Research Article

Evaluation of Indirect Solar Dryer for Drying of Some Wild Fruits Grown in Western Himalayan Region

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Abstract

Studies were undertaken to evaluate the indirect solar dryer for drying of some wild fruits *vis-a-vis* mechanical dryer and open sun drying on the basis of physico-chemical and sensory characteristics. Three major wild fruits i.e. wild ber (*Zizyphus mauritiana* L.), wild anola (*Phyllanthus emblica* L.) and wild bael (*Aegle marmelos* L. Corr.) were selected for the present study. Indirect solar dryer consists of two main parts viz. solar collector and drying chamber with thermal backup system. Average drying rate of 0.35 gm/h (open sun), 0.63 gm/h (solar dryer) and 4.32 gm/h (mechanical cabinet dryer) was recorded when the samples were dried intermittently in open sun, indirect solar dryer and mechanical cabinet dryer. Water activity of dried fruits ranged between 0.276 to 0.364, when dried with different modes of drying. All the physico-chemical characteristics of dried fruits were at par with those dried in cabinet drier and differ significantly with those dried in open sun. Further, the treated fruits dried in indirect solar dryer were rated best among all drying modes on the basis of highest sensory scores of colour, texture, taste and overall acceptability even after 3 months of storage of dried samples 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, solar dryer, cabinet dryer, physico-chemical and sensory

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Introduction

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 [1]. 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 [2]. Further, there is an increasing realization that the use renewable sources to meet the growing energy needs of a burgeoning population cannot be delayed any further [3]. India stands second in vegetables and fruits production, hardly 2% of the produce is processed and 25-30 % is being wasted due to lack of processing and preservation infrastructure [3]. Many a times, when the production is high, the farmers have to either sell their produce at very low price or it goes waste, there by incurring great economic loss to the farmers. However, this loss can be minimized by dehydrating fruits and vegetables [4]. Moisture removal from food products is one of the critical factors responsible for prevention of growth and reproduction of spoilage causing microorganisms [5]. Solar drying results in quicker drying rates compared to open sun drying by achieving higher temperatures, lower humidity, and increased air movement [6]. Drying food items in short times better preserves nutritional values of the products and optimal temperatures as compared to traditional dried [2,3]. Additionally, research has shown that solar drying can improve the quality of a product w.r.t. colour, flavour, appearance and other organoleptic qualities, which enhances the marketability of product and consequently allows for improved financial opportunities for farmers [7, 8]. Therefore, in the present energy crisis, it is desirable to harness the potential of solar technology for dehydration of fruits and vegetables, so that gas, oil and electricity can be saved. The indirect solar dryers are not only more effective than open sun drying, but have lower operating costs than that of mechanized industrial driers. Keeping the above facts in view, indirect solar drier having thermal backup system was evaluated for drying of some important wild fruits viz. aonla, bael, and ber grown in western Himalayan region.

Materials and Methods

Raw material

The wild ber, wild aonla and wild bael fruits were procured from the local areas/ market. The fruits were sorted, washed properly and prepared for drying. Different fruits were pre-treated prior to drying with different treatments and one control sample without pre-treatment was also kept. Wild ber fruits were pre-treated by immersing in 0.3% sodium hydroxide (NaOH) solution at 100^0C for 60 seconds i.e. lye peeling followed by washing in distilled water at 25^0C for 5 minutes [9]. Wild anola of uniform shape and size were sliced to make flakes of thickness from 2 to 3 mm and soaked in 0.1% KMS (potassium metabisulphite) solution for 5 minutes [10] 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 [11]. The fruits were dried in different modes of drying as per the detail of treatments given below:

T_1= Untreated fruits dried in open sun; T_2 = Treated fruits dried in open sun; T_3 = Treated fruits dried in indirect solar dryer; T_4= Untreated fruits dried in indirect solar dryer ; T_5= Treated fruits dried in mechanical cabinet dryer

Tray loads for wild ber fruits was 0.5 kg, whereas 1kg for wild aonla flakes and wild bael slices. Intermittent drying was done during the study. 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.

