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DRYING BEHAVIOUR OF CURRY LEAVES UNDER DIFFERENT DRYING TECHNIQUES

S R Sharma[1]*, T C Mittal[1], M S Alam[1], Anamika Bhardwaj[1] and Rakesh Sharda[2]

[1]Department of Processing and Food Engineering, [2]Department of Soil & Water Engineering
Punjab Agricultural University, Ludhiana – 141004, Punjab

ABSTRACT

Curry leaves – a miracle plant had been used in Indian kitchens from ancient times to enhance flavour and aroma of the food. But apart from their appetite tickling flavour, these leaves are known to have essential nutrients like copper, calcium, phosphorus, fibre, carbohydrates, energy, magnesium and iron. However, the crop is highly perishable and susceptible to microbial contamination. The shelf life of the leaves can be increased by using different drying techniques. In this study, control and pretreated curry leaves were dried under various drying techniques i.e. open sun drying, solar drying, solar tunnel drying and mechanical drying at 50ºC, 55ºC and 60ºC. The quality was determined on the basis of moisture content, time of drying, colour, chlorophyll content, rehydration ratio and sensory attributes. Among all the drying techniques, solar tunnel drying and mechanical drying at 55°C gave best results for pretreated curry leaves witnessing total drying time of 3.5 hours and 4.5 hours, respectively. The green colour of the leaves was retained better in mechanical drying system.

Keywords: Chlorophyll content, Curry leaves, Drying methods, Rehydration ratio, Sensory attributes

Curry leaves (*Murraya Koenigii*) are a green leafy perennial vegetable belonging to the Rutaceae family, which represents more than 150 genera and 1600 species. They are commonly known as “karipatta” and “sweet neem leaves” in Indian dialects (Kenghe *et al.*, 2015). The curry plant basically originated from India, Sri Lanka, Bangladesh, Andaman Islands and later spread to the other parts of the world. Due to presence of distinct aroma, it is most popular among South Indian cuisines. Volatile oil accounts for this desirable aroma (Singh, 2014). Apart from aroma, different parts of the plant contain various bioactive compounds which have potential to fight infection and strengthening the immune system (Gahlawat *et al.*, 2014).

Curry leaves are also used as a herb in Ayurvedic medicine due to high antioxidant potential and numerous health benefits. They reduce stomach disorders, prevent premature greying of hair, reduce weight and control diabetes. They serve as good nutritional supplements due to the presence of vitamin C, minerals, calcium, phosphorous, magnesium, iron and nicotinic acid (Dua and Srivastav, 2013). However, they have a very short shelf life and are highly perishable in nature (Sakhale *et al.*, 2007).

Drying is a feasible method of preservation of curry leaves. It increases shelf life of leaves by reducing their moisture content and therefore making their consumption possible in the off-season. Further, an appropriate pretreatment can help to retain quality of leaves effectively. Research needs to be done to explore the possibility of employing appropriate drying technique to reduce the losses and to retain optimum quality. The present investigation on drying behaviour of curry leaves was carried out to examine the effect of pretreatment and drying techniques on drying of curry leaves and to assess the quality of dried product.

*Corresponding author : sajeevrattan@pau.edu
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MATERIALS AND METHODS

Fresh samples of curry leaves were procured from the herbal garden of Punjab Agricultural University, Ludhiana in the morning hours on the day of conducting the experiment. The undesirable, damaged and contaminated parts were removed manually. Half of leaves were kept as such for drying i.e. control and remaining half were subject to pretreatment prior to drying.

Pretreatment

Curry leaves were subjected to pretreatment by dipping for 30 seconds in a solution of warm water at 60ºC having 2% KMS, 0.1% $MgCl_2$ and 0.1% $NaHCO_3$ and cooling immediately in tap water. Pretreatment prior to drying was primarily done to make enzymes inactive which would otherwise result in undesirable changes in color, texture, flavor and nutritive value of the products during processing and storage (Wiriya *et al.*, 2009; Tunde-Akintunde, 2010).

