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Effect of Packaging and Storage on Quality Characteristics of Dried Wild Pomegranate Arils *(Anardana)* Prepared in Solar Tunnel Drier

Abhimanyu Thakur[1*], N. S. Thakur[1], Hamid[1], Pradeep Kumar[1] and Kanchan Bhatt[1]

[1]Department of Food Science and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan – 173230, Himachal Pradesh, India.

Authors' contributions

This work was carried out by author AT during Ph.D. in Food Technology under the guidance of author NST. All authors have helped in preparation of manuscript and approved the final manuscript.

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ABSTRACT

Wild pomegranate (*Punica granatum* L.) fruits were procured from Karsog area of Mandi district of Himachal Pradesh, India (1265 m above mean sea level). The arils extracted from the fruits were dehydrated in a solar tunnel (30-45°C) drier to prepare value added product *Anardana.* The developed product was packed in three different packaging materials *viz.* gunny bags, aluminium laminated pouches (ALP) and aluminium laminated pouches with vacuum (ALPV) and stored under ambient and refrigerated temperature for a period of 12 months so as to evaluate overall effect of storage period, storage condition and packaging material. After 12 months of storage period, higher retention of various quality characteristics like TSS, titratable acidity, ascorbic acid, total sugars, anthocyanins content, sensory characteristic scores with less increase in moisture content, NEB (non-enzymatic browning),HMF (hydroxymethyl furfural) and furfural content was observed in *Anardana* packed in ALPV followed by ALP and gunny bags. The changes in the quality characteristics of the *Anardana* were slower in refrigerated storage conditions as compared to ambient conditions.

**Corresponding author: E-mail: abhimanyuthakurprashar@gmail.com;*

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1. INTRODUCTION

Pomegranate (*Punica granatum* L) fruit belonging to family Punicaceae is found growing in arid or semiarid zones in both subtropical and tropical conditions [1]. Pomegranates are native to central Asia and domestication of pomegranate started 3000-4000 BC in the North of Iran and Turkey [2-4]. Wild pomegranate resembles the cultivated pomegranate for various morphological characters and also regarded as its biotype which grows in Transcaucasia and Central Asia from Iran and Turkmenistan to northern India [3,5,6]. In India, it is found in the hill slopes of western Himalayan regions and mainly distributed in the states like Himachal Pradesh, Jammu and Kashmir and Uttarakhand at an altitude of 900 to 1800 m above mean sea level. In Himachal Pradesh, it is distributed in Solan, Sirmour, Mandi, Shimla, Kullu and Chamba districts [6-8]. The edible part (50%) of the pomegranate fruit is termed as aril which constitutes about 40% of the fruit with 10% seeds. Arils are potential source of total sugars, organic acids such as ascorbic acid, citric acid and malic acid with bioactive compounds such as phenols, flavonoids and anthocyanins [9,10]. The pomegranate fruit has been recognised as healing food since ancient times along with numerous beneficial effects in control of several diseases like vomiting, sore throat, brain diseases, spleen complaints, chest troubles, scabies, bronchitis, liver and kidney disorders [11,12]. The wild pomegranate arils (50.90-56.01%) are rich source of organic acids, sugars and antioxidant compounds like ascorbic acid, anthocyanins, phenols, flavonoids which contribute towards high antioxidant activity of the fruit. The various antioxidant compounds present in cultivated and wild forms of pomegranate fruit contributes towards its medicinal and pharmacological properties which also helps in the prevention of neurodegenerative disorders [8,12-14].

The wild pomegranate arils are rich in organic acids and dried to yield a value added product known as *anardana.* Due to intense sourness in the dried product it is used as acidulant in culinary purposes which improves the mouth feel of the food and digestion. *Anardana* is rich in various nutritive compounds like acids, vitamins, ascorbic acid, anthocyanins, total phenols, minerals and also have high antioxidant properties [15,16]. *Anardana* has a great demand in the market and every year worth crores of rupees is collected from the hills and sold at various markets throughout the country and abroad [17]. Traditionally the arils are dried in open sun and the varying seasonal conditions like rains and high humidity increases the drying time of the arils resulting in poor quality end product with high moisture content. Solar tunnel drying is a good alternative to overcome these problems without much addition in its cost of production. Further various advanced packaging techniques like vacuum packaging over traditional packaging (gunny bags) can retain higher quality characteristics during storage. So the present studies were carried out to compare the effect of storage and packaging materials on quality characteristics (physico-chemical and sensory) of dried wild pomegranate arils prepared in solar tunnel drier.

