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Comparative evaluation on drying of pomegranate arils for production of *anardana*

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ABSTRACT

Wild pomegranate is an important wild fruit of the Punicaceae family, which has great economic importance. Pretreated arils (steam blanched for 30 sec followed by sulphuring @ 0.3% for 60 min) were dried by different intermittent drying modes to minimize energy utilization and maximize quality retention of dried arils at a lower cost. Various drying modes used were mechanical cabinet drying (60±2°C), sun drying (18-31° C), solar tunnel (21-39°C) drying, a combination of solar tunnel + mechanical cabinet drier, a combination of open sun + solar tunnel drier and combination of open sun+ solar tunnel + mechanical cabinet drier. The quality of dried arils (anardana) obtained was compared based on various physical, chemical and sensory characteristics besides energy utilization in each method with economic analysis. Arils dried in mechanical cabinet drier possessed highest values of desirable physico-chemical characteristics viz., colour, TSS (45.20° B), titratable acidity (11.40 %), ascorbic acid (11.70 mg/100g), total sugars (25.45 %), anthocyanins (33.76 mg/100g), phenols (126.05 mg/100g), crude fibers (35.91 %), oil (8.89 %) and antioxidant activity (65.22 %). It took a minimum time (26 h) to dry a given tray load, had minimum non-enzymatic browning (0.06 OD), furfural (11.89 ppb) and hydroxy methyl furfural (0.90 ppm), besides highest energy consumption for drying. Mechanical cabinet-dried arils were rated best among all drying modes based on the highest sensory scores. However, the quality of solar-dried anardana was at par with the mechanically dried anardana with a low cost of production (Rs 251 per kg as against Rs 326 per kg).

Keywords: *Punica granatum* L., Antioxidants, Solar drying, Furfural

INTRODUCTION

Wild pomegranate (*Punica granatum* L.) is an important wild fruit of family Punicaceae. Pomegranate is native to Iran and extensively cultivated in its wild form in Syria, Afghanistan, Central Asia and India (Saxena *et al.*, 13). It is found at an elevation of 900-1800 m above mean sea level in Himachal Pradesh (HP), Jammu and Kashmir and Uttarakhand in India (Mishra *et al.,* 11). In HP, it is found in some parts of Solan, Sirmour, Mandi, Shimla, Kullu and Chamba districts. Because of its wild distribution, no systematic data on area and production is available in the state. It is commonly called as "*Daru*" in HP which is considered as one of the commercial fruit. Being a non climacteric fruit, its harvesting and collection starts after ripening during August and continues upto October (Dhandar and Singh, 4). The edible part of its fruit is arils, which are rich in organic acids (mainly citric acid), sugars, vitamins C and bioactive compounds such as flavonoids and phenols (Thakur *et al.*, 17). The wild pomegranate fruit has also got various medicinal properties including laxative, diuretic and used for curing vomiting, sore throat, earache, chest troubles, spleen complaints, bronchitis, liver and kidney disorders (Kirtikar and Basu, 8). Extracts of all parts of pomegranate fruit exhibit therapeutic properties and target a range of diseases including cancer, cardiovascular disorders, diabetes, male infertility, Alzheimer's disease, aging and AIDS (Lansky and Newman, 9). It has also been used in Persian cuisine as souring agent after its grinding where it is used in chutneys, relishes and spice rubs. A number of formulations of *anardana* have been used as ayurvedic medicines in the treatment of dysentery, diarrhoea, stomachache, inflammations hymenoletidosis, dyspepsia, bronchitis and cardiac problem (Hota *et al.,* 7). So, keeping in view the increasing demand of dried arils efforts were made in the present investigations with the objective to evaluate the quality of prepared *anardana* by intermittent drying by considering the value of energy saving using combination of two or more drying methods without compromising the quality of the product. Previously the research studies are only focused on the less drying time with higher utilization of energy which simultaneously increases the cost of the product. So the present study was carried out with

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the objective to reduce energy consumption and coat by means of combination of drying methods without compromising the quality of the product.