Drying

In this study control and pretreated curry leaves were

subjected separately to four different drying techniques to obtain best possible quality dried product. Various techniques used have been illustrated as follows:

Open sun drying

A known weight of fresh curry leaves was put in trays kept at a height on an angle iron table so that air could pass through the leaves from the bottom also and drying could take place at a faster rate. The material was kept for drying in the morning and in the evening it was removed from the tray. It was continued until the weight of the samples became constant.

Solar drying

The experiment was performed on multi-shelf domestic solar dryer developed at Punjab Agricultural University. Solar drying chamber consisted of a glass having 4-5mm thickness, flat plate solar collector and three metallic shelves painted black with air vent. The air vent allowed the passage of air inside the solar collector which eventually got heated up due to greenhouse effect; this hot air rose through the drying chamber going through trays and around the leaves, removing the moisture content.

Solar tunnel drying

The natural convection walk-in type solar tunnel dryer consisting of hemi-cylindrical metallic frame structure covered with UV stabilized polythene sheet of 200 micron was used for drying of curry leaves. The solar tunnel was 12 x 8 x 3.5 meters in dimension with three turbine fans and three sensors which measured relative humidity, temperature and time. Weight loss of curry leaves inside and outside of the tunnel was noted after each successive hour.

Mechanical drying

The experimental set up for mechanical drying of curry samples consisted of tray dryer with maximum attainable temperature of 200ºC. Electric heaters are fitted horizontally at the inlet of the dryer for heating the fresh air. A centrifugal blower at the bottom circulates the air inside the dryer. A 0.25 hp, three-phase 220V electric motor with direct online starter was used to power the blower. A known quantity of curry leaves was kept in the tray dryer at three different temperatures of 50, 55 and 60ºC. The tray dryer was put on for about 10-15 minutes before the start of the experiment for initial warming up of the system. The desired temperature was set by an automatic digital control. Using a sensitive electronic weighing balance, the weight of the samples was recorded at one hour interval.

Determination of quality parameters

Moisture content

The moisture content of curry leaves was determined using the standard oven method (AOAC, 2000).

Colour

The Hunter colorimeter was used for the experiment which is based on the Opponent-Colour. According to this theory, human eyes perceive color as opposite pairs measure in 'L', 'a' and 'b' scale. L scale indicated light versus dark where a low number (0-50) represented dark and a high number (51-100) represent light. The 'a scale' indicated red vs. green, positive being red and negative being green. Similarly, positive value of b indicated a yellow and negative indicated blue. All the three values were required to completely describe an object color. The dried curry leave samples obtained from various drying techniques were analyzed for 'L' 'a' and 'b' values.

Chlorophyll content

Firstly, 1g of finely cut curry leaves were taken in mortar and grinded to fine pulp with addition of 80% acetone. Then, the mixture was centrifuged at 500 rpm for 5 min and the supernatant was transferred to a 100 ml volumetric flask. The residue was again ground and centrifuged with the 20 ml of 80% acetone and the supernatant was transferred to the same volumetric flask. The procedure was repeated until the residue became colorless. The absorbance of the solution at 645 and 663nm was read against the solvent (80% acetone) blank in spectrophotometer. The amount of chlorophyll present (mg/100g) in the extract was calculated using the equation proposed by Nagata and Yamashita (1992) as follows:

Chlorophyll a = $0.999\ A_{663} - 0.989\ A_{645}$

Chlorophyll b = $1.77\ A_{645} - 0.328\ A_{663}$

Total chlorophyll = Chlorophyll a + Chlorophyll b

A_{663} = absorbance at 663 wavelength, A_{645} = absorbance at 645 wavelength

Rehydration ratio

A steel vessel containing 50ml of water was heated on heater till the water started boiling. 2.5g of dried sample was plunged to the boiling water for 10 minutes and then the sample was removed from the vessel and the water was drained out. With the help of a filter paper surface moisture was removed and the weight was measured. The rehydration ratio was calculated by using formula suggested by Pruthy *et al.* (1974).

Where, RR = $\frac{W_2}{W_1}$

RR = rehydration ratio

w_2= weight of rehydrated sample (g)

w_1 = weight of dried sample (g)

Sensory evaluation

The sensory evaluation of the dried product was conducted by a panel of five judges for visual appearance and aroma. The ratings assigned by the panel of judges were numerical scores ranging from 1 to 5 points. The value of one was attributed to a rating of very poor by the judges whereas a value of 5 was attributed to a rating of extremely good.

