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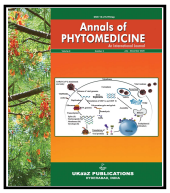

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Effect of packaging on phenols, flavonoids and antioxidant activity of dried wild pomegranate (*Punica granatum* L.) arils prepared in solar tunnel drier

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Abstract

Anardana, a dried product prepared from wild pomegranate (*Punica granatum* L.) fruits has been considered as a source of considerable medicinal value as a result of its high antioxidant potential. For the preparation of *anardana*, fruits were procured from wild pomegranate growing area of Himachal Pradesh (1265 m above mean sea level) and drying of arils was carried out in a solar tunnel drier (30-45 °C). The dried arils were packed in three different packaging materials *viz.* aluminium laminated pouches (ALP), aluminium laminated pouches with vacuum (ALPV) and gunny bags. All the packages were stored under ambient and refrigerated temperature which were further analyzed to evaluate the overall effect of packaging on total phenols (171.55 to 151.99 mg GAE/100 g), flavonoids (38.30 to 31.11 mg QuE/100 g), DPPH (2, 2-diphenyl-1-picrylhydrazyl) antioxidant activity (57.75 to 52.79 %), metal chelating activity (21.12 to 18.27 %), FRAP (ferric reducing antioxidant power 32.85 to 28.75 µM Fe^{2+}/100 g) and reducing power (0.576 to 0.484) during different storage conditions. After 12 months of storage period, higher retention of total phenols, flavonoids and antioxidant activity was observed in *anardana* packed in ALPV followed by ALP and gunny bags. The changes in the antioxidant characteristics of the *anardana* were slower in refrigerated storage conditions as compared to ambient.

1. Introduction

Wild pomegranate belonging to family Punicaceae is an important wild fruit which resembles the cultivated pomegranate (*Punica granatum* L.) for its various morphological characters (Mishra *et al.*, 2016; Thakur *et al.*, 2018a). The pomegranate fruit probably originated from South-West Asia and spread to other regions of the world like Mediterranean countries, India, China, Pakistan and Afghanistan (Narzary *et al.*, 2009) whereas, wild pomegranate grows in Transcaucasia and Central Asia from Iran and Turkmenistan to northern India (Chandra *et al.*, 2010). In India it is found wild in sub tropical tracts of north India particularly in Himachal Pradesh (HP), Uttarakhand and extending up to Jammu and Kashmir (Rawat *et al.*, 2012). In HP, it is found growing wild in some parts of Solan, Sirmour, Mandi, Shimla, Kullu, Bilaspur and Chamba districts (Thakur *et al.*, 2011; Thakur *et al.*, 2018b). The pomegranate fruit has been recognised as healing food since ancient times along with numerous beneficial effects in control of several diseases (Mageid *et al.*, 2016). Pomegranate fruit is one of the important sources of anti-oxidants like flavonoids which comprise approximately 0.20 to 1.0 % of the fruit. The isoflavones in the seeds of pomegranate fruit is composed of various compounds like genistein, diadzein, genistin, diadzin and estrone (Kumari *et al.*, 2012). The compounds like anthocyanins, ellagic acid derivatives and hydrolysable tannins like punicalagin, gallic and ellagic acid are responsible for the anti-oxidant activity of pomegranate fruit (Gill *et al.*, 2000). A very high antioxidant activity in cultivated (Aviram *et al.*, 2000; Singh *et al.*, 2002; Kalaycioglu and Erim, 2017) and wild pomegranate fruit (Hamid *et al.*, 2020a; Hamid *et al.*, 2020b) extracts (peel, juice and seeds) have been observed for its medicinal value and various human health benefits by various researchers. The unique anti-oxidant activity and various antioxidant compounds contribute towards its medicinal value, human health benefits and helps in the prevention of various neurodegenerative disorders (Kalaycioglu and Erim, 2017; Kashyap *et al.*, 2017; Thakur *et al.*, 2019).

The fruit being highly acidic in nature is processed into its dried form known as *anardana* which is used as an acidulant in culinary purposes. The *anardana* has high antioxidant potential and used in formulations of various ayurvedic medicines which are helpful in curing a number of ailments (Hota *et al.*, 2017). Limited studies have been carried out on effect of storage and packaging on antioxidant properties of *anardana*. Further, the advanced packaging techniques like vacuum packaging can retain higher anti-oxidant activity characteristics during storage. So, the present studies were carried out to compare the effect of packaging materials on total phenols, flavonoids and antioxidant activity of dried wild pomegranate arils during storage.

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2. Materials and Methods

2.1 Procurement of raw material and preparation of dried arils (*anardana*)

The wild pomegranate fruits were procured from Karsog area of Mandi district of Himachal Pradesh, India (1265 m above mean sea level). The fruit identification and authentication was carried out by Department of FST, YSPUHF, Solan, India. The fruits were further used for the preparation of *anardana* and the chemicals of analytical grade used during the entire study were procured from local market. Wild pomegranate arils were extracted and pre-treated as per the method suggested by Thakur *et al.* (2010), where arils were steam blanched for 30 sec followed by sulphuring with 0.30 % sulphur powder for 60 min in sulphur fumigation chamber before carrying out the drying. The pre-treated arils were spread on the perforated aluminium trays which were kept on the stands inside a solar tunnel drier of dimensions 297 × 204 × 183 cm. This drier had been made of polyethylene sheet of thickness 0.31 mm and the temperature recorded in this drier during these studies was in the range of 30-45 °C (Figure 1). The pre-treated arils were dried till they attained a constant weight.