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 fruits were further used for the preparation of *anardana* and the chemicals 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. [18], where arils were steam blanched for 30 seconds followed by sulphuring with 0.30% sulphur powder for 60 minutes 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 (Fig. 1.). This drier has 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. The pre-treated arils were dried till they attain a constant weight.

2.2 Packaging and Storage

The *anardana* was packed in different packaging materials (Fig. 2.) like gunny bags (T_1), aluminium pouches (ALP: T_2) and aluminium laminated pouches with vacuum (ALPV: T_3). All the packages were stored under ambient temperature and refrigerated temperature for a period of 12 months and overall effect of storage period, storage conditions and packaging was analyzed for changes in various quality attributes.

2.3 Physico-chemical and Sensory Analysis

The colour of *anardana* was observed visually by comparing with the colour cards of Royal Horticulture Society, London and the card numbers were mentioned along with the colour. Moisture, TSS, sugars, titratable acidity, ascorbic acid, anthocyanins, starch, NEB (non enzymatic browning), HMF (hydroxyl methyl furfural), furfural and residual SO_2 were determined according to Ranganna [19]. Water activity of the dried product was estimated by computer based digital water activity meter (HW3 model, Rotronic International, Switzerland).Total fibres content was estimated by the method given by Gould [20]. The sensory evaluation of the samples was carried out by 9 point hedonic rating test. Sensory evaluation of *anardana* was conducted to assess the consumer acceptance and panel of ten judges (Faculty members and students of the Department of Food Science and Technology) was selected to evaluate the product for sensory qualities on the basis of colour, texture, flavour and overall acceptability. Sensory evaluation was done at ambient temperature conditions and the mean score of all attributes was used to draw overall acceptability of the product [21, 22].

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

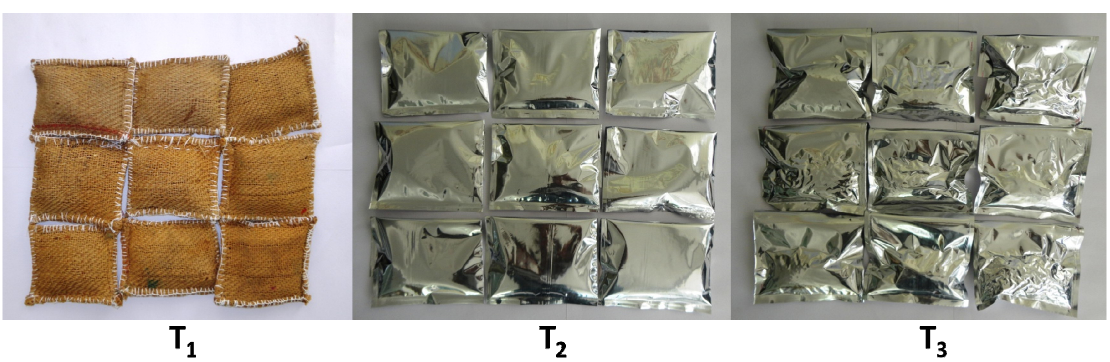


Fig. 2. *Anardana* packed in different packaging material
(T_1: Gunny bags, T_2: Aluminium laminated pouches and T_3: Aluminium laminated pouches with vacuum

2.4 Statistical Analysis

The data on physico-chemical characteristics of dried arils were analyzed by CRD (factorial) whereas, data pertaining to the sensory evaluation of dried wild pomegranate arils were analyzed by Randomized Block Design (RBD). The data on physico-chemical and sensory characteristics of dried arils were replicated three times. 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 AND DISCUSSION

Data pertaining to changes during storage in physico-chemical and sensory characteristics of *anardana* prepared under solar tunnel drier have been presented in Table 1 and Figs. 3-5.

3.1 Physico-chemical Characteristics

3.1.1 Visual colour

The colour of *anardana* as per Royal Horticultural Society Cards was retained as such [Red group 46 (A)] during twelve months of storage in ALPV under refrigerated conditions (Table 1). The intensity of red colour of *anardana* packed in ALPV and ALP stored under ambient conditions decreased slightly. The *anardana* packed in gunny bags has the maximum changes in the intensity of red colour and turned brown at the end of twelve months of storage. The intensity of red colour of *anardana* decreased during storage which might be due to the loss of colour pigments like anthocyanins. Non-enzymatic browning reactions could be the other major reason for the loss in intensity of red colour. Retention of better colour in refrigerated storage might be due to the better retention of colour of the product as a result of the suitable storage conditions where the rate of degradation of anthocyanins and rate of other chemical reactions was slower as compared to ambient. However, maximum intensity of red colour of *anardana* in ALPV might be due to the better retention of colour as a result of favourable conditions inside the pouch which created barrier to light, air and moisture, therefore prevented degradation of anthocyanins. A similar trend of decrease in intensity of red colour of *anardana* during storage has also been observed earlier [23,24].