MATERIALS AND METHODS

Wild pomegranate fruits harvested at optimum maturity were procured from Karsog area of district Mandi (HP) and brought to the department of Food Science and Technology, UHF, Nauni, Solan (HP) in the year 2018. The fruits were further used for various physico-chemical analysis and preparation of *anardana* by intermittent drying. Wild pomegranate arils were extracted and pre-treated as per the method suggested by Thakur *et al.* (19), where arils were steam blanched for 30 seconds followed by sulphuring with 0.30 per cent sulphur powder for 60 minutes in sulphur fumigation chamber before carrying out the drying and the residual level of SO_2 in *anardana* was 240.19 ppm. The following drying modes were used for the preparation of *anardana.*

In sun drying, the pre-treated arils (3 kg) were spread on the perforated aluminium trays and kept in the open sun (18 to 31 °C) in an inclined position for drying. Arils were dried in the sun till they attain a constant weight. In solar tunnel drying, the pre-treated arils (3 kg) were spread on the perforated aluminium trays and put on the stands inside a solar tunnel drier (21 to 39 °C). The pre-treated arils were dried till they attain a constant weight. In mechanical cabinet drying, the pre-treated arils (3 kg) were spread on the perforated steel trays and dried at constant temperature at 60 ± 2 °C inside the mechanical cabinet upto a constant weight. The trays were shifted inside the drier by rotation to ensure uniform heat transmission to all the trays. In the combination of solar tunnel drying and mechanical cabinet drying the pre-treated arils (3 kg) were spread on the perforated aluminium trays and put on the stands inside a solar tunnel drier (21 to 39 °C) until they attain a constant weight. After that these solar tunnel dried arils were further spread on the perforated steel trays and dried at constant temperature at 60 $\pm$ 2 °C inside a mechanical cabinet drier upto a constant weight. In the combination of sun drying and solar tunnel drying the pre-treated arils (3 kg) were spread on the perforated aluminium trays and kept in open sun (18 to 31 °C) for drying. Arils were dried in the sun till they attain a constant weight. The sun dried arils were further dried in solar tunnel drier (30 °C) upto a constant weight. In the intermittent drying by following three drying modes (sun drying + solar tunnel drying + mechanical cabinet drying) the pre-treated arils (3 kg) were spread on the perforated aluminium trays and kept in open sun (18 to 31 °C) for drying until they attain a constant weight. These sun dried arils were further dried in solar tunnel drier (21 to 39 °C) followed by mechanical cabinet drying (60 °C). When the arils attain a constant weight in solar tunnel drier then these were shifted to mechanical cabinet drier for further drying upto their constant weight.

The size of randomly selected fruits was determined with the help of digital vernier calliper by measuring the length and diameter in millimeters (mm). The weight of randomly selected fruits was measured with the help of digital weighing balance and the colour of randomly selected fruits and arils was observed visually by comparing with the colour cards of Royal Horticulture Society, London. Yield of dried arils was calculated by dividing the weight of dried arils by the weight of fresh arils and the time taken to dry a given tray load (12 kg) was calculated by recording the time (h) required by the material in the tray till it attains a constant weight after drying in respective drying modes.

Moisture content of the samples was determined by measuring the weight loss due to evaporation of water. TSS were measured by digital refractometer (range 0 to 80 °B) (Model Milwaukee MA871 Europe, Romania) at 20 °C and the results were expressed as degree Brix (°B). Titratable acidity was estimated by titrating known volume of sample against standard NaOH using phenolphthalein as an indicator. The pH of sample was determined by using a digital pH meter (CRISON Instrument, Ltd, Spain), whereas, sugars were estimated as per the standard procedure given by. Ascorbic acid content was determined using 2, 6-dichlorophenol-indophenol dye method. Total anthocyanins present in all samples were determined by spectrophotometric method given by Ranganna (12) which involves extraction of anthocyanins with 85 per cent ethanolic HCl and measuring its optical density at 535 nm. Total phenols content was determined by Folin-Ciocalteu procedure given by Singleton and Rossi (16) in which absorbance was measured at 765 nm in a spectrophotometer. Free radical scavenging activity was measured as per the method of Brand-Williams *et al.* (2) in which DPPH was used as a source of free radical. For observing the oil content the dried sample of 10 g was treated with petroleum ether in Soxhlet Extraction Apparatus for 16 h and the ether extract was filtered in pre-weighed beaker. The petroleum ether was evaporated completely from the beaker and the increase in weight of beaker represented the oil content (Ranganna, 12). Whereas, for measuring non enzymatic browning (NEB) the sample was keptfor 12 h in 20 ml of 60 per cent ethyl alcohol and the optical density (440 nm) of filtered extract of centrifuged sample was measured by UV-Vis spectrophotometer (Model Shimadzu, Japan) against a blank of 60 per cent alcohol (Ranganna, 12). Furfural content was determined by colorimetric method given by Ranganna (12). Optical density was measured at 520 nm. Absorbance was then plotted against concentration and concentration of furfural in the sample was calculated as mg per 100 g of sample. The HMF (hydroxy methyl furfural) content of different samples was determined by Luh, Leonard and Marsh's method as reported by Ranganna (12) and the optical density was recorded at 540 nm. Crude fibres content was estimated by the method given by Gould (5). Total ash was determined by taking known weight of samples in silica crucibles and then placed in a muffle furnace for ashing at 550 °C.

