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ORIGINAL ARTICLE

Effect of open air drying, LPG based drier and pretreatments on the quality of Indian gooseberry (aonla)

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Abstract The aonla fruits (whole fruit, pricking, splits, segments) were subjected to pretreatments like blanching, osmotic dehydration with salt (2%) and sugar (40%) in different experiments before drying to obtain a product with better keeping quality. An LPG based drier (CRIDA drier) with capacity to dry 50 kg of fresh Indian gooseberry (aonla) was used. Nutritional quality and rehydration characteristics of CRIDA drier dried products were higher and free from contamination. Drying time was shortest for blanched and osmotically dehydrated segments dried in CRIDA drier and the product had better vitamin C retention, rehydration characteristics and sensory acceptability compared to sun or cabinet drier dried product. The additional expenditure spent on gas in CRIDA drier is compensated by reduced labour cost and higher price for the better quality product. Alternate energy sources like biogas and biomass can be used as fuel in the CRIDA drier.

Keywords Aonla · Indian gooseberry · Osmotic dehydration · CRIDA drier · Rehydration ratio · Blanching

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Introduction

Indian gooseberry or aonla (*Emblica officinalis* L.), an Indian gooseberry, is an important minor fruit crop of the Indian sub continent (Kumar and Sagar 2009). The cultivation of aonla has increased in recent years, due to its hardy nature and its ability to grow in wastelands and dry lands (Yang et al. 2008). It is highly nutritive (160 and 20 times higher vitamin C content as compared to apple and orange, respectively) and has good medicinal value (Mitra et al. 2008). Aonla is a seasonal fruit and is highly perishable in nature as its storage life in atmospheric conditions after harvesting is only 5–6 days (Pathak et al. 2009). Appropriate storage and processing methods can curtail the post harvest losses to 30% (Goyal et al. 2008) and make the fruit available for longer period (Singh et al. 2009). A few post harvest technologies that exist are complex and are unaffordable to the marginal and small farmers at the farm level (Kumar and Nath 1993; Beinyuy and Joseph 2004). Aonla is highly acidic and astringent in taste due to which they are unpalatable and unsuitable for direct consumption and hence they are consumed mainly in the processed form.

Dehydration is the oldest and most viable low cost preservation technology for a small farmer to prolong shelf life of fruits and vegetables (Doymaz 2007; Mudgal and Pande 2009). Aonla supari, a spiced mouth freshener introduced by a few industries in the market, is prepared by open air drying. The main advantage of the open air drying is its low capital and operating costs. On the other hand the disadvantages are that it is laborious, weather dependent and the U.V. radiation in sun rays causes serious undesirable changes in the quality, flavour, texture of the products, long drying time and contamination of the product with dust and insects etc. (Ertekin and Yaldiz 2004). As a result the final product is of poor quality with low market acceptability and value (Bechoff et al. 2009). To overcome such difficulties, solar driers and cabinet driers with different sources of energy have been developed for drying. But most of the drying methods use expensive energy sources like electricity. This necessitated the development of low cost techniques involving pretreatments and alternative energy based drying methods. A liquid petroleum gas (LPG) fuel based drier was developed at CRIDA, Hyderabad, India (CRIDA drier) for drying fruits, vegetables and medicinal plants. The drier can be fabricated locally by any small-scale industry and can be used by small farmers of the developing countries.

The products may need to be blanched first to inactivate enzymes by using steam or hot water, and then dried to lower water activity with heated air to make them more shelf stable or obtain desirable product quality. The drying period of blanched aonla has been reduced by 2 days as compared to unblanched aonla (Singh et al. 2007). Higher vitamin C retention was observed in aonla segments as compared to whole fruits (Verma and Gupta 2004). Osmotic dehydration (OD), a novel, simple and inexpensive alternate approach is not only energy saving but also of low capital investment. Besides reducing the drying time, OD helps in better retention of nutrients like ascorbic acid, lower levels of anti-nutrients like tannins, higher retention of volatile aromas during subsequent drying and better retention of natural colour (without the need for sulfide addition) (Pragati and Dhawan 2003). The growing popularity of alternate medicines and herbal products are increasing the demand of aonla and aonla based products. Hence the present study was initiated with an aim to develop a nutritionally rich delicious product from aonla fruit by using appropriate pre treatment and drying method.

Materials and methods

Hand picked, well-matured, hard, greenish-yellow aonla of ‘Anand 2’ variety fruits were obtained from Hayath Nagar research farm of CRIDA. The average size of aonla fruits for each sample was determined using Vernier calipers.