Physico chemical analysis

Various physico-chemical parameters studied were size of fruits, weight of fruits, visual colour of fruits, drying time (hours), drying rate (gm/h), water activity, moisture content (W/W), titratable acidity (%), pH, total soluble solids (^{o}Brix), total sugars (%), reducing sugars (%), non-reducing sugars as per standard methods [12].

Sensory analysis

The sensory evaluation of prepared dried fruit samples was carried out by 9-point Hedonic rating test as given by [13]. The prepared samples were evaluated for sensory qualities on the basis of colour, texture, taste and overall acceptability on a 9-point hedonic scale.

Statistical analysis

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 [14]. The experiments were replicated three times.

Results and Discussion

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 collector is a rectangular box with dimension of 1.52 m × 1.21 m × 0.12 m. It was inclined at an angle of 30.8N latitude to receive maximum solar radiation. Whereas, the drying chamber is a metallic box of dimension 1.52 m × 1.21 m × 1.21m. There are four trays in drying chamber to accommodate the material to be dried. The drying chamber is 0.60 m above the ground level. There is a chimney at the top of the drying chamber for removal of moisture-laden air out of chamber. The design parameters of drying chamber as well as solar collector are given in **Table 1**.

Physico-chemical characteristics of fresh fruits

Data pertaining to the physical and chemical characteristics of fresh wild ber, aonla and bael is presented in the **Table 2**. The average length, diameter and weight of wild ber were recorded as 16.13 ± 0.25 mm, 17.06 ± 0.32 mm and 3.47 ± 0.11g. The visual colour of fruit was found to be reddish yellow. Average moisture content of wild ber was 72.24 ± 0.05 per cent, total soluble solids in the fruits were recorded as 8.50 ± 0.23 ^{o}Brix, while total, reducing and non reducing sugars were recorded as 6.45 ± 0.10 per cent, 5.46 ± 0.07 per cent and 0.93 ± 0.17 per cent, respectively. Similar results were also observed in different cultivars of *Zizyphus mauriatiana* L. [15, 16]. The average length, diameter and weight of aonla fruits were recorded as 23.12 ± 0.56 mm, 26.31 ± 0.35mm and 6.73 ± 0.21g, respectively which were in accordance with the finding of Thakur *et al*., [17]. The visual colour of fruit was found

pale green, average moisture content of wild aonla was 81.35 ± 0.26 per cent and total soluble solids in the fruits was recorded as 12.40 ± 0.04 (^{o}Brix), while total, reducing and non reducing sugars were recorded as 7.38 ± 0.08 per cent, 4.01 ±0.0.03 per cent and 3.19 ± 0.09 per cent, respectively. The average length, diameter and weight of bael slices were recorded as 49.49 ± 2.01 mm, 51.03 ± 1.40 mm and 76.18 ± 4.96g, respectively. The average moisture content of wild bael was 66.21 ± 0.44 per cent and total soluble solids in the fruits were recorded as 15.39 ± 0.05 (^{o}Brix), while total, reducing and non reducing sugars were recorded as 12.11 ± 0.07 per cent, 9.23 ± 0.06 per cent and 2.73 ± 0.13 per cent. Whereas, titratable acidity and pH of fruit were found as 0.31 ± 0.03 per cent and 5.00 ± 0.12 per cent, respectively which are well within the range suggested by [18].