The sensory evaluation of *anardana* was carried out to assess the consumer acceptance by Hedonic rating test.The samples were evaluated for sensory qualities on the basis of colour, texture, flavour and overall acceptability on a 9 point Hedonic scale. Taste panel comprised of faculty members and post graduate students of department of FST, UHF, Solan (HP) were selected randomly to evaluate the sensory parameters. Efforts were made to keep the same panel for sensory analysis throughout the entire period of study.

The raw material like fruit, sulphur powder, etc. were procured as per current prices in the market and cost of product was calculated taking into account the cost of raw material, ingredients, packaging material and processing cost.

The dataon physico-chemical characteristics of *anardana*were analyzed by CRD (factorial) (Cochran and Cox, 3) while the data pertaining to the sensory evaluation of dried wild pomegranate arils were analyzed by Randomized Block Design (RBD) as described by Mahony (10). Data on physico-chemical characteristics of fruit and dried arils during various experiments were replicated three times.

RESULTS AND DISCUSSION

Data on physical characteristics of wild pomegranate fruit presented in Table 1 indicate that the average length, breadth and weight of wild pomegranate fruits were recorded as 58.4 ± 0.78 mm, 52.1 ± 0.62 mm and 92.73 ± 4.93 g, respectively. Visual colour of mature fruit was found to be yellowish green, whereas, the colour of arils was observed as Red Purple (60 A).

The weight of arils per fruit and the weight of 100 arils were recorded as 51.80 ± 2.03 and 15.80 ± 1.91g, respectively. The edible portion was found 56.54 ± 3.78 per cent. Nearly similar results of these parameters of wild pomegranate fruit have also been reported byThakur *et al.*(17) in wild pomegranate fruit.

Table 1. Physical characteristics of wild pomegranate fruit

Characteristics	Mean ± S.E.
Length (mm)	58.4 ± 0.78
Breadth (mm)	52.1 ± 0.62
Weight (g)	92.73 ± 4.93
Colour of fruit	Yellowish green
*Colour of arils	Red Purple (60 A)
Weight of arils per fruit (g)	51.80 ± 2.03
Weight of 100 arils (g)	15.80 ± 1.91
Edible portion (%)	56.54 ± 3.78

*Colour card number of Royal Horticulture Society, London

The data of chemical characteristics of wild pomegranate fruit presented in Table 2 indicate that moisture content in the fruit arils was 71.53 ± 0.12 per cent and total solids were 28.47 ± 0.12 per cent.

The total soluble solids (TSS) in the fruit were recorded as 17.00 ± 0.40 °B, while the reducing and total sugars were found to be 7.39 ± 0.47 and 9.15 ± 0.13 per cent, respectively. These observations are within the range as reported byThakur *et al.*(17). Titratable acidity of this fruit was observed as 3.84 ± 0.32 per cent (as % citric acid), whereas, pH was recorded as 2.72 ± 0.04 in the arils. It also contained sufficient amount of ascorbic acid (19.79 ± 0.64 mg/100g), anthocyanins (9.06 ± 0.07 mg/100g) and total phenols (105.40 ± 0.81 mg/100g). The antioxidant activity and ash content of fruit were recorded as 42.18 ± 1.04 and 0.89 ± 0.22 per cent, respectively. Almost, similar results of these parameters have also been reported by Thakur *et al.*(17) in wild pomegranate fruit.