3.1.2 Moisture and water activity

Data given in Fig. 3(a) reveal that there was a general increasing trend in moisture content of *anardana* during entire storage period of 12 months. The overall moisture content in *anardana* increased from 10.55 to 12.75% during storage, lower (11.38%) was found in refrigerated storage conditions and higher (12.02%) in ambient storage conditions. The lower (10.75%) moisture content was recorded in *anardana* packed in ALPV as compared to gunny bags (13.28%) while comparing the overall effect of packaging materials on moisture content of *anardana*. Scrutiny of data presented in Fig. 3(b) indicates that there was a general increasing trend in the water activity of *anardana* during entire storage period of twelve months. The water activity in *anardana* increased from 0.348 to 0.454 during storage, lower (0.391) was found in refrigerated storage conditions and higher (0.421) in ambient storage conditions The lower (0.362) water activity was recorded in *anardana* packed in ALPV as compared to gunny bags (0.478) while comparing the overall effect of packaging materials on water activity of *anardana*.

Table 1 Effect of storage on *visual colour of *anardana* prepared under solar tunnel drier

Treatments	Storage conditions									
	Ambient storage (Months)					Refrigerated storage (Months)				
	0	3	6	9	12	0	3	6	9	12
T_1	Red 46 A	Red 46 A	Red 46 B	Red 46 A	Brown	Red 46 A	Red 46 A	Red 46 A	Red 46 B	Red 46 C
T_2	Red 46 A	Red 46 A	Red 46 A	Red 46B	Red 47 C	Red 46 A	Red 46 A	Red 46 A	Red 46 A	Red 46 B
T_3	Red 46 A	Red 46 A	Red 46 A	Red 46 A	Red 46 B	Red 46 A	Red 46 A	Red 46 A	Red 46 A	Red 46 A

T_1: Gunny bags, T_2: Aluminium laminated pouch and
T_3: Aluminium laminated pouch with vacuum
** Colour card number of Royal Horticulture Society, London*

Moisture content of *anardana* increased significantly during storage which might be due to the absorption of moisture from its surroundings as a result of hygroscopic nature of the dried product. Other reason of increase in the moisture content during storage might be because of the release/formation of moisture during non-enzymatic browning reactions in the product. Increase in the moisture content of product stored under refrigerated temperature conditions was observed less as compared to ambient which could be due to the slower rate of non-enzymatic reactions occurred in the product. Product packed in ALPV had negligible increase in moisture than product packed in ALP and gunny bags whereas; higher moisture uptake in gunny bags might be due to its higher permeability towards air and moisture. During storage, *anardana* showed a significant increase in water activity which might be due to its absorption of moisture. Increase in moisture content and water activity of *anardana* during storage has also been observed in earlier investigations [23-26].

3.1.3 Total soluble solids and titratable acidity

An appraisal of data Fig. 3(c) reveal that there was a general decreasing trend in TSS content of *anardana* during entire storage period of 12 months. The overall effect of storage period reveals that TSS of *anardana* prepared in solar tunnel drier decreased from 39.50 to 37.61°B during storage. Further, while comparing the overall effect of storage conditions it was found that higher (38.94°B) TSS were retained under refrigerated storage conditions as compared to ambient storage conditions (38.22°B). The overall effect of packaging materials indicates that higher (39.23°B) TSS were retained in ALPV as compared to gunny bag (37.70°B) during storage. The acid content of *anardana* during entire storage period of 12 months decreased significantly (Fig. 3d). The overall effect of storage period reveals that titratable acidity of *anardana* decreased from 10.90 to 9.30% during storage. Further, while comparing the overall effect of storage conditions it was found that maximum (10.29%) acid was retained under refrigerated storage conditions as compared to ambient storage conditions (9.91%). The overall effect of packaging materials indicates that maximum (10.74%) acid was retained in ALPV as compared to gunny bag (9.27%) during storage.