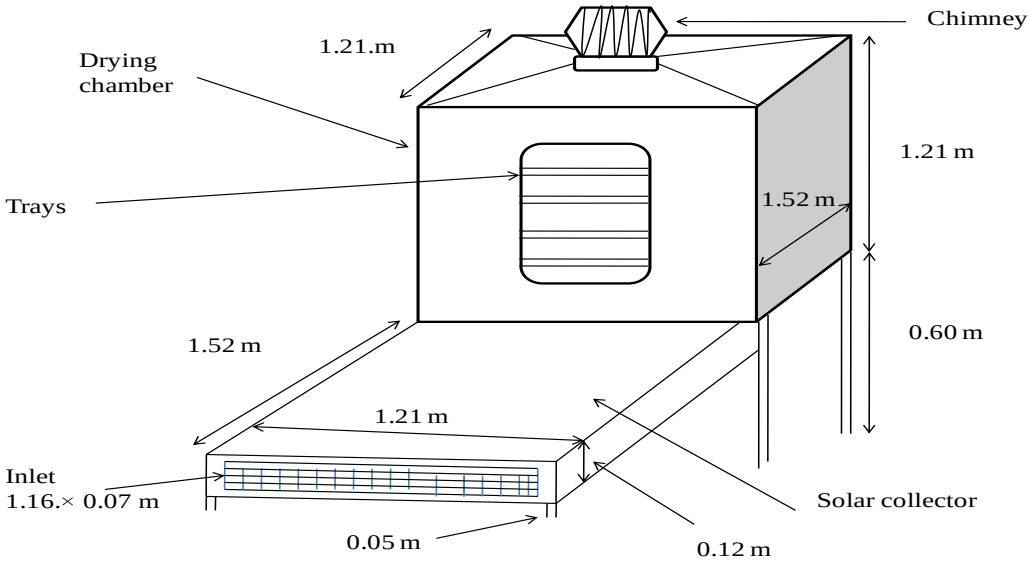


Figure 1 Diagram of a solar dryer

Table 1 Design parameter of solar collector and drying chamber of solar drier

Parameter	solar collector	drying chamber
Length (m)	1.52	1.52
Width (m)	1.21	1.21
Height	-	1.21
Area ($m^{2)}$	1.83	1.83
Absorber plate	GI sheet	GI sheet
Glazing	Normal window glass	Normal window glass
Number of trays		04
Casing/ Material	Iron sheet	Iron sheet

Table 2 Physico-chemical characteristics of fresh *Zizyphus mauriatiana* L. (wild ber), *Phyllanthusemblica* L. (wild aonla) and *Aegle marmelos* L. Corr. (wild bael) fruits

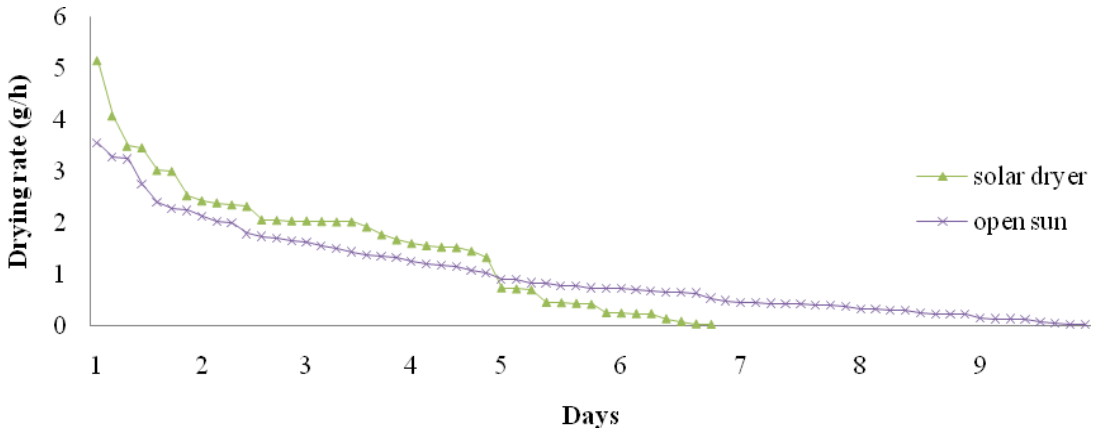
Characteristics	*Zizyphus mauriatiana* L. Mean + S.E	*Phyllanthusemblica* L. Mean + S.E	*Aegle marmelos* L. Mean + S.E
Size			
A) Length(mm)	16.13± 0.25	23.12 ± 0.56	49.49 ± 2.01
B) Diameter(mm)	17.06 ± 0.32	26.31 ± 0.35	51.03 ± 1.40
Weight (g)	3.47 ± 0.11	6.739± 0.217	76.18± 4.96
Visual colour	Reddish yellow	Pale green	Green
Moisture (per cent)	72.24 ± 0.5	81.35 ± 0.26	66.21 ± 0.44
Total soluble solids(^{o}Brix)	8.50 ± 0.04	12.40 ± 0.04	15.39 ± 0.05
Total sugars (%)	6.45 ± 0.10	7.38 ±0.087	12.11 ±0.07
Reducing sugars (%)	5.46 ± 0.07	4.01 ± 0.03	9.23 ± 0.06
Non –reducing Sugars (%)	0.93 ± 0.17	3.19 ± 0.09	2.73 ± 0.13
Titratable acidity (%)	0.39 ± 0.01	2.51 ± 0.02	0.31 ± 0.03
pH	5.46 ± 0.07	2.46 ± 0.05	5.0 ± 0.12