Table 2. Chemical characteristics of wild pomegranate fruit

Characteristics	Mean ± S.E.
Moisture (%)	71.53 ± 0.12
Total solids (%)	28.47 ± 0.12
TSS (°B)	17.00 ± 0.40
Reducing sugars (%)	7.39 ± 0.47
Total sugars (%)	9.15 ± 0.13
Titratable acidity (%)	3.84 ± 0.32
pH	2.72 ± 0.04
Ascorbic acid (mg/100 g)	19.79 ± 0.64
Anthocyanins (mg/100 g)	9.06 ± 0.07
Total phenols (mg GAE/100 g)	105.40 ± 0.81
DPPH anti-oxidant activity (%)	42.18 ± 1.04
Ash (%)	0.89 ± 0.22

Data pertaining to drying time indicate minimum (26 h) time to dry the arils was recorded in mechanical cabinet drier and maximum (249 h) in combination of three drying modes (open sun + solar tunnel + mechanical cabinet drier). The yield of sun dried arils (T_3) was found maximum (25.20 %) and minimum (19.91 %) in T_6. The higher yield of *anardana* observed in sun drying might be due to the retention of higher moisture content in this dried product. Arils dried in mechanical cabinet drier (T_1) had red group (46-B) colour which was most attractive as compared to other five drying modes, whereas, least attractive brownish red colour was observed in the arils dried by combination (T_6) of three drying modes (open sun + solar tunnel + mechanical cabinet drier). The higher intensity of red colour observed in *anardana* prepared in mechanical cabinet drier might be due to faster and controlled drying conditions which led towards better retention of colour pigments like anthocyanins and less browning in mechanical cabinet dried arils as compared to other drying modes. Similar trend of colour of *anardana* have also been reported by Sharma and Thakur (14) for mechanical cabinet dried arils. The lowest moisture content(5.46 %) and water activity(0.102)observed in T_6 might be due to the intermittent drying temperatures which promoted sufficient displacement of water vapours with increasing temperatures in respective drying modes. This is due to the greater temperature gradient between the three drying modes (lower temperature in open sun, slightly higher temperature in solar tunnel and then still higher temperature in mechanical cabinet drier), resulting in a greater driving force for water evaporation and thus produced product with lowest moisture content. The higher total solids content (94.54 %) of *anardana* observed in T_6 was due to the lower moisture content in dried product.

Data in the Table 3 unveil that maximum (45.20 °B) TSS were recorded in arils dried by mechanical

Table 3. Effect of different drying modes on the physico-chemical characteristics of wild pomegranate arils

Characteristics	Drying mode						$CD_{(0.05)}$
	T_1	T_2	T_3	T_4	T_5	T_6	
Yield (%)	20.16	23.50	25.20	20.07	24.67	19.91	1.14
Drying time (h)	26	140	155	196	228	249	2.75
*Visual colour	Red (46 B)	Red (53 C)	Red (53 D)	Red (43 C)	Red (43D)	Brownish Red	-
Moisture (%)	5.70	8.42	9.25	5.67	8.95	5.46	0.72
Total solids (%)	94.30	91.58	90.75	94.33	91.05	94.54	0.72
Water activity	0.118	0.212	0.363	0.106	0.289	0.102	0.05
TSS (°B)	45.20	43.60	40.40	42.90	40.20	42.10	0.81
Titratable acidity (%)	11.40	10.78	10.22	11.01	10.15	10.50	0.45
pH	2.92	2.93	2.95	2.94	2.96	2.97	0.03
Ascorbic acid (mg/100 g)	11.70	9.92	8.91	9.89	8.80	8.70	0.09
Total sugars (%)	25.45	23.82	21.8	22.56	20.81	22.09	0.13
Reducing sugars (%)	21.91	19.62	17.90	19.67	17.71	18.90	0.13
Anthocyanins (mg/100 g)	33.76	30.67	27.78	29.82	26.24	24.54	0.25
Total phenols (mg GAE/100 g)	126.05	118.61	110.03	117.18	109.66	107.98	0.23
DPPH anti-oxidant activity (%)	65.22	60.98	56.50	58.53	55.13	54.26	0.43
Ash (%)	4.14	4.12	4.12	4.13	4.12	4.14	NS
Crude fibers (%)	35.91	34.83	33.91	34.35	33.82	34.11	0.14
Oil (%)	8.89	8.61	7.89	8.21	7.59	8.08	0.15
Non enzymatic browning (OD)	0.06	0.08	0.09	0.09	0.10	0.13	0.01
Furfural (ppb)	11.89	13.49	17.78	15.68	17.98	18.87	0.90
Hydroxy methyl furfural (ppm)	0.90	1.02	2.01	1.72	2.41	3.02	0.09