Fruit treatments Whole fruits without any treatment. In pricking treatment aonla were pricked to a depth of 8–10 mm on the entire surface at the rate of 4 points/cm^2 with the help of a hand operated pricker having 2 halves with needles. Fruits were sliced into 6–12 mm depth (splits) using a sharp knife keeping the segments intact with seed. Fruits were sliced and made into segments of 2–2.5 mm thickness with a sharp knife.

Blanching and OD Aonla segments were blanched before OD. Blanching was carried out by immersing the aonla samples for 7 min in boiling water and soaking in cold water for 10 min. Blanched and unblanched samples were subjected to OD with hypertonic solution of 2% salt solution, or 40% sucrose solution for 12 h (Sagar and Kumar 2006). These samples were further dried by different methods.

Drying methods Blanched, unblanched, osmo-dehydrated and non-osmo-dehydrated samples were subjected to drying by open air sun drying, cabinet drier and by using CRIDA drier. Drying was continued until the moisture content of samples was brought down to 11–12%. Moisture content in the samples was estimated by recording weight of samples. In sun drying, drying of aonla was carried out by loading the samples on wire mesh tray kept on concrete platform in open sun. In cabinet drier, the samples were loaded into an electrically operated cabinet drier of 0.24 m^3 volume which is electrically operated with 1.5 Kw power. Cabinet drier drying was carried out at 50 °C. In CRIDA drier, an LPG based CRIDA drier, which was developed and fabricated in the work shop of CRIDA, Hyderabad, was used.

Design of CRIDA drier

A CRIDA drier with LPG as fuel consisted of a drying chamber of 6 m^3 volume, removable stand to mount 42 trays, furnace with 2 gas burners, 0.5 HP blower to blow the hot air, thermostat to maintain temperature and inlet and outlet openings for controlling humidity. The design features and specifications of the drier are illustrated in Fig. 1. About 42 trays (40 cm × 40 cm) can be arranged in a zigzag way so that the hot air moves in S-shape path. The drying chamber is fabricated with 16 gauge MS sheet. The chamber has 2 walls with 25 mm gap and the gap between the walls is insulated with glass wool. A furnace with 3 burners is placed outside the drying chamber. Furnace is made with 6 mm thickness copper heating element. The burners placed beneath the copper plate are fuelled with LPG and the gas flow to the burners is controlled with an electronic relay system based thermostat. These burners have a burning capacity of 150 g/h. A minimum threshold level of gas flow of 30 g/h is always maintained, to keep the burners lit even when the relay is in ‘off’ position after the required temperature is attained. The air heated in the