RESULTS AND DISCUSSION

Drying behavior of curry leaves

During open sun drying, the temperature and relative humidity varied between 31±3ºC and 24±2%, respectively. In case of solar tunnel drying, the ambient temperatures inside and the outside of the tunnel had a striking difference. The inside ambient conditions had the temperature range of 48.65±2ºC and relative humidity of 10%. In comparison, the outside temperature and relative humidity was found to be 27±1ºC and 32±3%, respectively.

Moisture content and drying time

It was evident from Fig.1 that the moisture content (% w.b.) of control samples varied between 4.05 to 5.73%. The minimum moisture content was found to be in leaves dried by solar tunnel drying. Mechanical drying at 55ºC and at 60ºC resulted in low moisture of 4.12 and 4.07%, respectively. The final value of moisture content can be considered as the equilibrium moisture content under the given set of air conditions. As during sun drying the temperature of the air fluctuates but is well below the mechanical drying air temperature therefore, final moisture content in sun drying was comparatively higher.

Pretreatment had a major impact on moisture content of dried curry leaves. The solar tunnel drying (3.91%), mechanical drying at 55ºC (3.95%) and at 60ºC (3.93%) caused lower moisture content compared to the control samples. The results of statistically factor mean values corroborated the results witnessing significant effect of pretreatment and drying technique on moisture content at 5% level of significance (Table 1).

Fig. 1 further revealed that the pretreated leaves showed better results when compared to control leaves in terms of lesser moisture content for various drying techniques. From the Fig. 1, it can be easily observed that the type of drying had major impact on moisture content of leaves. Pretreatment helped in lowering in the equilibrium moisture content (final moisture content) of product.

It is clear from the Fig. 2, showing drying time under various solar drying techniques, that the slope of the curves was lowest in open sun drying and highest in solar tunnel drying. Fig. 3 showing the trend of mechanical dried samples exhibited that with the rise in temperature, the slope of the curve increased indicating a higher drying rate at higher drying temperature. Among the different drying techniques used, solar tunnel drying witnessed minimum drying time followed by mechanical drying irrespective of tray air drying temperatures. The reduction in drying time for the samples dried under solar tunnel drying may be due to temperature increase and low relative humidity. It was observed that the solar tunnel drying followed by mechanical drying recorded time reduction by 75 percent irrespective of drying temperature (Table 1). The statistically analyzed factor mean values clearly show that the drying time was significantly affected by the pretreatment and drying technique (p=0.05).

Colour

It is clearly evident from Fig. 4 that open sun drying for control samples showed the highest (49.8) value of ‘L’. However, solar drying for curry leaves showed the least value (33.1) of ‘L’. Therefore, solar drying resulted in darker coloured leaves. As the sunlight was directly incident on curry leaves, darkening of leaves resulted and therefore low ‘L’. The ‘a’ value of mechanically dried leaves at 55ºC and solar tunnel dried leaves were -7.5 and -6.7, respectively; it means that greenness of curry leaves was maintained during these processes. The positive value of ‘b’ indicated yellowness and negative value indicated blueness. From this study open sun drying for control curry leaves sample showed the highest value (22.8) and mechanical drying at 50ºC depicted least value (17.6) of ‘b’.

Effect of pretreatment on colour of curry leaves for different drying techniques has been elicited in Fig. 5. Open sun dried leaves and solar dried leaves were found to be lightest (L= 44.2) and darkest (L= 24.8) in colour. Furthermost, mechanically dried leaves at 55ºC and solar tunnel dried leaves were found to be greener than other with ‘a’ as -6.7 and -5.4, respectively. Open sun drying imparted maximum yellowness (b= 22.8) to curry leaves and mechanical drying at 50ºC gave least (b= 14.3).