A significant decrease in TSS content of *anardana* might be attributed due to increase in the moisture content and degradation of chemical components like sugars and other soluble constituents. Highest retention of TSS in *anardana* under refrigerated storage might be due to slower rate of reactions at low temperature conditions as compared to ambient. *Anardana* packed in ALPV showed less decrease in TSS due to the negligible amount of residual moisture and air inside the pouch along with its minute permeable nature towards moisture and air as compared to other packaging material. The loss of acids content during storage might be due to their participation in the chemical reactions with sugars and amino acids leading towards the formation of NEB products and HMF as well as utilization in the inversion of non-reducing sugars to reducing sugars. Maximum acidity of *anardana* retained under refrigerated storage might be due to the slower rate of above reactions at low temperature. The *anardana* packed in ALPV have retained maximum acid content which might be due to the vacuum conditions inside the pouch which restricted the involvement of acids in various chemical reactions. Similar trend of results for above parameters have also been reported in *anardana* prepared from wild pomegranate fruit [24,25] and cultivated Maridula cultivar [26].

3.1.4 Reducing and total sugars

Scrutiny of data presented in Fig. 3(e) indicates that there was a general increasing trend in the reducing sugars content of *anardana* during storage. The reducing sugars content of *anardana* increased from 23.15 to 24.05 during storage, higher (23.80%) were found in ambient storage conditions and lower (23.38%) in refrigerated storage conditions. The higher (24.02%) reducing sugars were recorded in *anardana* packed in gunny bags as compared to ALPV (23.24%) while comparing the overall effect of packaging materials. The total sugars of *anardana* dried in solar tunnel drier decreased from 25.40 to 24.26% during storage (Fig. 3f). Further, while comparing the overall effect of storage conditions it was observed that more (25.11%) total sugars were retained under refrigerated storage conditions as compared to ambient storage conditions (24.54%). The overall effect of packaging materials indicates that higher (25.29%) total sugars were retained in ALPV as compared to gunny bags (24.13%) during storage.

A significant increase in reducing sugars during storage might be attributed to the inversion of non-reducing sugars and breakdown of polysaccharides into reducing sugars. Minimum increase in reducing sugars was observed in the product stored under refrigerated storage conditions as compared to ambient which might be due to the delayed inversion of non-reducing sugars as well as breakdown of polysaccharides by slowing down the chemical reactions as a result of low temperature. The *anardana* packed in ALPV had recorded minimum increase in reducing sugars which might be due to the vacuum conditions inside the pouch which restricted the conversion of polysaccharides to reducing sugars and did not allow the inversion reactions faster as compared to the others. Total sugars of the *anardana* deceased significantly during storage period of 12 months which might be attributed to the utilization of sugars in non-enzymatic browning reactions and formation of HMF. The total sugars were retained maximum in *anardana* stored under refrigerated storage conditions might be due to the slower NEB reactions as a result of low temperature. Further, better packaging conditions in ALPV might have restricted the formation of NEB products and HMF because of the higher concentration of SO_2 inside it. Above results for reducing and total sugars content are in conformity with the earlier findings in *anardana* prepared from wild and cultivated pomegranate cultivars [25-28].

3.1.5 Ascorbic acid and anthocyanins

Data appended in Fig. 3(g) reveal that the ascorbic acid content of *anardana* decreased during storage. The overall effect of storage period reveals that it decreased from 12.75 to 8.53 mg/100 g. Further, while comparing the overall effect of storage conditions it was found that higher (11.27 mg/100 g) ascorbic acid content was retained under refrigerated storage conditions as compared to ambient storage conditions (10.14 mg/100 g). The overall effect of packaging materials indicates that higher (11.83 mg/100 g) ascorbic acid content was retained in ALPV as compared to gunny bag (9.33 mg/100 g) during storage. The overall effect of storage period indicates that anthocyanins content of *anardana* decreased from 35.70 to 28.94 mg/100 g during storage (Fig. 3h). Further, while comparing the overall effect of storage conditions the maximum (33.64 mg/100 g) anthocyanins content was retained under refrigerated storage conditions as compared to ambient storage conditions (31.17 mg/100 g). The overall effect of packaging materials indicates that maximum (33.93 mg/100 g) anthocyanin content was retained in ALPV as compared to gunny bag (30.35 mg/100 g) during storage.