Figure 1: Drying of wild pomegranate arils for *anardana* preparation under solar tunnel drier.

2.2 Packaging and storage

The *anardana* was packed in the packaging materials like aluminium laminated pouch of 99.8 gsm (ALP), aluminium laminated pouches with vacuum (ALPV) and gunny bags. All the packages were stored under ambient temperature (9.8-24 °C) and refrigerated temperature (4-7 °C) for a period of 12 months and overall effect of storage was analyzed for changes in various antioxidant compounds and activity.

2.3 Total phenols

Total phenols content was determined by Folin-Ciocalteu procedure given by Singleton and Rossi (1965) in which extinction coefficient was measured at 765 nm in a spectrophotometer. A standard curve of gallic acid using its different concentrations was prepared and concentration of the samples was calculated from the standard curve. The concentration of total phenols in the sample was calculated and expressed as mg GAE/100 g of sample.

2.4 Total flavonoids

Total flavonoids content was estimated according to the method of Ilahy *et al.* (2011). 0.1 ml of methanolic extract (1 ml/g sample in 10 ml methanol for 12 h) was added to 1 ml of 80 % ethanol. 0.1 ml of 10 % aluminium nitrate, 0.1 ml of 1 M potassium acetate and 4.3 ml of 80 % ethanol was taken in a test tube and an aliquot of 0.5 ml was added. The absorbance was measured at 415 nm after 40 min of incubation at room temperature. A standard calibration curve of quercetin was prepared and total flavonoids in the sample was calculated and expressed as mg QuE/100 g of sample.

2.5 Antioxidant activity

DPPH (2, 2-Diphenyl-1-picrylhydrazyl) radical scavenging activity was measured as per the method of Brand-Williams *et al.* (1995). Metal chelating activity in terms of % was determined according to method of Dinis *et al.* (1994). Ferric reducing anti-oxidant power (FRAP) of the samples was estimated according to the method of Benzie and Strain (1996) and expressed as µM Fe^{2+}/100 g. Reducing power of the samples was determined as per the method of Oktay *et al.* (2003). The absorbance of the sample extract at 700 nm was taken as a measure of reducing power.

2.6 Statistical analysis

The data on various quality characteristics were replicated three times and analyzed by CRD (factorial). The significance ($p< 0.05$) or otherwise of data obtained from various experiments was judged with the help of F-Table using OPSTAT software.

3. Results

Data pertaining to changes during storage in total phenols, total flavonoids and antioxidant activity of *anardana* prepared under solar tunnel drier have been presented in Tables 1-6 and Figures 2-7.

3.1 Total phenols

Data pertaining to total phenols content given in Table 1 and Figure 2 indicate that there was a general decreasing trend in the total phenols content of *anardana* during entire storage period of 12 months. The overall effect of storage on total phenols reveals that it decreased from 171.55 to 151.99 mg GAE/100 g, higher (164.54 mg GAE/100 g) was found in refrigerated storage conditions and lower (159.17 mg GAE/100 g) in ambient storage conditions. The higher (165.62 mg GAE/100 g) total phenols content was recorded in *anardana* packed in ALP with vacuum as compared to gunny bags (157.20 mg GAE/100 g) while comparing the overall effect of packaging materials on total phenols content of *anardana*.

The combined effect of storage period and storage conditions shows that total phenols content decreased from 171.55 to 157.44 and 146.55 mg GAE/100 g under refrigerated and ambient storage conditions, respectively, during entire storage period. The combined effect of packaging materials and storage conditions depicts that maximum (167.31 mg GAE/100 g) total phenols content was found in ALP with vacuum under refrigerated storage conditions and minimum (152.79 mg GAE/100 g) in gunny bags under ambient conditions. Further, combined effect of packaging materials and storage period reveals that there was a gradual increase in total phenols content from 171.55 to 142.59, 153.78 and 159.61 mg GAE/100 g in gunny bags, ALP and ALP with vacuum, respectively.

Table 1: Effect of storage on total phenols (mg GAE/100 g) of dried wild pomegranate arils prepared under solar tunnel drier

V / S / T	Ambient storage (Months) 0	3	6	9	12	Mean	Refrigerated storage (Months) 0	3	6	9	12	Mean
T_1	171.55	162.33	152.97	143.43	133.69	152.79	171.55	166.65	161.68	156.64	151.49	161.60
T_2	171.55	166.27	160.87	155.50	149.75	160.79	171.55	168.19	164.77	161.30	157.80	164.72
T_3	171.55	167.81	164.01	160.14	156.20	163.94	171.55	169.45	167.33	165.18	163.02	167.31
Mean	171.55	165.47	159.28	153.02	146.55		171.55	168.10	164.59	161.04	157.44	
Mean (V)			159.17						164.54			

T x S interaction Table							CD(0.05)	
T	0	3	6	9	12	Mean (T)	Storage period (S)	0.33
T_1	171.55	164.49	157.33	150.04	142.59	157.20	Storage conditions (V)	0.21
T_2	171.55	167.23	162.82	158.40	153.78	162.76	Packaging material (T)	0.25
T_3	171.55	168.63	165.67	162.66	159.61	165.62	S × V	0.46
Mean (S)	171.55	166.78	161.94	157.03	151.99		T × V	0.36
							T × S	0.56
							V × S × T	0.80

T_1: Gunny bag, T_2: Aluminium laminated pouch, T_3: Aluminium laminated pouch with vacuum.