On comparing Fig.4 and Fig.5, it could be deduced that pretreatment imparted dark colour to curry leaves when compared to control one. In addition to this,

Table 1. Statistically analyzed factor mean values for different responses

Quality Parameter	Pretreatments (A)		Drying Techniques (B)					
	Control	CT	OSD	SD	STD	MD50	MD 55	MD60
Moisture Content (%wb)	4.56	4.82	5.48	4.77	4.09	5.20	4.61	3.94
LSD (5%)	A: 0.006	B:0.01	AB: 0.014	C.V: 0.18				
Drying time (hrs)	12.42	10.51	26.0	22.76	4.25	5.75	5.25	4.75
LSD (5%)	A: 0.222	B:0.385	AB: 0.545	C.V: 2.82				
Chlorophyll Content	265.32	257.58	227.19	266.74	266.56	259.13	277.46	272.61
LSD (5%)	A: 0.645	B:1.12	AB: 1.58	C.V: 0.36				
Rehydration Ratio	3.56	2.80	2.71	3.23	3.32	2.81	3.39	3.63
LSD (5%)	A: 0.013	B:0.023	AB: 0.033	C.V: 0.62				
Appearance	4.22	3.50	2.75	4.12	3.91	3.25	4.62	4.50
LSD (5%)	A: 0.187	B:0.324	AB: NS	C.V: 7.05				
Flavour	4.38	3.78	3.55	4.40	3.75	3.95	4.70	4.15
LSD (5%)	A: 0.066	B:0.114	AB: 0.161	C.V: 2.35				

Note: CT-Chemical treatment; OSD-Open sun drying; SD-Solar drying; STD- Solar tunnel drying; MD50- Mechanical drying at 50ºC; MD55-Mechanical drying at 55ºC; MD60- Mechanical drying at 60ºC

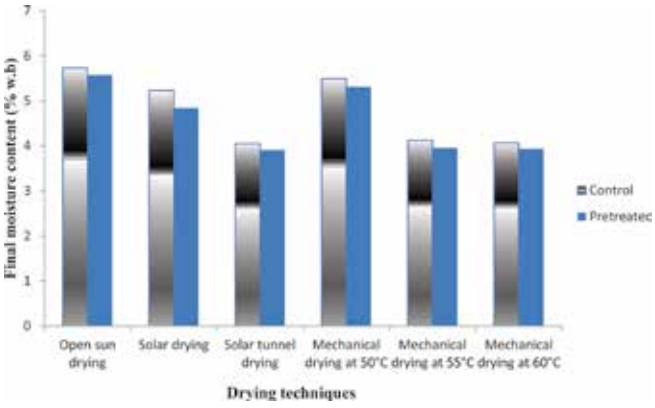

Fig. 1. Final moisture content of dried curry leaves under different drying techniques