* Colour card number of Royal Horticulture Society, London

T_1: Cabinet drying, T_2: Solar tunnel drying, T_3: Open sun drying, T_4: Solar tunnel drying + Cabinet drying, T_5: Open sun drying + Solar tunnel drying, T_6: Open sun drying + Solar tunnel drying + Cabinet drying cabinet drier (T_1) which might be due to the minimum involvement of various soluble constituents in various chemical reactions as a result of faster rate of drying as compared to the arils dried in open sun, solar tunnel drier and combination of these drying modes and minimum (40.20 °B) in T_5. Maximum reducing (21.91 %) and total (25.45 %) sugars were found in the arils dried in mechanical cabinet drier which might be due to reduced rate of involvement of reducing sugars in various chemical reactions including browning because of the faster drying in mechanical cabinet drier while, minimum reducing (17.71 %) and total sugars (20.81 %) were recorded in the arils dried by combination of open sun and solar tunnel drier (T_5). Sharma and Thakur (14) have also reported higher content of TSS as well as total and reducing sugars in the arils dried under mechanical cabinet drier. The highest acid content (11.40 %) of *anardana* observed in mechanical cabinet drier might be due to the reduced rate of involvement of acids in various browning reactions because of the faster drying and lower moisture content in mechanical cabinet drier as compared to other drying modes. Nearly similar trend of results of acid content of *anardana* have been reported by Sharma and Thakur (15) in *anardana* prepared under mechanical cabinet drier.