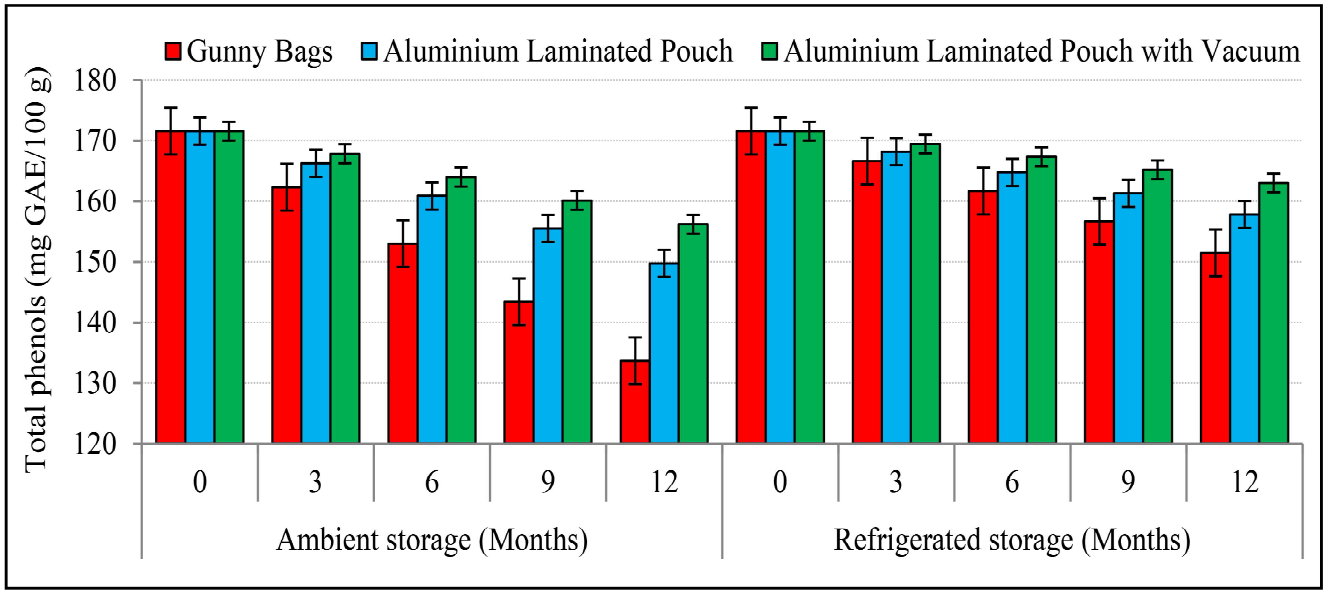

Figure 2: Effect of storage on total phenols (mg GAE/100 g) of dried wild pomegranate arils prepared under solar tunnel drier (error bars indicates standard error of the mean values).

3.2 Total flavonoids

An appraisal of data given in Table 2 and Figure 3 reveal that during entire storage there was a general decreasing trend in total flavonoids content of *anardana* prepared in solar tunnel drier. The overall effect of storage period indicates that total flavonoids content of *anardana* decreased from 38.30 to 31.11 mg QuE/100 g during storage. Further, while comparing the overall effect of storage conditions it was found that maximum (36.13 mg QuE/100 g) total flavonoids content was retained under refrigerated storage conditions as compared to ambient storage conditions (33.29 mg QuE/100 g). The overall effect of packaging materials indicates that higher (36.85 mg/100 g) total flavonoids content was retained in ALP with vacuum as compared to gunny bag (32.07 mg QuE /100 g) during storage.

The combined effect of storage period and storage conditions shows that total flavonoids content decreased from 38.30 to 28.08 and 34.14 mg/100 g under ambient and refrigerated storage conditions, respectively, during entire storage period. However, combined effect of packaging materials and storage conditions depicts that higher (37.23 mg QuE/100 g) total flavonoids content was retained in ALP with vacuum under refrigerated storage conditions and lower (29.38 mg QuE/100 g) in gunny bags under ambient conditions. The combined effect of packaging materials and storage period reveals that there was a gradual decrease in total flavonoids content from 38.30 to 35.76, 31.65 and 25.93 mg QuE/100 g in ALP with vacuum, ALP and gunny bags, respectively.

Table 2: Effect of storage on total flavonoids (mg QuE/100 g) of dried wild pomegranate arils prepared under solar tunnel drier

V / S / T	Ambient storage (Months) 0	3	6	9	12	Mean	Refrigerated storage (Months) 0	3	6	9	12	Mean
T_1	38.30	34.00	29.60	25.15	19.85	29.38	38.30	36.44	34.52	32.53	32.00	34.76
T_2	38.30	36.70	33.85	31.91	29.38	34.03	38.30	38.15	36.45	35.12	33.91	36.39
T_3	38.30	37.10	36.40	35.56	35.00	36.47	38.30	37.20	37.30	36.85	36.52	37.23
Mean	38.30	35.93	33.28	30.87	28.08		38.30	37.26	36.09	34.83	34.14	
Mean (V)			33.29						36.13			

T x S interaction Table							$CD_{(0.05)}$	
T	0	3	6	9	12	Mean (T)	Storage period (S)	0.12
T_1	38.30	35.22	32.06	28.84	25.93	32.07	Storage conditions (V)	0.07
T_2	38.30	37.43	35.15	33.52	31.65	35.21	Packaging material (T)	0.09
T_3	38.30	37.15	36.85	36.21	35.76	36.85	S × V	0.17
Mean (S)	38.30	36.60	34.69	32.85	31.11		T × V	0.13
							T × S	0.20
							V × S × T	0.29

T_1: Gunny bag, **T_2:** Aluminium laminated pouch, **T_3:** Aluminium laminated pouch with vacuum.