The *anardana* showed a significant decrease in ascorbic acid during the entire storage period which might be due to its oxidation and direct effect of ambient storage temperature on this vitamin. The ascorbic acid is oxidized to dehydroascorbic acid under aerobic conditions, followed by hydrolysis and further oxidation into furfural [29]. Highest retention of ascorbic acid content in *anardana* under refrigerated storage might be due to slower rate of oxidation reactions at low temperature conditions as compared to ambient. Better conditions inside ALPV might have restricted the participation of ascorbic acid in various oxidation reactions. Whereas, highest permeability of gunny bags towards oxygen might have led towards the highest rate of ascorbic acid degradation during storage. A significant decrease in anthocyanins content of *anardana* observed during storage might be attributed to their susceptible nature towards oxidative losses caused by air, moisture, temperature and light. Product stored under refrigerated temperature conditions retained more anthocyanins as a result of slower rate of oxidation reactions under low temperature conditions. ALPV retained more anthocyanins which might be due to the opaqueness of aluminium foil in the ALP to light and impermeability of the packaging material to oxygen, water vapours and vacuum inside the pouch that prevented photo-oxidation of anthocyanins. Similar decreasing trend for ascorbic acid and anthocyanins content of *anardana* during storage have also been observed by Bhat et al. [23], Sharma et al. [25] and Singh and Kingsley [27].

3.1.6 Starch and total fibres

Data in Fig. 3(i) elucidates the starch content of *anardana* decreased from 2.76 to 2.42%. The overall effect of storage conditions, keeping other factors constant, shows that higher (2.63%) starch content was retained in refrigerated storage conditions as compared to ambient conditions (2.49%). While comparing the overall effect of packaging materials the maximum (2.70%) starch content was retained in ALPV as compared to gunny bags (2.38%). The overall effect of storage on total fibres content of *anardana* reveals that it decreased slightly during storage (Fig. 3j) from 3.40 to 2.97%. The minimum (3.05%) and maximum (3.21%) total fibres content was found in ambient and refrigerated storage conditions, respectively. The overall effect of packaging material reveals that maximum (3.30%) total fibres content of *anardana* was found in ALPV as compared to gunny bags (2.93%).

The starch content of *anardana* decreased during storage period which might be due to conversion of starch into sugars. The product packed in ALPV retained more starch might be due to the slower rate of conversion of starch into sugars as compared to gunny bags as a result of its moisture and oxygen barrier properties and variation in initial oxygen present in the package. The starch content was retained maximum under refrigerated storage conditions might be due to the slower conversion of starch into sugars at low temperature. The total fibres content of *anardana* decreased slightly during storage which might be attributed to breakdown and depolymerization of polysaccharides into monosaccharides. The other reason for the decrease in total fibres content of *anardana* might be due to the absorption of moisture from the surroundings which led to the decrease in the total fibres content on weight basis. *Anardana* stored under refrigerated conditions retained more total fibres which might be due to the slower rate of reactions under low temperature conditions. Product packed in ALPV experienced minimum decrease in total fibres content as compared to other packaging material which might be due to impervious nature of laminates to air and water vapours and the vacuum inside the pouch also restricted the breakdown of polysaccharides.

3.1.7 NEB (Non enzymatic browning), HMF (Hydroxymethyl furfural) and furfural

The data in Fig. 3(k) reveal that NEB of *anardana* in terms of absorbance increased from 0.090 to 0.177 during storage. Further, while comparing the overall effect of storage conditions it was found that lower (0.113) NEB was found under refrigerated storage conditions as compared to ambient (0.150) storage conditions. The overall effect of packaging materials indicates that minimum (0.102) NEB was observed in ALPV as compared gunny bags (0.168). The overall effect of storage on the HMF of *anardana* reveals that it increased from 1.05 to 7.64 ppm, higher (5.65 ppm) was found in ambient storage conditions and lower (2.85 ppm) in refrigerated storage conditions (Fig. 3l). While comparing the overall effect of packaging materials on HMF indicates that minimum (2.25 ppm) HMF was found in ALPV as compared to aluminium gunny bags (6.52 ppm). During storage the furfural of *anardana* increased from 15.40 to 56.06 ppb, lower (28.30 ppb) was found in refrigerated storage conditions and higher (41.98 ppb) in ambient storage conditions (Fig. 3m). The minimum (24.14 ppb) furfural was recorded in *anardana* packed in and ALPV as compared to gunny bags (46.99 ppb) while comparing the overall effect of packaging materials on furfural of *anardana*.