Mechanical cabinet dried arils had maximum (11.70 mg/100g) ascorbic acid which might be due to the reduced loss of ascorbic acid because of faster drying rate which reduced the exposure time of arils for oxidation, whereas, arils dried by combination (T_6) of three drying modes had minimum (8.70 mg/100g) ascorbic acid. Nearly similar trend of results of ascorbic acid content of *anardana* have been reported by Sharma and Thakur (14) in mechanical cabinet, solar tunnel and open sun. Maximum antioxidant activity (65.22 %) was observed in the arils dried in mechanical cabinet drier (T_1)which might be due to the better stability of various antioxidant compounds during faster and continuous drying in mechanical cabinet drier which reduced the exposure time of arils for various chemical and oxidation processes leading to the retention of higher antioxidant properties, whereas, minimum (54.26 %) in arils dried by the combination of three drying modes like open sun, solar tunnel and mechanical cabinet drier (T_6). Nearly similar trend of higher antioxidant activity of *anardana* have been reported by Thakur *et al.* (18) in *anardana* prepared under mechanical cabinet drier. The arils dried in mechanical cabinet drier (T_1) had maximum (33.76 mg/100g) anthocyanins content due to the controlled drying conditions in mechanical cabinet drier and non exposure of arils to intermittent drying cycles and fluctuating temperatures as experienced by the arils in other drying modes, whereas, arils dried by combination (T_6)of open sun, solar tunnel and mechanical cabinet drier had minimum (24.54 mg/100g) anthocyanins. Nearly similar trend of results of anthocyanin content of *anardana* have been reported by Thakur *et al.* (18) and Hamid *et al.* (19) in *anardana* prepared under mechanical cabinet drier. Data in the same Table unveil that maximum (126.05 mg/100g) phenols were recorded in mechanical cabinet dried arils (T_1) due to the involvement of phenols in enzymatic reactions to a lesser extent because of fast drying in mechanical cabinet drier as compared to other drying modes and minimum (107.98 mg/100g) in T_6. Nearly similar trend of results of total phenols content of *anardana* have been reported by Sharma and Thakur (15) in mechanical cabinet drier. Mechanical cabinet dried arils (T_1) having the highest crude fibre content (35.91 %) and the arils dried through combination of open sun and solar tunnel drier (T_5) had lowest (33.82 %). Maximum (8.89 %) oil content was recorded in mechanical cabinet dried arils (T_1) due to the lesser involvement of oil in the oxidation during the period of drying as a result of faster and continuous drying and minimum (7.59 %) in arils dried by combination of open sun and solar tunnel drier (T_5). Minimum NEB (0.06) was observed in the arils dried in mechanical cabinet drier (T_1) due to fast drying rate and uniform drying which minimized the chances of non-enzymatic degradation along with the formation of polymerization products which are ultimately responsible for browning, whereas, maximum NEB (0.13) in arils dried through intermittent drying by combination of open sun, solar tunnel and mechanical cabinet drier (T_6). Nearly similar trend of results for NEB of *anardana* have been reported by Sharma and Thakur (13) for cabinet dried arils. There was no significant difference in values of ash content in arils dried in different drying modes. Hydroxy methyl furfural is an organic compound formed by the degradation sugars. The lowest values for HMF (0.90 ppm) in arils dried in the mechanical cabinet drier might be due to slower degradation of hexose sugars to form HMF because of efficient moisture removal and fast drying of arils under controlled conditions of temperature, whereas, arils dried by T_6 recorded the maximum HMF (3.02 ppm). The *anardana* prepared in mechanical cabinet drier recorded the lowest values of furfural(11.89 ppb) which might be due to the inhibition of polymerization of ascorbic acid to form furfural because of lowering of moisture of arils through efficient moisture removal and fast drying of arils under controlled conditions of temperature and maximum (18.87 ppb) in arils dried by T_6. The results of furfural obtained in *anardana* in the present studies are closer to those reported earlier by Sharma and Thakur (13).

Data related to various sensory characteristics of dried arils in different drying modes are presented in Table 4. Maximum scores of colour (8.00), texture (8.00), taste (8.60) and overall acceptability (8.55) were obtained in the arils dried in mechanical cabinet drier (T_1), whereas, minimum scores of all the above characteristics were observed in the arils dried by combination of open sun, solar tunnel and mechanical cabinet drier (T_6). Thus, on the basis of maximum sensory characteristics scores and desirable physico-chemical characteristics, arils dried in the mechanical cabinet drier (T_1) were found to be the best. Similarly higher sensory scores have been reported by Thakur *et al.* (18) in *anardana* prepared under mechanical cabinet drier as compared to solar tunnel drier. The reason of best score of colour might be due to less browning observed in the arils, while the good texture of arils might be due to low moisture content in the arils and quick drying of arils thereby improved the overall acceptability. Drying under controlled conditions in mechanical cabinet drier reduced the drying time and therefore low moisture content of cabinet dried arils prevented deteriorative chemical reactions like NEB by restricting Maillard reaction and other associated reactions leading to the development of a good dried (*anardana)* product with the maximum overall acceptability scores.

Energy utilization and economic evaluation of drying techniques is important to know for the optimization and for cost of product. Drying cost in food industry is high out of total production cost, therefore energy consumption in various driers need to calculate and thus need to find out method with least energy consumption for drying without compromising quality as well as cost of the product. In this study different drying methods were applied to study the variation in energy utilization with respect to maintenance of product quality. Table 5 shows that mechanical cabinet drier utilized higher industrial energy for the drying of the arils beside solar, sun and combinations of drying methods. Although higher energy consumption in mechanical drier reduce the product drying time as compare to product developed by other methods, but simultaneously it increases the cost of production of product (Rs 326.67/kg). Out of 6 treatments energy consumption is highest in mechanical cabinet drier (13 units) as compare to combination of methods such as Solar tunnel drying + Cabinet drying (T_4) (24 units) and Open sun drying + Solar tunnel drying + Cabinet drying (T_6) (16 units) respectively. However intermittent drying is helpful in reduction of energy consumption but simultaneously it increases the drying time which results in degradation of product quality. So trend in consumption of energy in different drying methods will directly varies the product final cost as Rs. 326.67/kg in T_1, 251.0/kg in T_2, 233.3/kg in $T_{3,}$ 314.92 in $T_{4,}$ 239.0 in T_5 and 312.12 inT_6, respectively. Thus it was concluded that treatment T_6 utilizes very less energy but it has lower sensory acceptability. So treatment T_4 was found to be the best without much energy utilization and comparative overall acceptability of the product.