Physicochemical characteristics of dried fruits

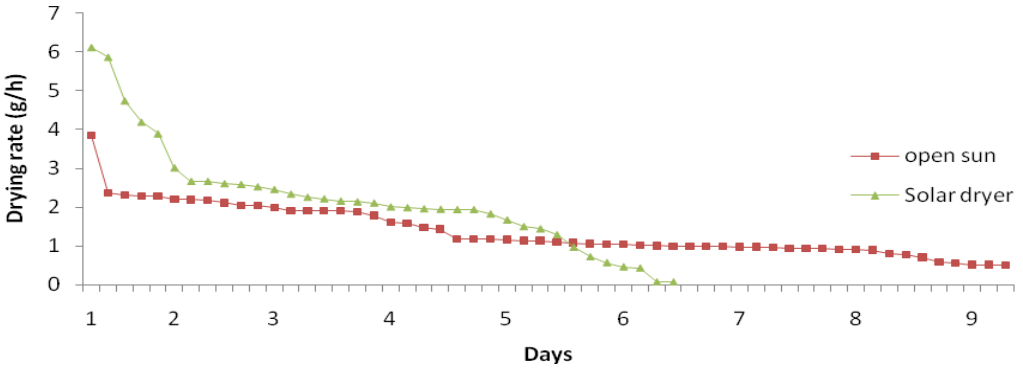
Data pertaining to various physicochemical characteristics of dried wild ber, aonla flakes and bael slices have been presented in **Table 3**. Significant changes were recorded in different modes of drying. For all fruits minimum time, minimum moisture content, water activity and pH were found in mechanical cabinet dryer (T_5). Maximum total soluble solids, total sugars, reducing sugars, non-reducing sugars and titratable acidity were also recorded in fruit dried in mechanical cabinet dryer (T_5). This might be due to the fast and efficient moisture removal from the fruits in the mechanical cabinet drier because of the continuous air movement and controlled temperature as compared to the fluctuating and low temperature in solar dryer and open sun. Similar trend of results have also been reported by various workers [19, 20]. Data related to drying rate of wild ber, aonla flakes and bael slices has been presented in **Figure 2**. Maximum rate of drying was observed when the samples were dried in solar dryer compared to open sun, which indicated higher efficiency of the solar dryer.

Table 3 Effect of different modes of drying on physicochemical properties of dried wild ber *(Zizyphus mauriatiana* L.), wild aonla (*Phyllanthus emblica* L.) flakes and wild bael *(Aegle marmelos* L. Corr.) slices

