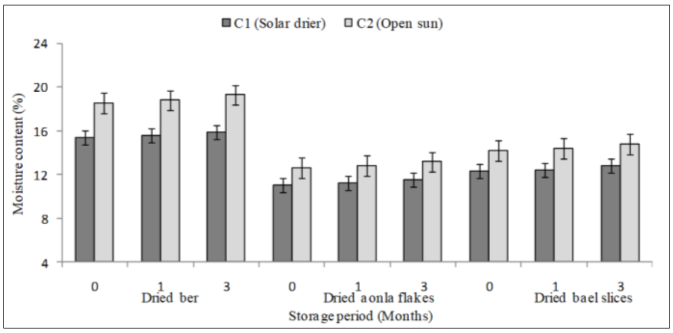

Fig 2: Change in moisture content of dried ber, aonla flakes and bael slices during storage

Titratable acidity and pH

There was a slight decrease in titratable acidity during storage period of wild ber, wild aonla flakes and wild bael slices. In wild ber titratable acidity in (C_1) i.e. fruit dried in solar dryer decreased from 1.06 to 1.01 per cent and from 0.77 to 0.71 per cent in control (C_2), in wild aonla flakes titratable acidity of flakes dried in solar dryer (C_1) decreased from 3.99 to 3.77 per cent and 3.18 to 2.99 per cent in control (C_2) and in wild bael slices it decreased from 0.84 to 0.77 per cent (C_1) and from 0.74 to 0.64 per cent in control (C_2) during storage. The loss of acids during storage was due to their participation in the chemical reactions with sugars and utilization in the inversion of non-reducing sugars to reducing sugars. While pH of dried wild ber, wild aonla flakes and wild bael slices increased as storage period proceed. pH of wild ber fruit dried in solar dryer (C_1) increased from 3.54 to 3.61 and from 4.98 to 5.07 in control (C_2), for wild aonla flakes pH in (C_1) increased from 2.28 to 2.33 and 2.56 to 2.63 in control (C_2)

and in case of wild bael slices it increased from 4.33 to 4.39 in (C_1) and 4.46 to 4.54 in control (C_2) during storage period. Similar trend of results in titratable acidity and pH has been reported by Sharma *et al*. (2006) [22] in dehydrated apple rings and Abdelgader and Ismail (2011) [23] in dried mango slices. Decrease in titratable acidity and increase in pH of dried wild ber, wild aonla flakes and wild bael slices is presented in Tables 1-3.

Total soluble solids and total sugars

Total soluble solids and total sugars of all three dried wild fruits showed a decrease trend during storage period. Total soluble solids of wild ber fruit dried in solar dryer (C_1) decreased from initial value 12.34 to 12.15 ºB and from 10.01 to 9.83 ºB in control (C_2) while total sugars decreased from 9.13 to 8.97 per cent in (C_1) and from 8.57 to 8.42 per cent in control (C_2). In dried wild aonla flakes total soluble solids in (C_1) decreased from 27.14 to 26.73 ºB and from 22.72 to 22.36 ºB in control (C_2) while total sugars in (C_1) decreased from 21.16 to 20.80 per cent and from 19.39 to 19.00 per cent in control (C_2). The total soluble solids of wild bael silces dried in solar dryer (C_1) decreased from 33.55 to 33.05 ºB and from 29.70 to 29.26 ºB in control (C_2) during storage period. Total sugars in (C_1) decreased from 26.18 to 25.70 per cent and from 23.66 to 23.21 per cent in control (C_2) during storage. The decrease in total soluble solids of fruit during storage was due to the increase in moisture, decrease in acids and total sugars (Yahia, 2003) [24]. The slight loss in total sugars during storage was due to the utilization of sugars in non-enzymatic browning reactions (Foda *et al.,* 1970) [25]. Similar trend of decrease in TSS and total sugars have also been reported by Aruna *et al*. (1998) [26] in papaya powder and Sharma *et al*. (2013) [27] in dried wild pomegranate arils. Data of total soluble solids and total sugars of dried wild ber, wild aonla flakes and wild bael slices during storage period is presented in Tables 1-3.