The non-enzymatic browning of dried arils increased during storage which might be due to carbonyl-amino reactions, such as reducing sugars with amino acids (Maillard reaction) and oxidation reactions, such as conversion of polyphenols into polycarbonyls [30]. According to Mahadeviah [31], the reaction between aldehydes, ketones groups of reducing sugars with amino acids, peptides and proteins (Maillard reaction), nitrogenous matter and organic acids themselves, led to browning of arils. Arils packed in ALPV exerted its significant influence in checking browning during storage while the arils packed in other packaging treatments apparently recorded higher NEB. The arils packed in ALPV showed the minor degradation of sugars because of the retention of higher amount of residual SO_2 and lower moisture level in arils inside the pouch. The increase in HMF of arils during storage might be attributed to the acid catalyzed degradation of reducing sugars or as an intermediate product of NEB reactions [32]. The ALPV restricted oxygen and water vapour intrusion to a maximum extent because of the better conditions inside the pouch, therefore, results in less HMF formation as compared to other packaging material. The minimum increase in HMF content was observed in *anardana* stored under refrigerated temperature conditions might be due to the slower rates of degradation of sugars and other reactions occurred in the product which helped in the formation of less HMF compounds. *Anardana* showed a significant increase in furfural content during storage which might be due degradation of ascorbic acid by oxidation/reduction and intermolecular re-arrangement reactions which further led to the formation of dehydroascorbic acid and furfural. The other possible reason for the increase in furfural content might be due to its formation as an intermediate product of NEB reactions. Minimum increase in furfurals was observed in the product stored under refrigerated temperature conditions as compared to ambient which might be due to the low temperature conditions which delayed the degradation of ascorbic acid and NEB reactions by slowing down the chemical reactions. The minimum increase in furfurals was noticed in the product packed in ALPV which might be due to the vacuum conditions inside the pouch which restricted the above reactions and did not allowed to occur these reactions faster as compared to the others. Present results for the above parameters are in conformity with the earlier results reported in *anardana* prepared from wild pomegranate fruits [23,24].