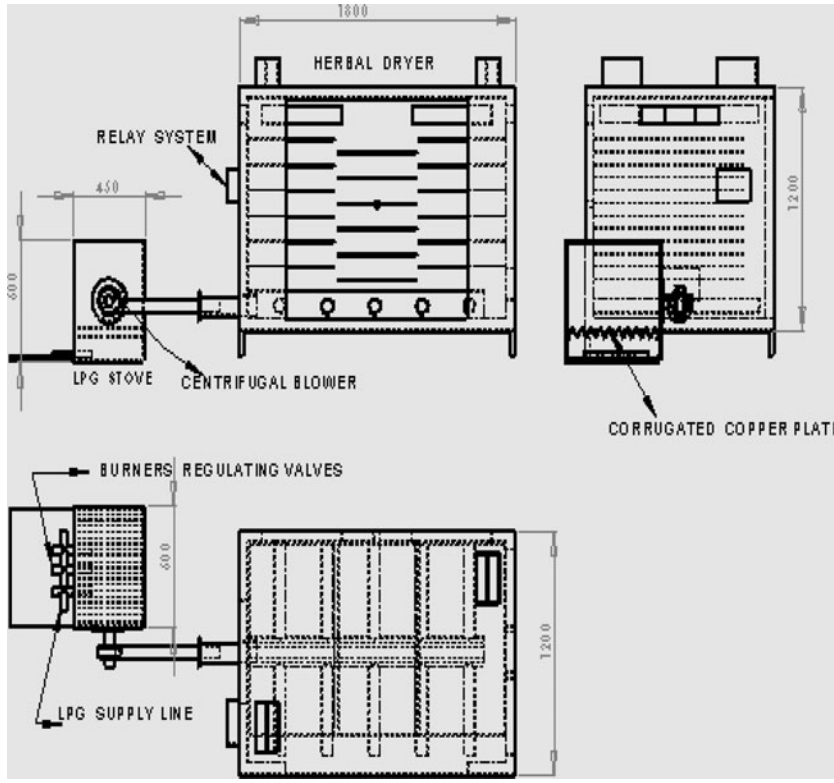

Fig. 1 Schematic diagram of CRIDA drier (Herbal) with LPG stove

furnace is blown into the drying chamber at a rate of 450 m^3/min with 0.5 h.p. blower. The temperature and humidity inside the drying chamber is measured with the help of sensors attached to the thermostat-relay control system. A display panel is placed outside the drier to show the set temperature and humidity. Required temperature in the chamber is maintained by controlling the gas flow into the burners automatically. The humidity is maintained by opening and closing of the ventilators, which are arranged at the top and bottom of drying chamber. The capacity of drier is 50 kg of fresh aonla. The drier can be used to dry different fruits and vegetables and the capacity of the drier depends on the type of the product.

The study was conducted during January–February 2007 and 2008.

Quality evaluation Vitamin C content in fresh and dried samples was determined by the 2, 6-dichlorophenolindophenol-titrimetric extraction method (AOAC 2000). Reconstitution quality of the samples was evaluated by soaking 10 g sample in boiling water for 5 min (Ranganna 1986). After soaking, the excess water was removed with the help of filter paper and the samples were weighed. Rehydration ratio (RR) and coefficient of restoration (COR) of the samples were computed as follows:

$$\mathrm{RR} = \frac{Wr}{Wd}$$

$$\mathrm{COR} = \frac{Wr(100 - A)}{Wd - Wm} \times 100$$

where: W_r is weight of rehydrated sample (g), W_d is weight of dry sample used for rehydration (g), A is moisture content of fresh sample (% wb) and Wm is moisture content of the dried sample taken for rehydration.

Sensory evaluation The sensory evaluation of dried aonla sample was assessed on the basis of colour, texture, appearance, and overall acceptability. The pretreated aonla segments (OD and blanched samples) were chosen for sensory evaluation. The other samples like whole fruits, pricking, and splits were discarded because of their poor appearance, presence of yeast and off-odours with physical signs of spoilage. As aonla is not a common dietary item, its sensory evaluation by a panel of judges is very difficult and hence large quantities of samples were prepared and were given to a panel of 20 judges belonging to different regions. Samples were coded and some duplicated to test the efficacy of judges. A panel of 5 judges was selected, who qualified at 5% probability level. The different attributes of sensory evaluation were rated on the basis of a 9—point Hedonic scale (1—dislike extremely to 9—like extremely) as per by BIS (1971).

Storage Aonla samples that were selected for sensory evaluation were stored in sealed polyethylene bags with

40 μ thickness at 25 °C and 30–34% RH for 6 months. After 6 months the vitamin C was estimated.

Statistical analysis The experiment was conducted using a factorial completely randomized design. The data was analyzed statistically using a general linear model for analysis of variance (Wilkinson et al. 1996). The data represent the average of 3 replicates Significance between control and treatments were compared at 0.05 probability levels.

Results and discussion

The ambient temperature, RH and wind velocity were 14.1–29.5 °C, 33–82% and 3.5 km/h, respectively. The average daily solar radiation was 10. The size of the fruit, vitamin C content and moisture content of the samples were 29.9 to 35.9 mm, 310 mg/100 g and 82%, respectively.

Drying time Drying time of whole fruit without OD in open air sun drying was 405 h while it was only 39 h in CRIDA drier (Table 1). Pricking and splitting reduced the drying time by 27 and 47%, respectively over whole fruits (Table 1). In aonla fruit a thin waxy layer around the fruit was observed even after complete drying. Splitting of fruit punctures this layer and might have helped in reducing the drying time. The drying time of aonla segments was low as compared to whole fruits/pricking/splitting by 87, 37 and 17 h, respectively (Table 1). The increase in surface area in segments has contributed to quicker drying. The drying time was reduced considerably by 30 h in OD samples as compared to control. Drying of OD segments in CRIDA drier took only 15 h as against 145 h in conventional sun drying. Blanching of aonla segments further reduced the drying time as compared to unblanching. CRIDA drier maintained the set temperature (50±2 °C) with better accuracy than cabinet drier or open air sun drying. The continuous flow of hot air even after set temperature was attained helped in maintaining the set temperature, whereas in the cabinet drier the hot air flow was stopped after the set temperature was attained.