Treatments	Drying time (h)	Water activity	Moisture (%)	Total soluble solids (^{0}Brix)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Titratable acidity (%)	pH
Wild Ber (*Zizyphus mauriatiana* L.) fruits									
T_1	242.00	0.50	18.53	10.01	8.57	6.94	1.54	0.77	4.98
T_2	227.00	0.48	15.36	10.79	8.90	7.06	1.73	0.99	4.16
T_3	144.00	0.41	17.24	12.34	9.13	7.29	1.70	1.06	3.54
T_4	165.00	0.44	16.52	10.81	8.91	7.09	1.72	0.95	4.19
T_5	26.10	0.36	12.62	13.08	9.37	7.42	1.84	1.13	3.16
$CD_{(0.05)}$	7.45	0.01	0.47	0.23	0.07	0.05	0.08	0.04	0.12
Wild aonla (*Phyllanthus emblica* L.) flakes									
T_1	237.30	0.33	12.63	22.72	19.39	10.01	8.91	3.18	2.56
T_2	215.30	0.30	12.37	24.80	20.06	10.93	8.67	3.72	2.43
T_3	124.30	0.28	11.07	27.14	21.16	11.45	9.22	3.99	2.28
T_4	173.00	0.29	12.01	24.90	20.14	10.95	8.73	3.77	2.37
T_5	18.30	0.23	10.33	28.24	22.65	12.23	9.89	4.28	2.10
$CD_{(0.05)}$	9.28	0.05	0.25	0.30	0.09	0.06	0.09	0.09	0.08
Wild bael (*Aegle marmelos* L. Corr.) slices									
T_1	239.00	0.34	14.19	29.70	23.66	14.78	8.43	0.74	4.46
T_2	219.00	0.31	13.88	30.66	24.34	15.41	8.48	0.80	4.38
T_3	134.00	0.29	12.23	33.55	26.18	16.82	8.89	0.84	4.33
T_4	165.30	0.30	12.88	31.43	24.88	15.96	8.46	0.81	4.35
T_5	22.30	0.24	11.26	34.91	27.18	17.33	9.35	0.89	4.27
$CD_{(0.05)}$	5.05	0.03	0.21	0.28	0.22	0.16	0.18	0.06	0.06



(a)



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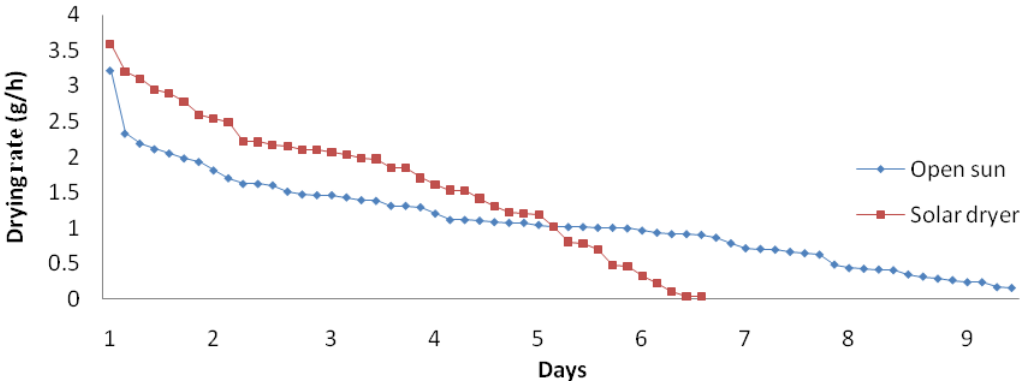

(C)

Figure 2 Drying rate in different modes of drying for (a) wild ber fruits, (b) wild aonla flakes and (c) wild bael slices

Table 4 Sensory characteristics of dried *Zizyphus mauriatiana* L. (wild ber), *Phyllanthusemblica* L. (wild aonla) flakes and *Aegle marmelos* L. Corr. (wild bael) slices in different modes of drying