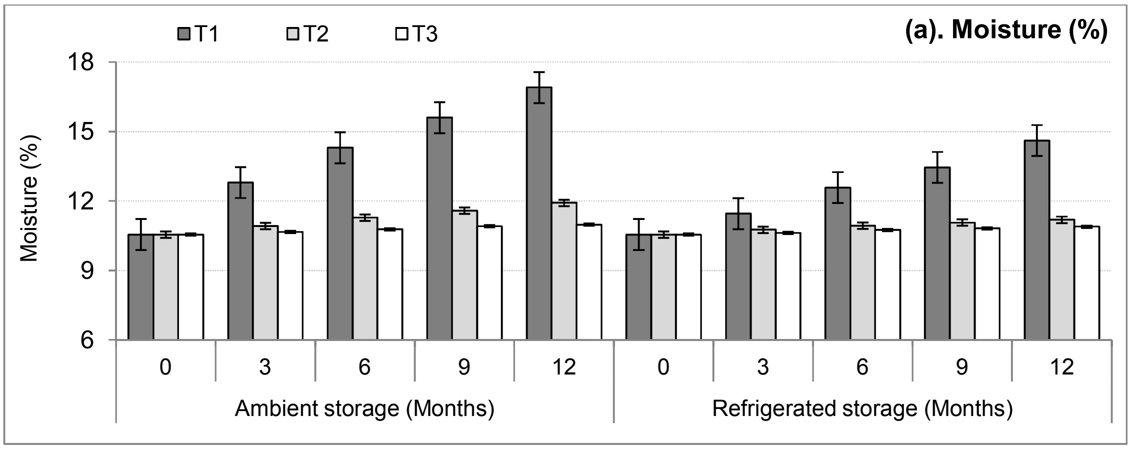
3.1.8 Residual SO_2

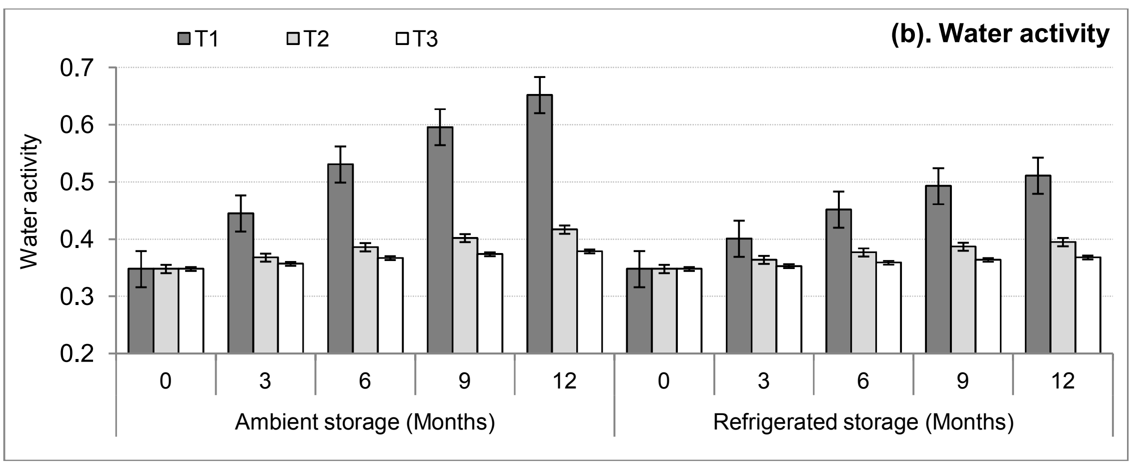
Data in Fig. 3(n) indicate that residual sulphur dioxide of *anardana* decreased from 162.00 to 101.30 ppm. The lower (123.22 ppm) and higher (132.19 ppm) sulphur dioxide were found in ambient and refrigerated storage conditions, respectively. The overall effect of packaging material reveals that maximum (148.91 ppm) sulphur dioxide was recorded in *anardana* packed in ALPV as compared to gunny bags (91.58 ppm). Significant reduction of residual SO_2 in *anardana* was observed during storage which might be due to its escape from the packaging material. The other possible reason of the decrease in SO_2 content might be due to its participation in oxidation process during storage. *Anardana* stored under refrigerated conditions retained higher SO_2 which might be due to the slower rate of oxidation reactions under low temperature conditions. The retention of higher SO_2 in ALPV might be due to minute no residual air and impermeable nature of the ALP which hindered the exchange of gases and created a better barrier for the removal of SO_2. The decrease in SO_2 during storage of dried apricots packed in polyethylene pouch stored under ambient conditions has been observed by Sen et al. [33].