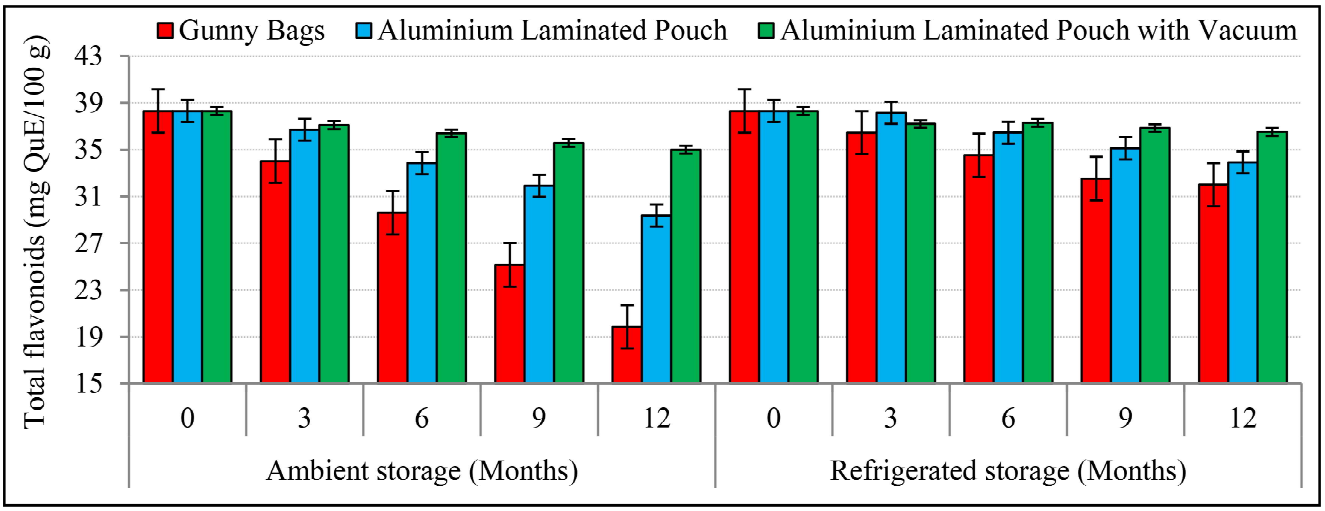

Figure 3: Effect of storage on total flavonoids (mg QuE/100 g) of dried wild pomegranate arils prepared under solar tunnel drier (error bars indicates standard error of the mean values).

3.3 DPPH (2, 2-diphenyl-1-picrylhydrazyl) antioxidant activity

Data in Table 3 and Figure 4 elucidate that the DPPH antioxidant activity of *anardana* prepared in solar tunnel drier decreased from 57.75 to 52.79 %. The lower (53.97 %) and higher (55.78 %) antioxidant activities were found in *anardana* stored under ambient and refrigerated storage conditions, respectively. The overall effect of packaging material reveals that maximum (56.95 %) antioxidant activity of *anardana* was found in ALP with vacuum as compared to gunny bags (52.48 %). The combined effect of storage period and storage conditions shows that DPPH antioxidant activity decreased from 57.75 to 51.18 and 54.40 % under ambient and refrigerated storage conditions, respectively, during entire storage period. The combined effect of packaging materials and storage conditions depicts higher (57.13 %) antioxidant activity was found in ALP with vacuum under refrigerated storage conditions and minimum (50.93 %) in gunny bags under ambient conditions. Further, the combined effect of packaging materials and storage period reveals that there was a gradual decrease in antioxidant activity from 57.75 to 56.22, 53.14 and 49.02 % in ALP with vacuum, ALP and gunny bags, respectively.

3.4 Metal chelating activity

An appraisal of data given in Table 4 and Figure 5 reveals that the metal chelating activity of *anardana* prepared in solar tunnel drier decreased from 21.12 to 18.27 % during storage. Further, while comparing the overall effect of storage conditions it was found that maximum (20.15 %) metal chelating activity was retained under refrigerated storage conditions as compared to ambient (18.90 %). Overall effect of packaging material indicates that highest (20.76 %) metal chelating activity was found in ALP with vacuum as compared to gunny bags (18.02 %). The combined effect of storage period and storage conditions shows that metal chelating activity decreased from 21.12 to 17.17 and 19.37 % under ambient and refrigerated storage conditions, respectively, during entire storage period. The combined effect of packaging material and storage conditions shows that highest (20.81 %) metal chelating activity was found in ALP with vacuum under refrigerated storage conditions and lowest (16.81 %) in gunny bags under ambient storage conditions. The combined effect of packaging material and storage period indicates that there was a significant decrease in metal chelating activity from 21.12 to 20.30, 18.55 and 15.98 % in ALP with vacuum, ALP and gunny bags, respectively.