Vitamin C Vitamin C content was highest (274–310 mg/100 g) in fresh aonla. Lower vitamin C content in dried samples is due to leaching, oxidation and thermal destruction during drying. These results are in conformity with the findings of Amin and Bhatia (1962). The vitamin C retention was minimum in whole fruit and sun drying (14.7%) and maximum in segments (Table 1). The greater retention of vitamin C in segments might be due to reduced time of exposure of sample to drying temperature. The

Table 1 Influence of pre-treatments, osmotic dehydration and drying methods on drying time and vitamin C content

Treatment	Drying time, h		Vitamin C, mg/100 g fruit		Vitamin C retention,%	
Sun drying	OD	No OD	OD	No OD	OD	No OD
Whole fruit	340	405	55	46	17.6	14.7
Pricking	248	292	90	64	29.1	20.5
Splits	165	217	104	76	33.4	24.4
Segments	149	201	146	108	52.7	36.8
Cabinet drier						
Whole fruit	40	48	76	55	24.5	17.6
Pricking	32	36	107	69	34.6	22.2
Splits	26	31	113	86	36.3	27.6
Segments	24	29	221	165	67	63.4
CRIDA drier						
Whole fruit	33	39	93	75	30.1	24.1
Pricking	25	29	115	85	37	27.0
Splits	20	26	122	117	39.4	37.9
Segments	15	22	279	228	83.2	74.2
Source of variation	**Lsd (p<0.05)**		**Lsd (p<0.05)**			
Pre treatments	8.9		13.6			
OD	10.9		16.6			
Drying methods	8.9		13.6			
Pre treatments × OD	15.4		23.5			
Pre treatments × drying	NS		NS			
OD × drying	NS		NS			
Pre-treatments × OD × drying	NS		NS			

OD osmotic dehydration (n=3)

Table 2 Influence of OD and blanching on drying time and vitamin C of aonla segments

Treatments	Drying time, h		Vitamin C, mg/100 g fruit		Vitamin C retention,%	
No blanching	Sun	CRIDA	Sun	CRIDA	Sun	CRIDA
OD with salt	161	15	122	243	57.2	86.8
OD with sugar	162	16	86	231	37.3	77.9
No OD	220	30	71	201	14.2	64.6
Blanching						
OD with salt	145	14	75	202	45.5	56.8
OD with sugar	145	15	66	175	30.2	51.42
No OD	194	20	43	130	18.6	45.9
Blanching	89.1			115.3		41.4
Source of variation	**LSD (p<0.05)**		**LSD (p<0.05)**			
Drying methods	8.9		13.58			
OD	10.91		16.6			
Blanching	8.9		13.58			
Drying × OD	15.43		23.5			
Drying × blanching	NS		NS			
OD × blanching	NS		NS			
Drying × OD × blanching	NS		NS			

OD osmotic dehydration (n=3)

CRIDA drier dried aonla segments retained maximum vitamin C (75%) when compared to open air sun drying (40%) and cabinet drier (47%) (Table 1). Higher retention of vitamin C in CRIDA drier is due to maintenance of the required temperature and humidity (40%) with better accuracy due to uniform hot air flow as compared to cabinet drier. The unblanched segments osmotically dehydrated with salt and further drying in CRIDA drier showed maximum vitamin C retention (86%) (Table 2). The maximum retention of vitamin C was observed in OD with salt (87%) when compared to sugar (78%) and no OD (Table 2). Better retention of vitamin C in OD with salt is due to reduced activity of oxidizing enzymes and protective effect of salt on oxidation/degradation. Vitamin C is heat labile and water soluble and hence it is susceptible to blanch related nutrient leaching, diffusion and thermal degradation which might have contributed to lower retention of vitamin C in blanched samples as compared to

Table 3 Influence of OD, blanching and drying methods on rehydration characteristic of aonla segments

Treatments	RW		Dehydrated wt.		Rehydration ratio		COR	
No blanching	Sun	CRIDA	Sun	CRIDA	Sun	CRIDA	Sun	CRIDA
OD with salt	27.4	42.4	6.9	5.84	2.7	4.2	0.58	0.89
OD with sugar	22.4	31.2	6.2	6.5	2.2	3.1	0.47	0.66
No OD	18.8	23.4	7.0	7.2	1.9	2.3	0.4	0.49
Blanching								
OD with salt	16.4	25.6	8.0	6.8	1.6	2.6	0.35	0.54
OD with sugar	19.6	24.5	7.4	7.3	1.9	2.5	0.42	0.52
No OD	17.6	17.4	7.9	8.1	1.8	1.7	0.37	0.37
Source of variation	**LSD (p<0.05)**		**LSD (p<0.05)**					
Drying methods	1.07		0.17					
Blanching	1.07		0.17					
OD	1.30		0.20					
Drying × blanching	1.51		NS					
Drying × OD	1.84		0.29					
OD × blanching	1.84		NS					
Drying × OD × blanching	NS		NS					

OD osmotic dehydration, *RW* rehydrated weight unblanched aonla. These findings are in conformity with the earlier reports of Negi and Roy (2000), Taiwo et al. (2001) and Ndawula et al. (2004).