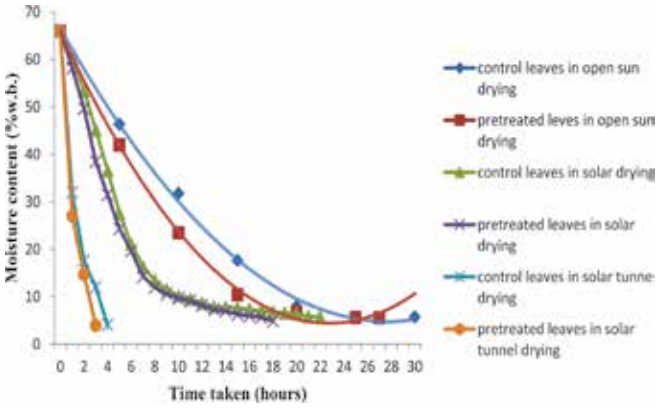

Fig. 2. Drying time of curry leaves under various sun drying techniques

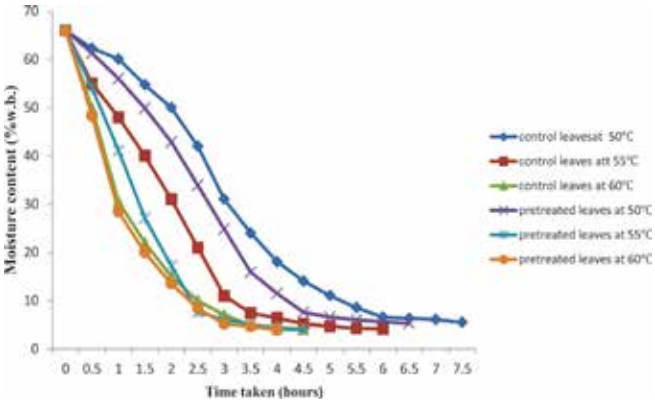

Fig. 3. Drying time of curry leaves under mechanical drying technique

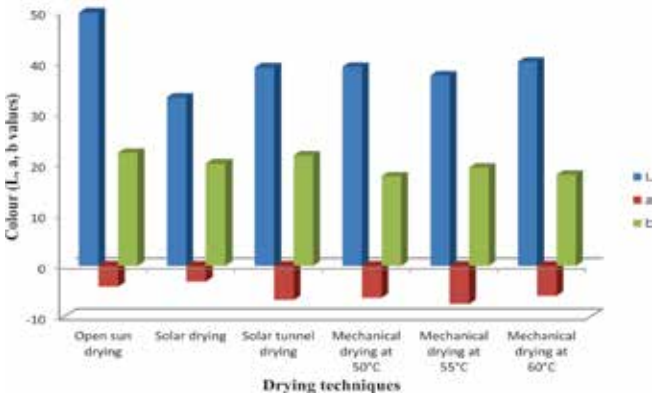

Fig. 4. Colour determination for control curry leaves

control samples were found to retain more greenness than pretreated samples. Yellowness was also found to be higher in control samples. The colour of various samples dried using different drying techniques has been shown in Fig. 5.

Chlorophyll content

The values of chlorophyll in dried samples of curry leaves were found to vary significantly. The effect of drying method and the effect of pretreatment were studied to evaluate chlorophyll content of dried samples.

From the Fig.6, it was clear that the maximum loss of chlorophyll for the control samples was found in open sun drying method (225.3 mg/100g) followed by solar drying, mechanical drying at 60ºC and at 50ºC with chlorophyll value as 229.1, 254.4 and 263.19 mg/100g, respectively. The maximum retention of chlorophyll was found in mechanical drying at 55ºC (276.74 mg/100g) followed by solar tunnel drying (271.29 mg/100g), mechanical drying at 50ºC (263.19 mg/100g) and mechanical drying at (254.39 mg/100g) respectively. Pretreated curry leaves also followed similar trend with maximum chlorophyll content in mechanical drying at 55ºC (285.81mg/100g) and minimum in open sun drying (254.23 mg/100g).

The maximum loss of chlorophyll content in sun dried sample may be attributed to the direct sunlight falling on the leaves whereas in solar and mechanical drying, there was no direct solar radiation and condition of drying were controlled in mechanical system.It is clearly evident from the Fig. 6, that pretreatment had major impact on the chlorophyll content. The retention of the chlorophyll was better in pretreated samples. The maximum retention was found to be in mechanical drying at 55ºC for pretreated leaves as 285.81 mg/100g which decreased to 276.74 mg/100g for control leaves. It was also clear that the mechanical drying methods showed better chlorophyll retention than solar drying methods. The statistically analyzed factor mean values clearly indicated the higher effect of drying technique in comparison to pretreatments at 5 percent level of significance (Table1)