Table 3: Effect of storage on DPPH anti-oxidant activity (%) of dried wild pomegranate arils prepared under solar tunnel drier

V / S / T	Ambient storage (Months) 0	3	6	9	12	Mean	Refrigerated storage (Months) 0	3	6	9	12	Mean
T_1	57.75	52.52	50.23	47.92	46.23	50.93	57.75	54.90	53.63	52.10	51.80	54.04
T_2	57.75	55.60	53.72	52.63	51.32	54.20	57.75	57.10	55.95	55.18	54.95	56.19
T_3	57.75	57.20	56.80	56.10	55.98	56.77	57.75	57.38	57.12	56.95	56.45	57.13
Mean	57.75	55.11	53.58	52.22	51.18		57.75	56.46	55.57	54.74	54.40	
Mean (V)			53.97						55.78			

T x S interaction Table							$CD_{(0.05)}$	
T	0	3	6	9	12	Mean (T)	Storage period (S)	0.27
							Storage conditions (V)	0.17
T_1	57.75	53.71	51.93	50.01	49.02	52.48	Packaging material (T)	0.21
T_2	57.75	56.35	54.84	53.91	53.14	55.19	S × V	0.38
T_3	57.75	57.29	56.96	56.53	56.22	56.95	T × V	0.30
Mean (S)	57.75	55.78	54.58	53.48	52.79		T × S	0.47
							V × S × T	0.66

T_1: Gunny bag, T_2: Aluminium laminated pouch, T_3: Aluminium laminated pouch with vacuum.

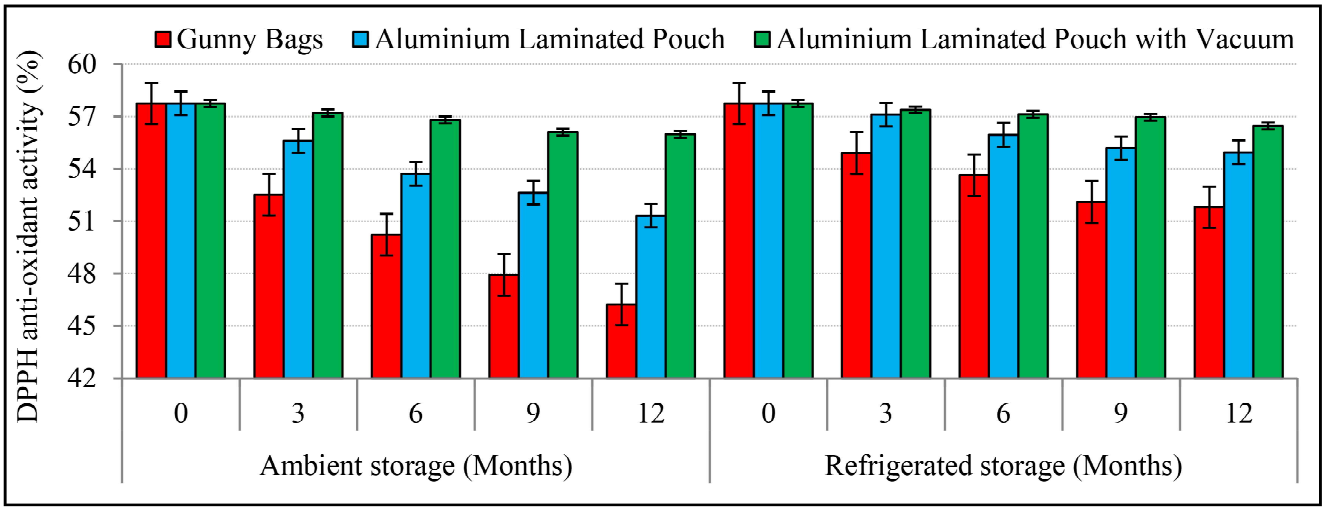

Figure 4: Effect of storage on DPPH antioxidant activity (%) of dried wild pomegranate arils prepared under solar tunnel drier (error bars indicates standard error of the mean values).

Table 4: Effect of storage on metal chelating activity (%) of dried wild pomegranate arils prepared under solar tunnel drier

V / S / T	Ambient storage (Months) 0	3	6	9	12	Mean	Refrigerated storage (Months) 0	3	6	9	12	Mean
T_1	21.12	17.80	16.25	14.88	14.00	16.81	21.12	19.55	18.96	18.60	17.95	19.24
T_2	21.12	19.95	19.21	18.25	17.37	19.18	21.12	20.64	20.40	20.05	19.72	20.39
T_3	21.12	21.01	20.80	20.42	20.14	20.70	21.12	21.00	20.89	20.61	20.45	20.81
Mean	21.12	19.59	18.75	17.85	17.17		21.12	20.40	20.08	19.75	19.37	
Mean (V)			18.90						20.15			

T x S interaction Table							$CD_{(0.05)}$	
T	0	3	6	9	12	Mean (T)	Storage period (S)	0.27
							Storage conditions (V)	0.17
T_1	21.12	18.68	17.61	16.74	15.98	18.02	Packaging material (T)	0.21
T_2	21.12	20.30	19.81	19.15	18.55	19.78	S × V	0.38
T_3	21.12	21.01	20.85	20.52	20.30	20.76	T × V	0.30
Mean (S)	21.12	19.99	19.42	18.80	18.27		T × S	0.47
							V × S × T	0.67

T_1: Gunny bag, T_2: Aluminium laminated pouch, T_3: Aluminium laminated pouch with vacuum.