Treatments	Texture	Colour	Taste	Overall Acceptability
Wild ber (*Zizyphus mauriatiana* L.) fruits				
T_1	6.20	6.20	6.00	6.13
T_2	7.20	7.00	6.40	6.86
T_3	8.40	8.60	8.60	8.53
T_4	7.00	6.80	6.20	6.66
T_5	8.20	8.40	8.20	8.26
$CD_{(0.05)}$	0.77	0.47	0.62	0.33
Wild aonla (*Phyllanthus emblica* L)flakes				
T_1	6.20	6.60	7.00	6.60
T_2	7.20	7.20	7.60	7.33
T_3	7.80	8.00	8.60	8.13
T_4	6.80	7.00	7.40	7.06
T_5	7.60	7.80	8.40	7.93
$CD_{(0.05)}$	0.54	0.65	0.47	0.29
Wild bael (*Aegle marmelos* L. Corr.) slices				
T_1	7.00	6.20	7.20	6.80
T_2	7.40	7.20	7.80	7.46
T_3	8.00	8.20	8.80	8.33
T_4	7.20	7.00	7.40	7.20
T_5	7.80	8.00	8.40	8.06
$CD_{(0.05)}$	0.49	0.65	0.54	0.31

Sensory characteristics of dried fruits

Data related to various sensory attributes viz. texture, colour, taste and overall acceptability of dried ber fruit, aonla flakes and bael slices is presented in **Table 4**. Data showed that maximum scores for texture, colour, taste and overall acceptability were recorded in fruit dried in solar dryer (T_3) and minimum scores were observed in control (T_1) for all the three fruits. Highest score for colour, texture, taste and overall acceptability was given to treated fruit dried in

solar dryer due to non exposure of sample to direct sun and protection from external environmental factors. The sensory score for all the treatments were above 6.0 (*Like slightly)*. Further, use of additive, like potassium metabisulfite and citric acid might have inhibited the browning reaction by binding with the carbonyl group of reducing sugars and other compound, resulting in good colour, flavor of dried products [21]. Sharma *et al.*, [2] has also observed similar results while drying of sweet bell pepper (*Capsicum annum*).

Change in moisture content and sensory characteristics of dried wild fruits during storage

Moisture content

The samples dried in solar dryer (C_1) were also evaluated for changes in moisture content and sensory characteristics during storage at ambient temperature and compared with untreated control samples dried in open sun. 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 per cent (C_1) to 15.99 per cent and from 18.53 per cent to 19.30 per cent in control (C_2) during storage. In case of aonla flakes slices moisture content increased from 11.07 per cent to 11.53 per cent (C_1) and 12.63 per cent to 13.17 per cent in control (C_2) and in bael slices it increased from 12.28 per cent to 12.78 per cent (C_1) and 14.19 per cent 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 [22]. Increase in moisture content of wild ber, wild aonla flakes and wild bael slices during storage interval is presented in **Figure 3 (a-c)**.