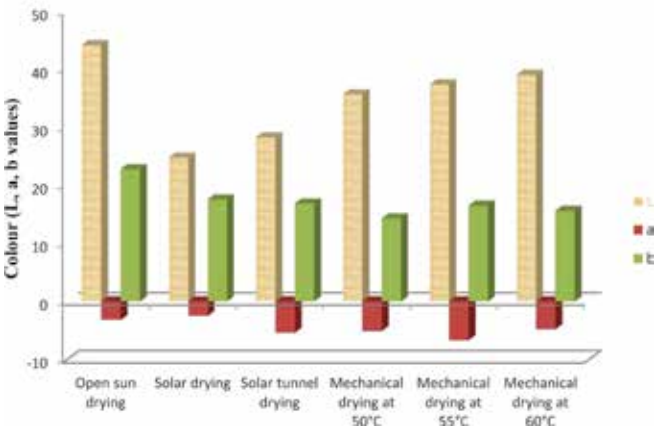

Fig. 5 Colour determination for pretreated curry leaves

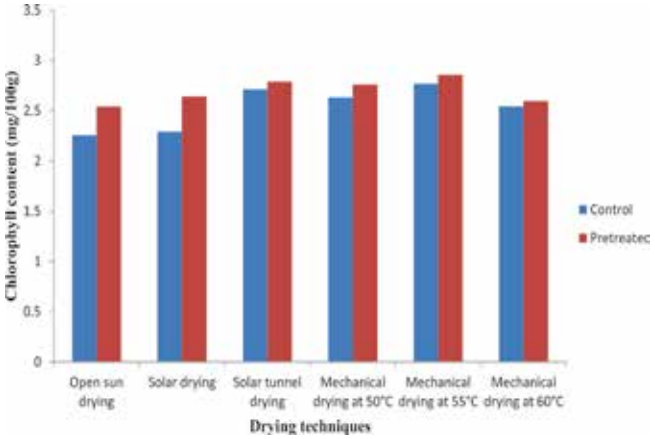

Fig. 6. Chlorophyll content of curry leaves for different drying treatment

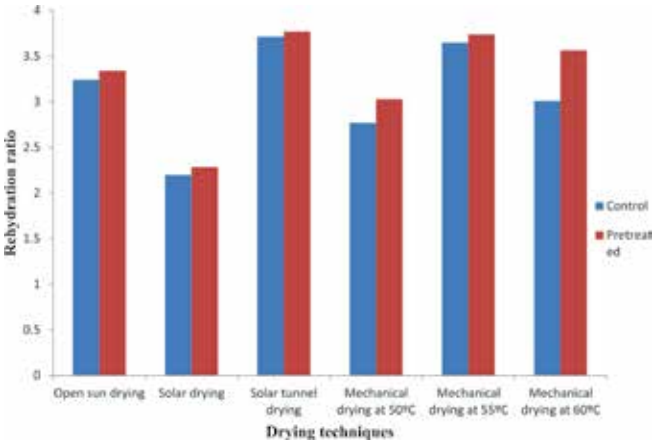

Fig. 7. Rehydration ratio of curry leaves for different drying treatment

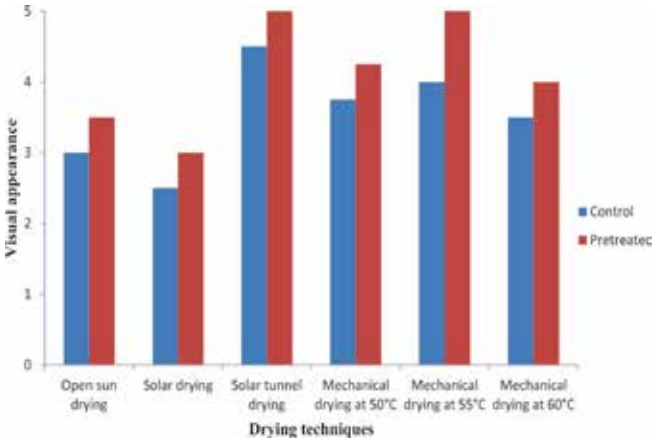

Fig. 8 .Visual Appearance of curry leaves for different drying treatment

Rehydration ratio

Fig.7 depicted that the rehydration ratio varied from 2.19 to 3.64 for the control samples. The maximum ratio was found to be in solar tunnel dried leaves and least in solar drying. Drying method had major impact on the rehydration ratio. Besides solar tunnel drying, the leaves dried mechanically at 55ºC represented fairly high rehydration ratio with 3.64 for control curry leaves. But, beyond this temperature i.e. 60º, the ratio plunged to 3.01.

Rehydration ratio for pretreated samples was found to be in range of 2.28 to 3.76. The solar tunnel drying (3.76) and mechanical drying (3.7) were on par with significantly higher ratios. Solar drying represented least rehydration ratio with the value of 2.28. To further add, Fig. 7 depicted that rehydration ratio was higher when leaves were subjected to pretreatment. It was clearly evident from the graph that pretreatment had impact on rehydration ratio especially for mechanical drying. Table 1 depicting the statistical analyzed factor mean values corroborates the significant effect of pretreatment and drying technique on rehydration ratio (p=0.05).