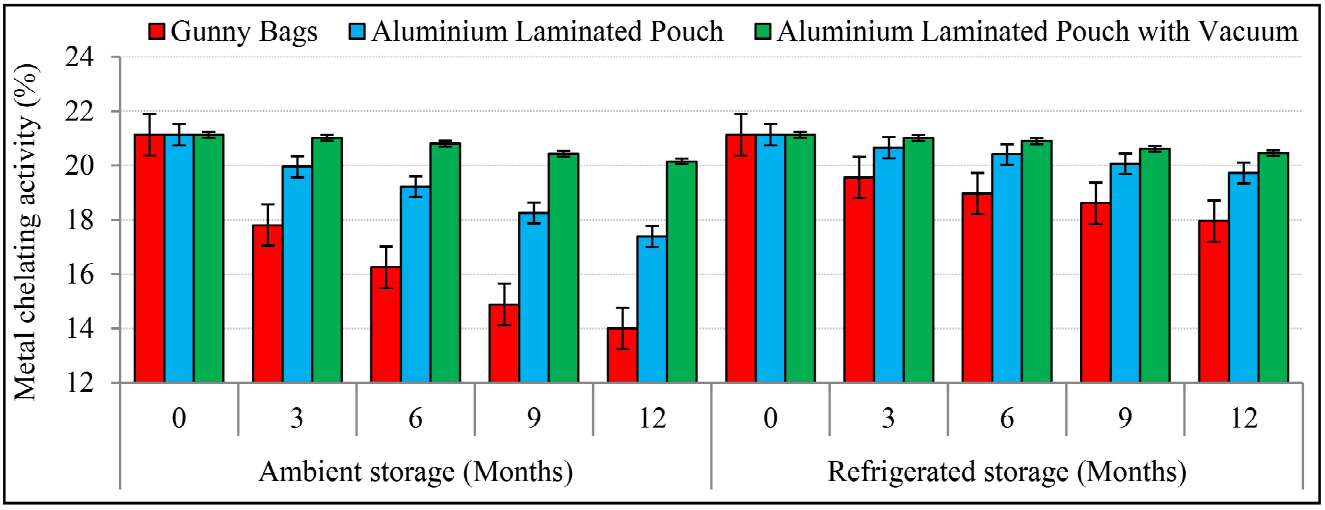

Figure 5: Effect of storage on metal chelating activity (%) of dried wild pomegranate arils prepared under solar tunnel drier (error bars indicates standard error of the mean values).

3.5 FRAP (Ferric reducing antioxidant power)

Data in Table 5 and Figure 6 reveals that during storage there was a general decrease in FRAP of *anardana* prepared in solar tunnel drier. The overall effect of storage period reveals that the FRAP of *anardana* dried in solar tunnel drier decreased from 32.85 to 28.75 µM Fe^{2+}/100 g and retained higher (31.31 µM Fe^{2+}/100 g) in refrigerated conditions and lower (29.41 µM Fe^{2+}/100 g) in ambient storage conditions. The higher (31.39 µM Fe^{2+}/100 g) FRAP was retained in ALP with vacuum as compared to gunny bags (28.92 µM Fe^{2+}/100 g). The combined effect of storage period and storage conditions shows that FRAP decreased from 32.85 to 27.03 and 30.47 µM Fe^{2+}/100 g under ambient and refrigerated storage conditions, respectively, during entire storage period. The combined effect of packaging materials and storage conditions depicts higher (31.63 µM Fe^{2+}/100 g) FRAP was found in ALP with vacuum under refrigerated storage conditions and lower (26.87 µM Fe^{2+}/100 g) in gunny bags under ambient conditions. Further, the combined effect of packaging materials and storage period reveals that there was a gradual decrease in FRAP from 32.85 to 30.65, 29.44 and 26.18 µM Fe^{2+}/100 g in ALP with vacuum, ALP and gunny bags, respectively.

3.6 Reducing power

The data in Table 6 and Figure 7 reveal that there was a general decreasing trend in reducing power of *anardana* during entire storage. The overall effect of storage period reveals that reducing power in terms of absorbance decreased from 0.576 to 0.484 during storage. Further, while comparing the overall effect of storage conditions it was found that higher (0.543) reducing power was found under refrigerated storage conditions as compared to ambient (0.501) storage conditions. The overall effect of packaging materials indicates that maximum (0.566) reducing power was retained in ALP with vacuum as compared to gunny bags (0.469). The combined effect of storage period and storage conditions shows that reducing power decreased from 0.576 to 0.449 and 0.518 under ambient and refrigerated storage conditions, respectively, during entire storage period. The combined effect of packaging materials and storage conditions depicts higher (0.569) reducing power was found in ALP with vacuum under refrigerated storage conditions and minimum (0.427) in gunny bags under ambient conditions. Further, the combined effect of and packaging materials and storage period reveals that there was a gradual decrease in reducing power from 0.576 to 0.556, 0.496 and 0.399 in ALP with vacuum, ALP and gunny bags, respectively.

Table 5: Effect of storage on FRAP (µM Fe^{2+}/100 g) of dried wild pomegranate arils prepared under solar tunnel drier

V	Ambient storage (Months)					Mean	Refrigerated storage (Months)					Mean
S / T	0	3	6	9	12		0	3	6	9	12	
T_1	32.85	28.10	26.30	24.52	22.60	26.87	32.85	31.20	30.76	30.28	29.75	30.97
T_2	32.85	30.75	29.80	29.29	28.35	30.21	32.85	31.35	31.10	30.90	30.52	31.34
T_3	32.85	31.25	31.01	30.48	30.15	31.15	32.85	31.52	31.41	31.23	31.15	31.63
Mean	32.85	30.03	29.04	28.10	27.03		32.85	31.36	31.09	30.80	30.47	
Mean (V)			29.41						31.31			

T x S interaction Table						
T	0	3	6	9	12	Mean (T)
T_1	32.85	29.65	28.53	27.40	26.18	28.92
T_2	32.85	31.05	30.45	30.10	29.44	30.78
T_3	32.85	31.39	31.21	30.86	30.65	31.39
Mean (S)	32.85	30.70	30.06	29.45	28.75	

$CD_{(0.05)}$	
Storage period (S)	0.24
Storage conditions (V)	0.15
Packaging material (T)	0.19
S × V	0.34
T × V	0.26
T × S	0.42
V × S × T	0.59

T_1: Gunny bag, **T_2:** Aluminium laminated pouch, **T_3:** Aluminium laminated pouch with vacuum.