Wild pomegranate fruits are rich source of organic acids, vitamin C, anthocyanins, phenols and various antioxidant compounds and could be utilized for preparation of *anardana* through economically valid techniques with less energy consumption without compromising with the product quality. So, pre-treated arils(steam blanched for 30 seconds followed by sulphur fumigation @0.3% for 60 minutes), can be dried efficiently in solar drier with lower energy consumption as compare to cabinet drier and possessed minimum changes in quality characteristics like in TSS, acidity, ascorbic acid, sugars, anthocyanins, phenols, crude fibers, oil and antioxidant activity beside intense red colour. Thus through intermmitant drying product cost can be lowered with less energy utilization during drying process beside good sensory acceptability which could be further used as an acidulant in many culinary preparations which will potentially give society a way to take advantage of this fruit's large health benefits. Thus considering energy consumption using combination of drying methods

Table 4. Effect of different drying modes on sensory characteristics of wild pomegranate arils

Characteristics	T_1	T_2	T_3	T_4	T_5	T_6	$CD_{0.05}$
Colour	8.00	7.90	7.00	7.55	7.00	6.00	0.27
Texture	8.00	7.80	7.00	7.50	7.00	6.80	0.85
Taste	8.60	7.90	7.00	7.80	6.90	6.00	0.32
Overall acceptability	8.55	7.95	6.80	7.70	6.50	6.00	0.61

T_1: Cabinet drying, T_2: Solar tunnel drying, T_3: Open sun drying, T_4: Solar tunnel drying + Cabinet drying, T_5: Open sun drying + Solar tunnel drying, T_6: Open sun drying + Solar tunnel drying + Cabinet drying

Table 5. Comparison of energy utilization in different drying methods and effect on cost of dried wild pomegranate arils

Particulars	Quantity	Rate (Rs.)	Amount (Rs.)					
			T_1	T_2	T_3	T_4	T_5	T_6
Fruit (Arils @ 56.54 %)	10 Kg (5654 g)	30/ kg	300	300	300	300	300	300
Sulphur Powder (0.3 %)	16.96 g	180/ kg	3.05	3.05	3.05	3.05	3.05	3.05
Processing cost @ 10 %	13 units	-	30.31	30.31	30.31	30.31	30.31	30.31
Electricity (Energy consumption) @ 0.5 unit/h	8 units 6 units respectively	3.00	39	-	-	24	-	18
Total cost of production of anardana (yield @ 20.16, 23.50, 25.20, 20.07, 24.67, 19.91% respectively)	1139.85 g 1328.00 g 1424.81 g 1134.76 g 1394.84 g 1125.71 g respectively	-	372.36	333.36	333.36	357.36	333.36	351.36
Total cost of production/100 g of anardana	100 g	-	32.67	25.10	23.33	31.49	23.90	31.21
Total cost of production/kg of anardana	1 Kg	-	326.67	251.0	233.3	314.92	239.0	312.12

T_1: Cabinet drying, T_2: Solar tunnel drying, T_3: Open sun drying, T_4: Solar tunnel drying + Cabinet drying, T_5: Open sun drying + Solar tunnel drying, T_6: Open sun drying + Solar tunnel drying + Cabinet drying

without compromising the quality of the product solar tunnel drier can be used for lowering the cost of product preparation.

AUTHORS' CONTRIBUTIONS

Investigation, Original draft- writing and editing, Statistical analysis& interpretation of results (CS). Conceptualization, Methodology, Validation, Editing-review, Supervision (NST). Critical review-original draft & editing (AT). Review original draft & editing (H). Review original draft & editing (KB). All authors reviewed the results and approved the final version of manuscript.