Rehydration characteristics Rehydration ratio was more in segments compared to other pretreated of fruits (Table 3). OD of segments with salt and CRIDA drier drying had better rehydration ratio. Drying of samples in CRIDA drier had higher rehydration ratio (4.2) when compared to sun drying (2.2). For CRIDA drier dried samples, coefficient of rehydration was higher as compared to Sun drying. This indicates that CRIDA dried samples possess better reconstitution properties than Sun dried counterparts. This behaviour may be attributed to the change in rate of drying in sun drying and in CRIDA drier drying. CRIDA drier drying gives higher rate of drying resulting in higher coefficient of reconstitution than sun drying.

Fluctuation in diurnal temperature during sun drying causes irreversible cellular rupture and dislocation resulting in loss of tissue integrity producing a dense structure of collapsed greatly shrunken capillaries with reduced hydrophilic properties (Krokida and Maroulis 2001). Better reconstitution quality in CRIDA drier is due to less detrimental effect of temperature on the quality of aonla samples as the drying temperatures are uniform and drying is faster, so the destruction of cells is less. Pervin et al. (2008) observed similar results during drying of peas.

Sensory quality Dehydrated products obtained using CRIDA drier was liked very much because of its appealing colour, preferable texture, flavour and better overall acceptability (Table 4). This may be because of the reduced drying period in CRIDA drier and less exposure of the segments to the hot drying air. Sun dried product was disliked very much as the colour was not acceptable, the texture was poor and the taste was only moderately acceptable (Table 4). Segments osmotically dehydrated with salt and drying in CRIDA drier had higher acceptability, as the colour of the product and texture were appealing.

Fuel consumption and economics of drying The average gas consumption in different pre treated aonla ranged from 1.47 to 3.5 kg/batch of aonla dried after different pretreatments. The gas consumption in drying of untreated aonla was 3.5 kg/batch of drying (Table 5).The lowest gas consumption was in osmotically dehydrated segments (0.08 kg/h). The electricity consumed in cabinet drier was 2.7 kw/kg/h of dried product. The expenditure on the gas used for drying was in the range of Rs 44-105/batch of

Table 4 Influence of OD, blanching, drying methods on sensory scores of judges

Treatments		Colour		Texture		Taste		Overall acceptability	
No blanching		Sun	CRIDA	Sun	CRIDA	Sun	CRIDA	Sun	CRIDA
OD with salt		4.1	8.8	4.3	8.5	4.1	8.8	4.3	8.8
OD with sugar		3.5	8.1	4.3	7.5	4.0	7.6	4.0	8.1
No OD		2.7	6.8	3.5	6.6	2.3	6.6	2.8	7.3
Blanching									
OD with salt		3.5	7.5	4.6	7.3	4.3	7.1	3.6	7.0
OD with sugar		3.2	7.0	4.0	6.8	4.1	6.6	3.6	6.6
N o OD		2.2	6.5	2.3	5.5	2.1	5.5	2.1	5.8
Source of variation	**df**	**MSS**							
		Colour		Texture		Taste		Overall acceptability	
Judges	5	0.1[ns]		0.392[ns]		0.32[ns]		0.558[ns]	
Drying	1	329.38[a]		183.68[a]		227.5[a]		268.3[a]	
Blanching	1	9.38[a]		8.68[a]		6.72[a]		21.12[a]	
OD	2	13.04[a]		18.29[a]		24.85[a]		13.16[a]	
Drying × blanching	2	0.889[a]		1.68[a]		8[a]		5.01[a]	
Drying × OD	1	0.014[ns]		0.264[ns]		1.014[ns]		0.389[ns]	
OD × blanching	2	0.514[ns]		1.014[ns]		0.181[ns]		0.167[ns]	
Drying × OD × blanching	2	0.431[ns]		0.931[ns]		0.292[ns]		0.056[ns]	
Errors	55	0.25		0.345		0.3304		0.219	