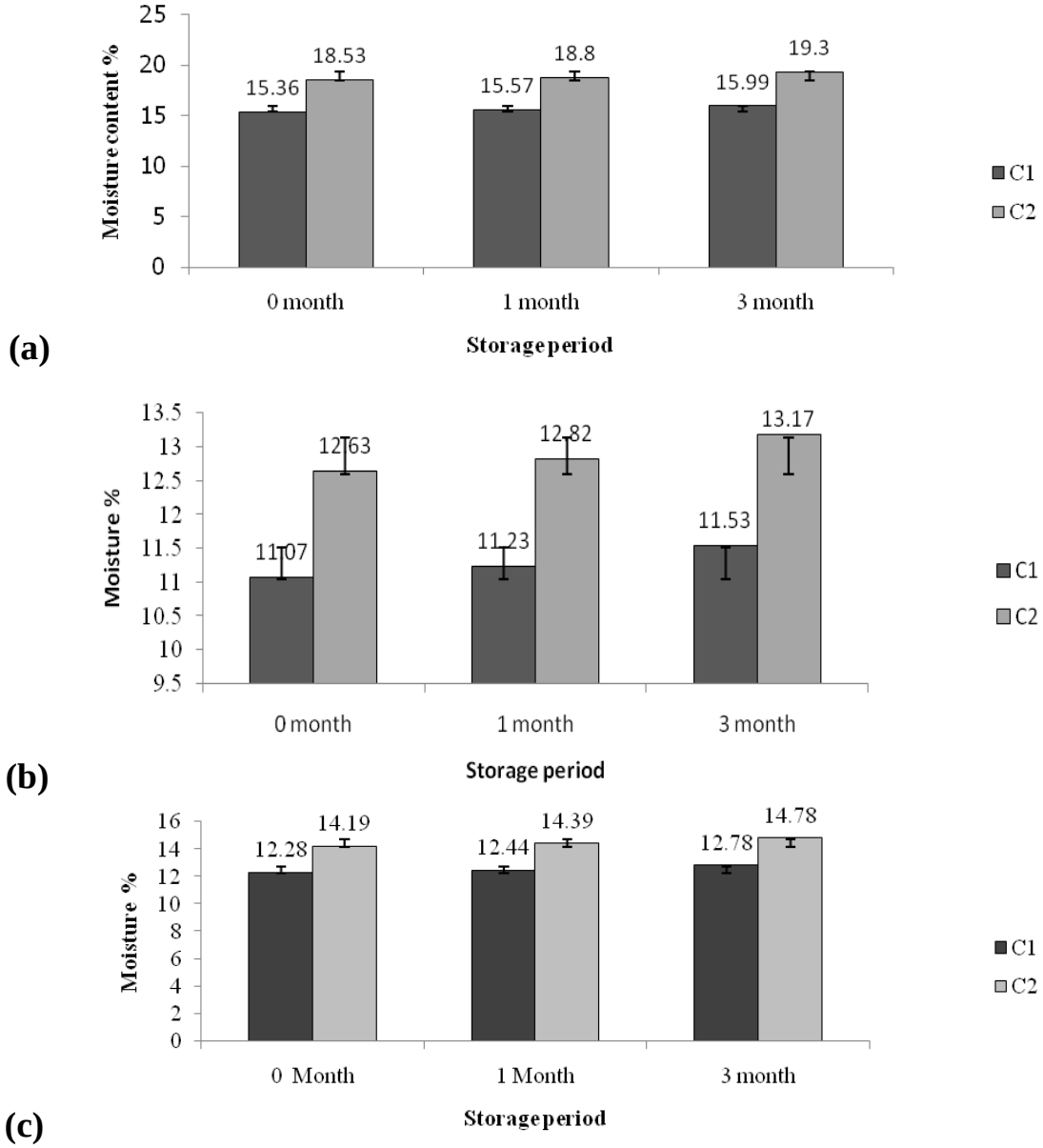

Figure 3 Changes in moisture content of (a) dried ber fruits, (b) aonla flakes and (c) bael slices during storage

Sensory characteristics

Data pertaining to effect of mode of drying on various sensory characteristics viz. appearance, texture, taste and overall acceptability of dried ber fruits, aonla flakes and bael slices is presented in **Figure 4 (a-c)**. 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 with pre-treatments. The appearance score decreased significantly from an initial score of 7.15, 7.75 and 7.40 to 6.85, 7.5 and 7.2 in dried ber, aonla flakes and bael slices after 3 months of storage at ambient conditions, respectively. Similarly, the overall acceptability score of dried ber, aonla flakes and bael slices showed a significant decrease from an initial score of 7.15, 7.35 and 7.15 to 6.6, 7.05 and 6.85, respectively after 3 months of storage. Similar results were also reported by Muralikrishna *et al.* [21] and Sharma *et al.*, [2].