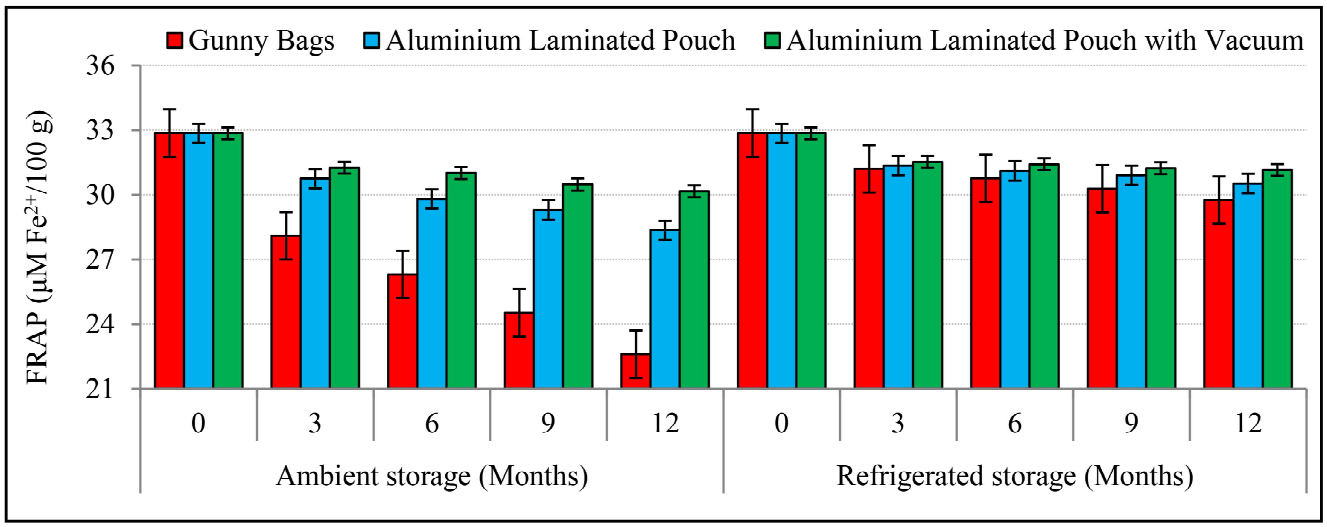

Figure 6: Effect of storage on FRAP (µM Fe^{2+}/100 g) of dried wild pomegranate arils prepared under solar tunnel drier (error bars indicates standard error of the mean values).

Table 6: Effect of storage on reducing power (absorbance at 700 nm) of dried wild pomegranate arils prepared under solar tunnel drier

V	Ambient storage (Months)					Mean	Refrigerated storage (Months)					Mean
S / T	0	3	6	9	12		0	3	6	9	12	
T_1	0.576	0.442	0.410	0.374	0.333	0.427	0.576	0.510	0.505	0.501	0.465	0.511
T_2	0.576	0.528	0.512	0.483	0.462	0.512	0.576	0.555	0.548	0.538	0.529	0.549
T_3	0.576	0.570	0.561	0.555	0.551	0.563	0.576	0.572	0.569	0.565	0.561	0.569
Mean	0.576	0.513	0.494	0.471	0.449		0.576	0.546	0.541	0.535	0.518	
Mean (V)			0.501						0.543			

T x S interaction Table							$CD_{(0.05)}$	
T	0	3	6	9	12	Mean (T)	Storage period (S)	0.03
							Storage conditions (V)	0.01
T_1	0.576	0.476	0.458	0.438	0.399	0.469	Packaging material (T)	0.02
T_2	0.576	0.542	0.530	0.511	0.496	0.531	S × V	NS
T_3	0.576	0.571	0.565	0.560	0.556	0.566	T × V	0.03
Mean (S)	0.576	0.530	0.518	0.503	0.484		T × S	0.05
							V × S × T	NS

T_1: Gunny bag, **T_2:** Aluminium laminated pouch, **T_3:** Aluminium laminated pouch with vacuum.