Reducing sugars and non-reducing sugars

Reducing sugar increased during storage period while there was a decrease in non-reducing sugar. Reducing sugars in wild ber fruit dried in solar dryer (C_1) increased from 7.29 to 7.37 per cent and from 6.94 to 7.02 per cent in control (C_2) during storage period while non-reducing sugars in (C_1) decreased from 1.74 to 1.54 per cent and 1.54 to 1.32 per cent in (C_2). Reducing sugars of wild aonla flakes in (C_1) increased from 11.45 to 11.58 per cent and from 10.01 to 10.13 per cent in control (C_2) while non-reducing sugars in (C_1) decreased from 9.22 to 8.75 per cent and 8.91 to 8.48 per cent in (C_2) during storage period. In dried wild bael slices reducing sugars in (C_1) increased from 16.82 to 17.00 per cent and from 14.78 to 14.95 per cent in control (C_2) while non-reducing sugars (C_1) decreased from 8.89 to 8.26 per cent and 8.43 to 7.84 per cent in (C_2) during storage period. The slight increase in reducing sugars of dried fruit during storage attributed to the inversion of non-reducing sugars and other polysaccharides into reducing sugars. Similar trend of increase in reducing sugars has been reported by Sra *et al.* (2014) [28] in dried carrot slices. Non-reducing sugars decreased during storage period due to inversion of non-reducing sugars in to reducing sugars. Increase in reducing sugar and decrease of non-reducing sugar of dried wild ber, wild aonla flakes and wild bael slices is presented in Tables 1-3.

Table 1: Effect of treatment and storage period on titratable acidity, pH, TSS, total sugars, reducing sugars and non-reducing of dried ber fruits

Treatment (C)	Titratable acidity (%)				pH			
	Storage interval (S) Months			Mean (C)	Storage interval (S) Months			Mean (C)
	0	1	3		0	1	3	
C_1	1.06	1.04	1.01	1.03	3.54	3.56	3.61	3.57
C_2	0.77	0.75	0.71	0.74	4.98	5.01	5.07	5.02
Mean (S)	0.92	0.90	0.86		4.26	4.29	4.34	
C.D. (0.05)	C=0.03, S=NS C× S=NS				C=0.10, S=NS C× S=NS			
	Total soluble solids (ºBrix)				**Total sugars (%)**			
C_1	12.34	12.26	12.15	12.25	9.13	9.07	8.97	9.06
C_2	10.01	9.93	9.83	9.92	8.57	8.52	8.42	8.50
Mean (S)	11.17	11.09	10.99		8.85	8.80	8.70	
C.D. (0.05)	C=0.19, S=NS, C× S=NS				C=0.05, S=0.06, C× S=NS			
	Reducing sugars (%)				**Non- reducing sugars (%)**			
C_1	7.29	7.31	7.37	7.32	1.74	1.67	1.54	1.65
C_2	6.94	6.96	7.02	6.97	1.54	1.47	1.32	1.44
Mean (S)	7.11	7.13	7.19		1.64	1.57	1.43	
C.D. (0.05)	C=0.03, S=0.04 C×S=NS				C=0.05, S=0.06, C× S=NS			

C1= treated fruit + solar dried; C2= Untreated + open sun dried

Table 2: Effect of treatment and storage period on titratable acidity, pH, TSS, total sugars, reducing sugars and non-reducing of dried aonla flakes

Treatment (C)	Titratable acidity (%)				pH			
	Storage interval (S) Months			Mean (C)	Storage interval (S) Months			Mean (C)
	0	1	3		0	1	3	
C_1	3.99	3.91	3.77	3.89	2.28	2.30	2.33	2.31
C_2	3.18	3.11	2.99	3.09	2.56	2.59	2.63	2.59
Mean (S)	3.58	3.51	3.83		2.42	2.45	2.48	
C.D. (0.05)	C=0.04, S=0.06 C× S=NS				C=0.06, S= N/A C× S=NS			
	Total soluble solids (ºBrix)				**Total sugars (%)**			
C_1	27.14	27.00	26.73	26.96	21.16	21.03	20.80	21.00
C_2	22.72	22.60	22.36	22.56	19.39	19.28	19.00	19.24

Mean (S)	25.72	25.59	25.33		20.32	20.20	19.97	
C.D. (0.05)	C=0.16, S=0.13, C× S=NS				C=0.03, S=0.03 C×S=NS			
	Reducing sugars (%)				**Non- reducing sugars (%)**			
C_1	11.45	11.50	11.58	11.51	9.22	9.05	8.75	9.01
C_2	10.01	10.06	10.13	10.07	8.91	8.75	8.48	8.71
Mean (S)	10.73	10.78	10.85		9.06	8.90	8.62	
C.D. (0.05)	C=0.04, S=0.05 C×S=NS				C=0.04, S=0.07, C× S=NS			

C1= treated fruit + solar dried; C2= Untreated + open sun dried

Table 3: Effect of treatment and storage period on titratable acidity, pH, TSS, total sugars, reducing sugars and non-reducing of dried bael slices