Rehydration ratio can be attributed to final moisture content of dried samples. As the final moisture content was higher in sundried samples, its water absorbing capacity was relatively less and hence low rehydration ratio.

Sensory evaluation

Visual appearance is one of the important aspects to determine the response of development to temperature. According to Fig. 8, the control leaves solar tunnel dried leaves were found to be 4.5 i.e. very good in the appearance followed by mechanical drying at 55ºC having good appearance (4). Solar drying adversely affected the leaves and had worst appearance among the group with value as 2.5. Pretreated leaves also followed the same trend as control leaves. Pretreated solar tunnel dried leaves and mechanically dried leaves at 50ºC were best among all and reflected excellent appearance (5). Mechanical drying at 50ºC and at 60ºC was next in the list with the values 4.25 and 4. Solar drying imparted bad (3) appearance to the pretreated curry leaves. Fig. 8 illustrates impact of pretreatment on the visual appearance of curry leaves. Pretreatment had significant impact on appearance of curry leaves. They gave better results than control samples. Low score in open sun and solar drying may be attributed to darkening of samples due to direct solar radiation whereas green colour was maintained in mechanically and solar tunnel dried samples. Pretreatment further helped in retention of green colour and hence better score on visual appearance scale. The statistically analyzed data also corroborated the results showing

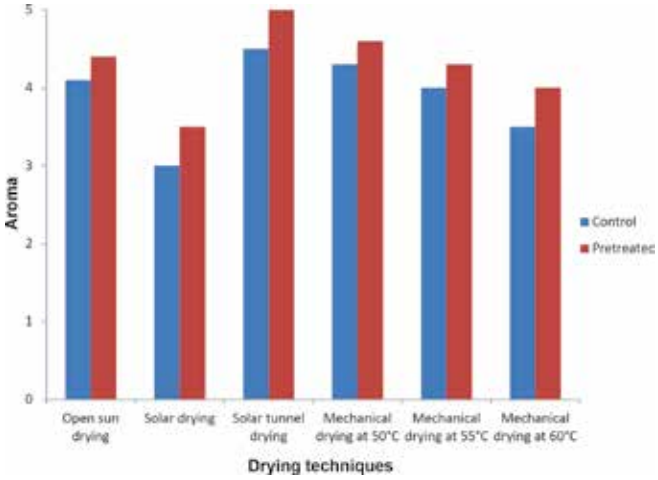

Fig. 9. Aroma of curry leaves for different drying treatments

significant effect of pretreatment and drying technique on visual appearance (Table1).

In context of aroma of dried product, Fig. 9 depicted the effect different drying techniques on the aroma of the curry leaves. It was clear from the Table that the solar tunnel drying gave the desired aroma. Control solar tunnel dried leaves (4.5) and mechanically dried leaves at 50ºC (4.3) were on par with each other and gave very good aroma. Solar dried leaves failed to retain desirable aroma as they gave least value i.e.3. The statistically analyzed factor mean values as shown in Table 1 clearly depict the significant effect of pretreatment and drying methods. It was clearly evident from Fig. 9 that aroma decreased with increase in temperature of mechanical drying. Also, pretreatment had major impact on the aroma. The aroma was better in pretreated samples. Low score in open sun and solar drying may be attributed to direct solar radiation whereas green colour was maintained in mechanically and solar tunnel dried samples.

It can be concluded that the pretreatment effectively retained various quality parameters whereas, among various drying techniques solar tunnel drying followed by mechanical drying at 55ºC gave better results. The solar tunnel drying has an advantage over mechanical drying in terms of negligible operational cost but was at par with mechanical drying for quality attributes, but preferred if operated at full load capacity in comparison to mechanical drying.

Authors' contribution

Conceptualization of research work and designing of experiments (SR, TC); Execution of field/lab experiments and data collection (SR, AB, RS); Analysis of data and interpretation (SR, TC, MS); Preparation of manuscript (SR, TC, MS, AB)

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