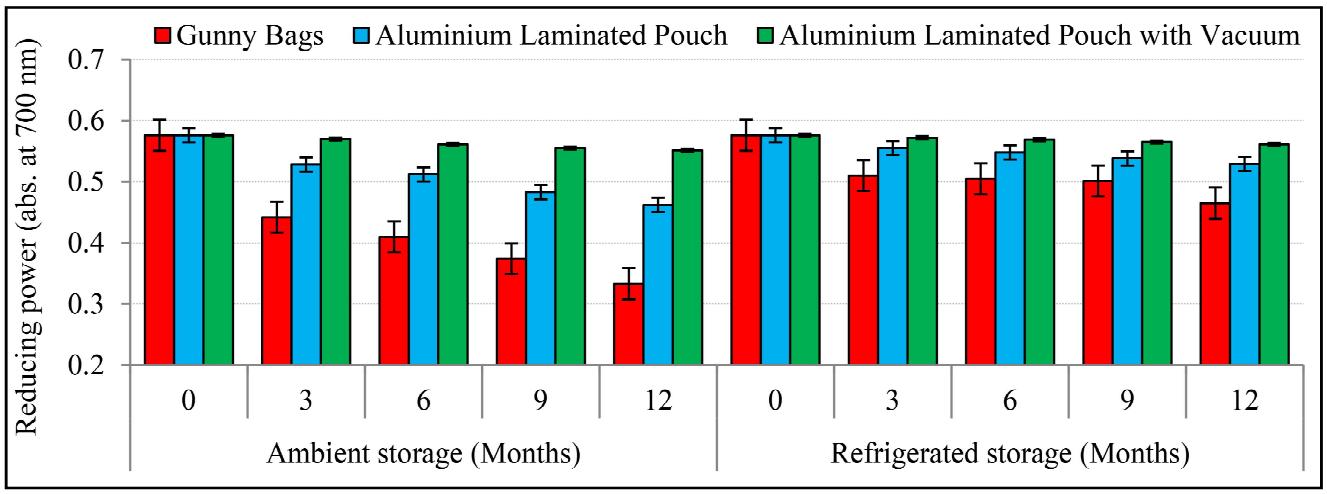

Figure 7: Effect of storage on reducing power (absorbance at 700 nm) of dried wild pomegranate arils prepared under solar tunnel drier (error bars indicates standard error of the mean values).

4. Discussion

The decrease in total phenols content of *anardana* during storage might be due to the oxidation and hydrolytic degradation of phenolic compounds (Kotsiou and Tasioula-Margari, 2016). *Anardana* stored under refrigerated conditions retained more total phenols content which might be due to the slower rate of oxidation reactions under low temperature conditions. Product packed in ALP with vacuum retained maximum total phenols which might be due to the better conditions inside the pouch which restricted the moisture and oxygen movement inside the pouch and minimised the oxidative and hydrolytic changes of phenolic compounds as compared to gunny bags. The decrease in total phenols content of *anardana* during storage has also been observed by Bhat *et al.* (2014) and Sharma and Thakur (2016). Further, they have observed the minimum losses of total phenols in *anardana* in ALP under refrigerated storage conditions as compared to PEP and thermoform trays. The total flavonoids content of *anardana* decreased significantly during storage which might be attributed to their oxidation process and their involvement in non-enzymatic reactions (Odriozola-Serrano *et al.,* 2009). *Anardana* stored under refrigerated conditions retained more total flavonoids content which might be due to the slower rate of oxidation reactions under low temperature conditions as the degradation of flavonoids is highly temperature and light dependent. Product packed in ALP with vacuum retained maximum total flavonoids which might be due to the better conditions inside the pouch which restricted the moisture and oxygen movement inside the pouch and minimised the oxidative changes of flavonoids as compared to gunny bags. Whereas, the highest rate of flavonoids degradation observed in gunny bags might be due to its poor barrier property towards light which led to the photo-oxidation of flavonoids (Del-Toro-Sanchez *et al.,* 2015). The above results are in conformity with the findings of Sonawane and Arya (2013) in dried Jambhul.

During storage period of 12 months DPPH antioxidant activity of *anardana* decreased significantly which might be due to the degradation of its chemical characteristics like ascorbic acid, total phenols, flavonoids and anthocyanins and other reason could be the non-enzymatic browning reactions. Metal chelating activity, FRAP and reducing power of *anardana* showed a significant decrease during storage which might be due to the susceptible nature of antioxidants towards oxidative losses caused by air, temperature and light. The loss of antioxidant activity and other antioxidant properties was lower in the *anardana* stored under refrigerated temperature condition as compared to ambient which might be due to the slower rates of degradation of various antioxidant compounds present in the product which helped in the retention of higher antioxidant activity. *Anardana* packed in ALP with vacuum retained maximum antioxidant properties which might be due to the favourable conditions inside the pouch which created barrier to light, air and moisture, therefore, prevented degradation of various antioxidant compounds by photo-oxidation (Tananuwong and Tangsrianugul, 2013; Thakur *et al.,* 2020). A slight decrease in metal chelating activity of quince candy packed in PE pouch, laminate and plastic jar has also been observed by Mir *et al.* (2015). Muzzaffar *et al.* (2016) have also observed decrease in FRAP and reducing power of pumpkin candy stored under ambient temperature conditions.

5. Conclusion

Antioxidant compounds or activity in any food material are directly related towards its contribution to human health which in turn protect against degenerative diseases and ageing. The retention or stability of these compounds with respect to storage conditions and packaging material is one of the major concerns to achieve maximum health benefits of any food material. Our findings demonstrate that the highest total phenols and flavonoid content of dried wild pomegranate arils was retained in ALP with vacuum which was stored under refrigerated storage conditions. The antioxidant activity of the same in terms of DPPH (2, 2-diphenyl-1-picrylhydrazyl) antioxidant activity, metal chelating activity, FRAP (ferric reducing antioxidant power and reducing power) was retained in ALP with vacuum followed by ALP and gunny bags. All the packaging materials were found suitable for the storage of dried wild pomegranate arils under both ambient and refrigerated storage conditions. However, the losses in above quality characteristics of *anardana* were found highest in gunny bags which were stored under ambient temperature conditions.

Conflict of interest

The authors declare that there are no conflicts of interest in the course of conducting the research. All the authors had final decision regarding the manuscript and decision to submit the findings for publication.

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