Treatment (C)	Titratable acidity (%)				pH			
	Storage interval (S) Months			Mean (C)	Storage interval (S) Months			Mean (C)
	0	1	3		0	1	3	
C_1	0.84	0.82	0.77	0.81	4.33	4.35	4.39	4.35
C_2	0.74	0.70	0.64	0.69	4.46	4.48	4.54	4.96
Mean (S)	0.79	0.76	0.71		4.39	4.41	4.67	
C.D. (0.05)	C=0.04, S=0.05 C× S=NS				C=0.04, S=N/A C× S=NS			
	Total soluble solids (ºBrix)				**Total sugars (%)**			
C_1	33.55	33.38	33.05	33.33	26.18	25.99	25.70	25.96
C_2	29.70	29.54	29.26	29.50	23.66	23.49	23.21	23.45
Mean (S)	31.62	31.46	31.15		24.92	24.74	24.46	
C.D. (0.05)	C=0.05, S=0.06, C× S=NS				C=0.16, S=0.20, C× S=NS			
	Reducing sugars (%)				**Non- reducing sugars (%)**			
C_1	16.82	16.85	17.00	16.89	8.89	8.68	8.26	8.61
C_2	14.78	14.82	14.95	14.85	8.43	8.23	7.84	8.17
Mean (S)	15.80	15.84	15.97		8.66	8.45	8.05	
C.D. (0.05)	C=0.09, S=0.11, C× S=0.13				C=0.16, S=19, C× S=0.13			

C1= treated fruit + solar dried; C2= Untreated + open sun dried

Sensory characteristics

Data pertaining to effect of mode of drying on various sensory characteristics viz. appearance and overall acceptability of dried ber fruits, aonla flakes and bael slices is presented in Figure 3 and 4. It is clear from the data that the samples dried in indirect solar drier recorded higher scores for various sensory attributes compared to those dried in open sun. Further, these scores decreased during the storage period; however the decrease was comparatively less in the samples dried in solar drier. The appearance scores decreased significantly from an initial score of 7.50, 8.50 and 7.80 to 7.20, 8.20 and 7.50 in solar dried ber, aonla flakes and bael slices after 3 months of storage at ambient conditions, respectively. Similarly, the overall acceptability scores of dried ber, aonla flakes and bael slices dried in solar drier showed a significant decrease from an initial score of 7.50, 8.20 and 7.50 to 7.00, 8.00 and 7.20, respectively after 3 months of storage. Similar trend of decrease in overall acceptability scores have also been observed by Rahman *et al.* (2010) [29] in carrot slices and Bhatt *et al.* (2014) [21] in dried wild pomegranate arils.

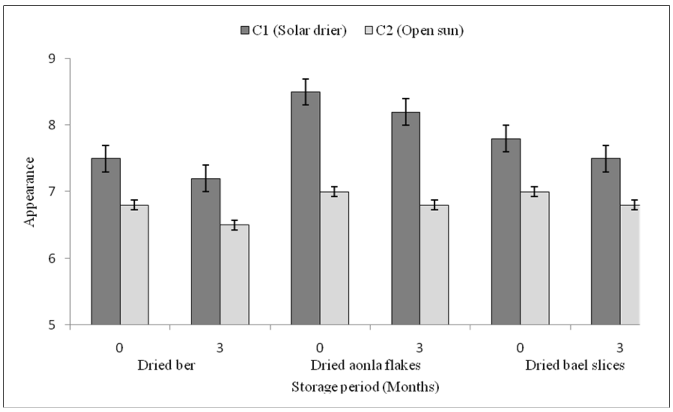

Fig 3: Effect of mode of drying on appearance scores of dried ber, aonla flakes and bael slices during storage

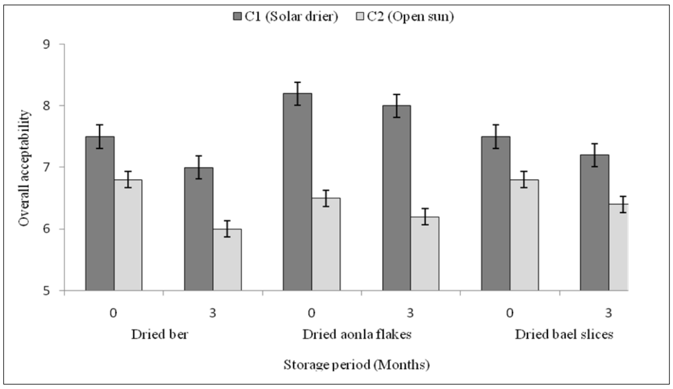

Fig 4: Effect of mode of drying on overall acceptability scores of dried ber, aonla flakes and bael slices during storage

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