DF Degrees of Freedom, [ns] Non significant

[a] Significant at $p<0.05$

Table 5 Energy consumption in various treatments

Treatment	Gas used by CRIDA drier, kg	Electricity in cabinet drier, KW	Cost of gas spent/batch of aonla dried, Rs	Electricity cost/batch of dried aonla, Rs
WF + OD	3.25	64	97.50	444.50
WF + No OD	3.5	72	105	280.00
Pricking + OD	2.31	57	69.30	199.50
Pricking + NO OD	2.61	59	78.30	206.50
Splits + OD	2.16	53	64.80	185.50
Splits + NO OD	2.4	58	72.0	203.00
Segments + OD salt	1.5	127	45.0	182.00
Segments + OD sugar	1.56	–	46.80	
Segments + No OD	3.1	–	93.0	
Segments + blanching + OD salt	1.47	–	44.1	
Segments + blanching + OD sugar	1.58	–	47.4	
Segments + blanching + No OD	2.2	–	66.0	

WF whole fruit, *OD* osmotic dehydration

aonla drying whereas the amount spent on electricity ranged between Rs 364 and 889. The drying of aonla in CRIDA drier is more economical as compared to drying in cabinet drier. The additional expenditure spent on gas in CRIDA drier can be compensated by reduced labour cost and the product is likely to fetch higher price due to better quality and acceptability.

Shelf-life Vitamin C content of fruits decreased during storage in all the treatments (Fig. 2). Maximum retention of vitamin C after 6 months was in the fruits dried in CRIDA drier when compared to sun drying (Fig. 2). During storage, oxidizing enzymes like ascorbic acid oxidase, peroxidase and others might cause decrease in vitamin C of the fruits (Damodaran et al. 2001). Activity of these enzymes might have been reduced in the products dried in CRIDA drier and osmotically dehydrated fruits.

Conclusion

An LPG based drier developed at CRIDA for dehydration of vegetables, fruits and medicinal plants was evaluated for drying of aonla. Aonla segments osmotically dehydrated with salt and dried in CRIDA drier took less drying time and retained maximum vitamin C, whereas in open air drying the retention of vitamin C was very low. Maximum rehydration and coefficient of rehydration were found in

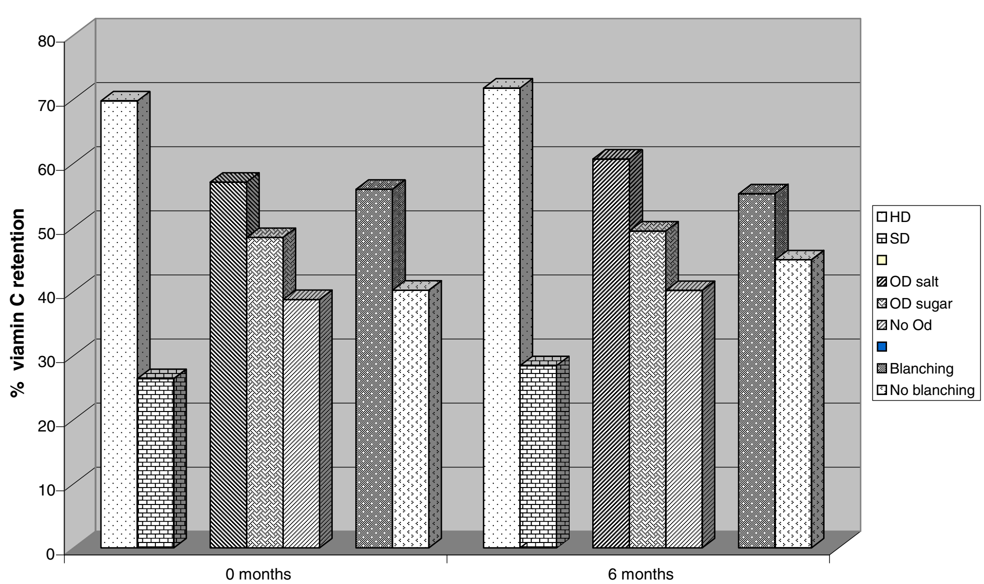

Fig. 2 Vitamin C retention during storage for 6 months as influenced by drying methods, osmotic dehydration and blancing in aonla segments

osmotically dehydrated aonla segments and dried in CRIDA drier. All the pretreated aonla segments dried in CRIDA drier were very much acceptable in terms of sensory appealing colour, texture and taste, compared to Sun drying or cabinet drying.

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