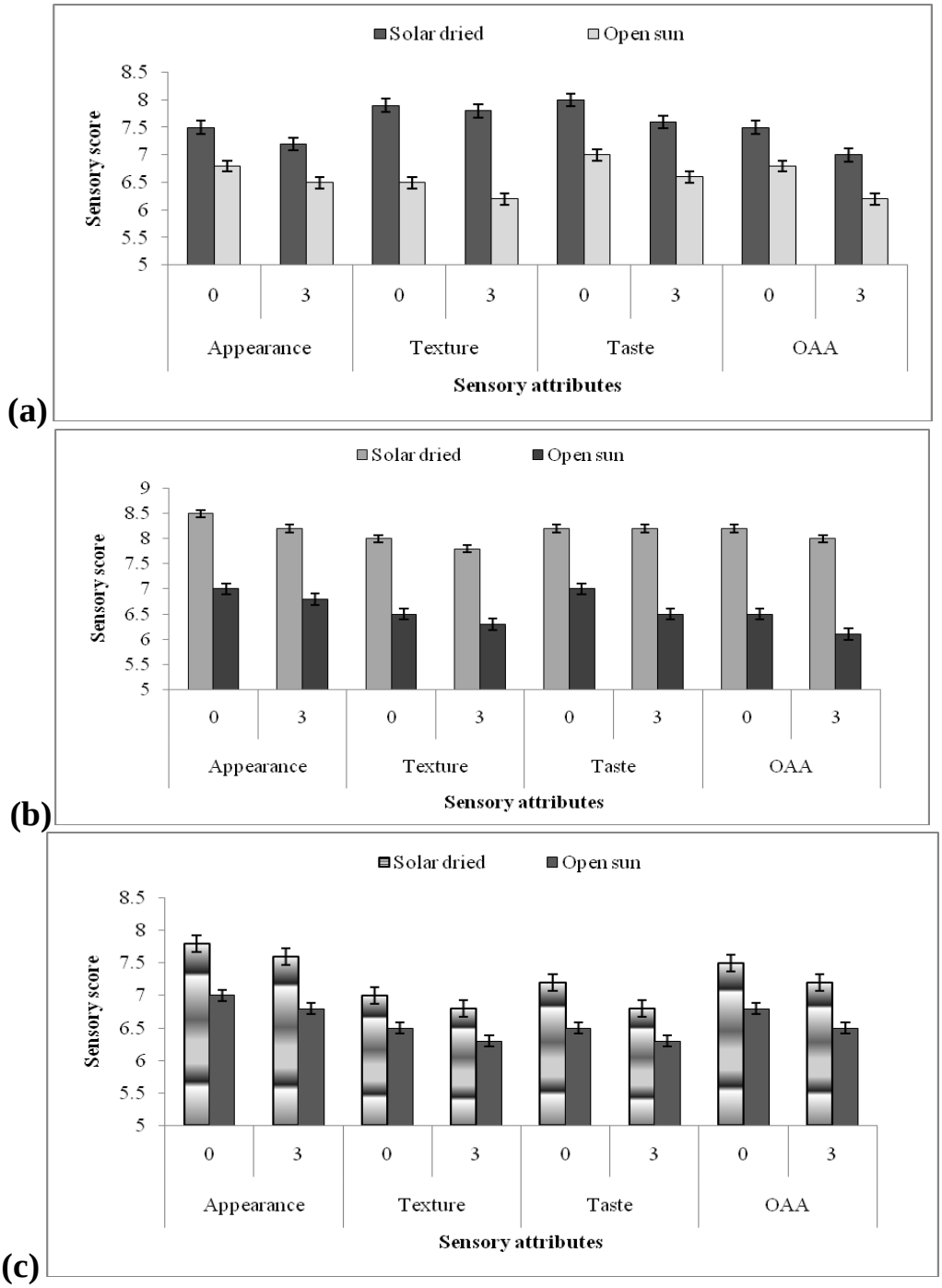

Figure 4 Effect of mode of drying on sensory attributes of (a) dried ber fruits, (b) aonla flakes and (c) bael slices during storage

Conclusion

The results of present investigation concluded that the average rate of drying was higher in solar dryer as compared to open sun. The chemical constituents of all the samples dried in indirect solar drier were at par with those dried in mechanical drier but better than those dried in open sun. Almost comparable rehydration characteristics were observed for solar and cabinet dried samples. The fruits dried in open sun had high value of water activity so faster deterioration of sample during three months storage was observed. The fruits dried in indirect solar dryer were rated best among all drying modes on the basis of their higher sensory scores of appearance, 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 and cost effective for small and marginal farmers, to prevent postharvest loss of their perishable crop due to lack of transport and storage facilities.

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