DECLARATION

The authors declare no conflict of interest.

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REFERENCES

1. Bakshi, P. Bhushan, B. Sharma, A. and Wali, V.K. 2014. Studies on variability in physicochemical traits and multiplication of *Daru* (wild pomegranate) collections. *Indian J. Hort.* **71**: 12-15.
2. Brand-Williams, W. Cuvelier, M.E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. *LWT-Food Sci. Technol..* **28**: 25-30.
3. Cochran, W.G. and Cox, G.M. 1957. Completely Randomized, Randomized Block and Latin Square Designs. In: *Experimental Design.* 2nd ed. John Wiley & Sons, New York, pp. 95-145.
4. Dhandar, D.G. and Singh, D.B. 2002. Current status and future needs for the development of pomegranate. In: *Programme and discussion papers*, National Horticulture Conference, New Delhi, p.12.
5. Gould, W.A. 1978. *Food Quality Assurance*. AVI Publishing Company, Westport, Connecticut, New York. 314p.
6. Hamid, Thakur, N.S., Thakur, A. and Kumar, P. 2020. Effect of different drying modes on phenolics and antioxidant potential of different parts of wild pomegranate fruits. *Sci. Hortic.* **274**: 109656.
7. Hota, M., Dahiya, D.S. and Sharma, D.K. 2017. Effect of various drying methods on quality of pomegranate (*Punica granatum* L.) arils. *The Bioscan* **12**: 851-54.

8. Kirtikar, K.R. and Basu, B.D. 1975. *Indian Medicinal Plants*: Vol 2. Bishen Singh and Mehendrapal Singh (Eds.) New Delhi and Dehra Dun. pp.1485-98.

9. Lansky, E.P. and Newman, R.A. 2007. *Punica granatum* (pomegranate) and its potential for prevention and treatment of inflammation and cancer. *J. Ethnopharma.* **109**: 177–206.

10. Mahony, M.O. 1985. Sensory Evaluation of Food. In: *Statistical Methods and Procedures*. Marcel Dekker, Inc, New York. 512p.

11. Mishra, G., Sharma, G., Taria, S., Lata, S. and Negi, D. 2016. Determination of pollen viability of wild pomegranate accessions in the mid-hill zone of Himachal Pradesh. *In. J. Farm Sci.* **6**: 105-10.

12. Ranganna, S. 2009. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGraw Hill, New Delhi. 1112p.

13. Saxena, A.K., Manan, J.K. and Berry, S.K. 1987. Pomegranate: post harvest technology, chemistry and processing. *Indian Food Packer.* **41**: 43-60.

14. Sharma, A. and Thakur, N.S. 2016a. Effect of different packaging treatments on some chemical constituents of *anardana*. *Indian J. Farm Sci.* **6**: 64-69.

15. Sharma, A. and Thakur., N.S. 2016b. Comparative studies on quality attributes of open sun and solar poly-tunnel dried wild pomegranate arils. *Indian. J. Bio-Resour. Stress Man.* **7**: 136-41.

16. Singleton, V.L. and Rossi, J.A. 1965. Colorimetry of total phenolics with phosphomolybedic phosphotungstic acid reagents. *Am. J. Eno Viti.* **16**: 144-58.

17. Thakur, A., Thakur, N.S., Hamid, and Kumar, P. 2018. Studies on Physico-chemical and antioxidant properties of wild pomegranate fruits in different locations of Himachal Pradesh, India. *Indian J. Current Microbiol. Appl. Sci*. **7**: 2842-50.

18. Thakur, A., Thakur, N.S., Hamid., Chauhan, M. and Sharma, C. 2020. Comparison of quality of *anardana* (dried arils) pre-pared in mechanical cabinet and solar tunnel drier from wild pomegranate (*Punica granatum* L.) fruits procured from different locations of Himachal Pradesh, India. *J. Appl. Natural Sci*. **12**: 71 – 78.

19. Thakur, N.S., Bhat, M.M., Rana, N. and Joshi, V.K. 2010. Standardization of pre-treatments for the preparation of dried arils from wild pomegranate. *J. Food Sci Technol.* **47**: 620-25.

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