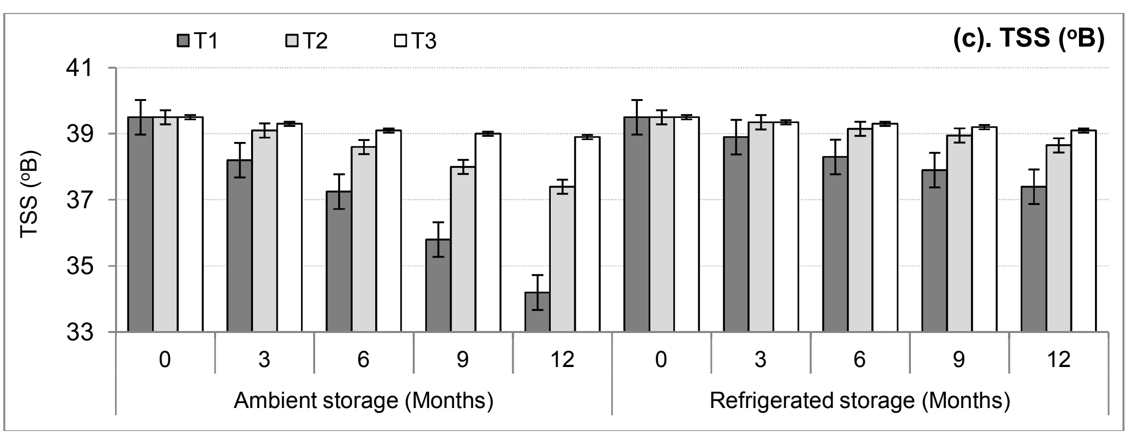
3.2 Sensory Characteristics

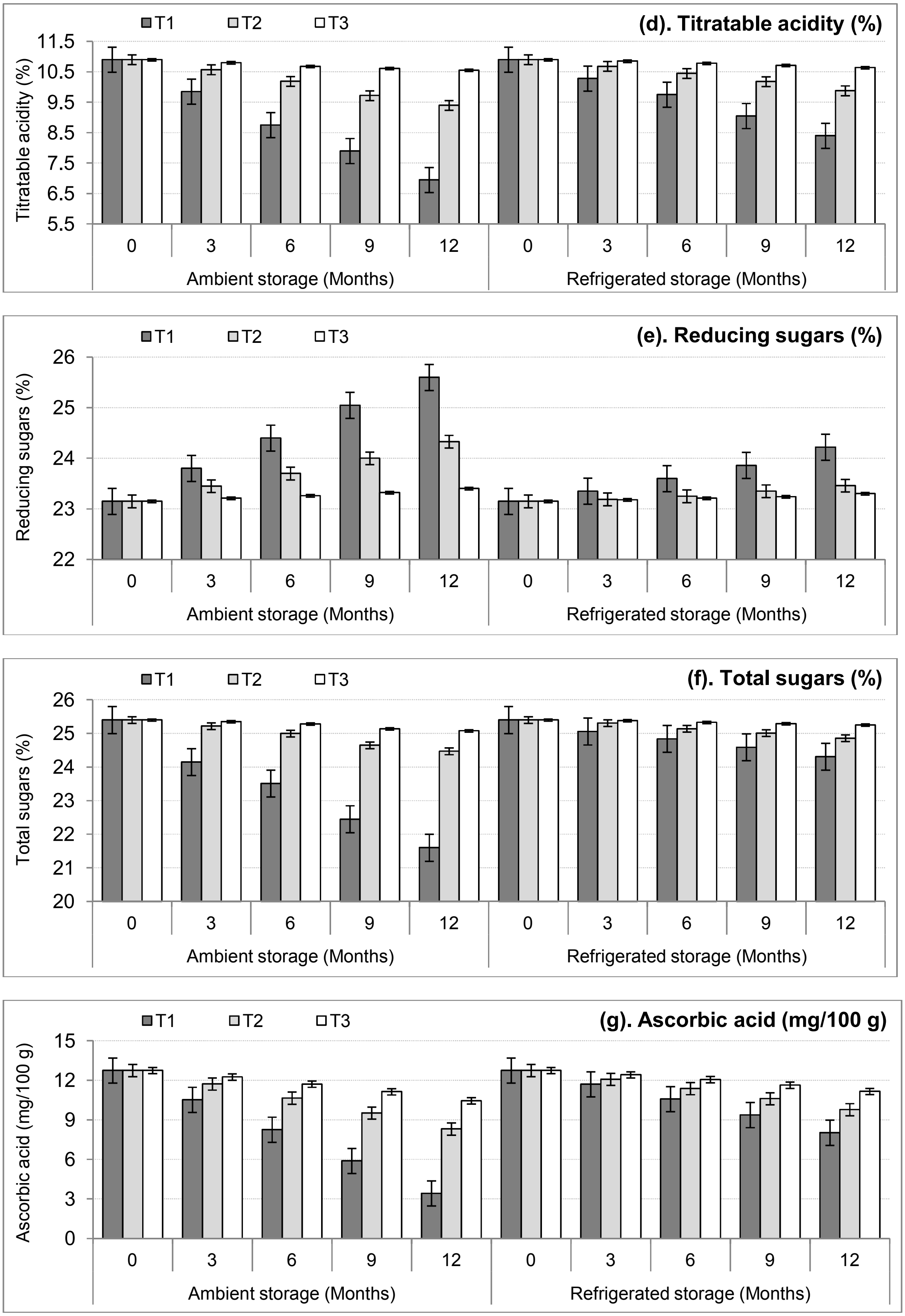
During storage there was a general decrease in colour scores of *anardana* from 8.00 to 6.63 (Fig. 4a). While comparing overall effect of storage conditions, it was observed that colour scores were retained higher (7.64) in refrigerated conditions as compared to ambient conditions (7.07). The overall effect of packaging material on colour scores of the product shows that it was retained higher (7.62) in and ALPV as compared gunny bags (7.02). The data in Fig. 4(b) highlight a general decrease in texture scores of *anardana.* The texture scores of *anardana* decreased from 8.30 to 7.36, retained higher (7.99) in refrigerated storage conditions and lower (7.73) in ambient storage conditions. The higher (8.07) and lower (7.69) texture score were recorded in *anardana* packed in ALPV and gunny bags, respectively while comparing the overall effect of packaging materials on texture score. The data presented in Fig. 4(c) reveal that there was a significant decrease in flavour scores of *anardana* from 7.90 to 6.71. While comparing overall effect of storage conditions, it was observed that flavour scores were retained higher (7.58) in refrigerated conditions as compared to ambient conditions (7.07). The overall effect of packaging material on flavour scores of the product shows that it was retained higher (7.63) in ALPV as compared gunny bags (6.99). The data in Fig. 4(d) highlight a general decrease in overall acceptability scores of *anardana* from 8.07 to 6.90, retained higher (7.74) in refrigerated storage conditions and lower (7.29) in ambient storage conditions. The higher (7.77) and lower (7.23) overall acceptability scores were recorded in *anardana* packed in ALPV and gunny bags, respectively while comparing the overall effect of packaging materials on overall acceptability scores during storage.

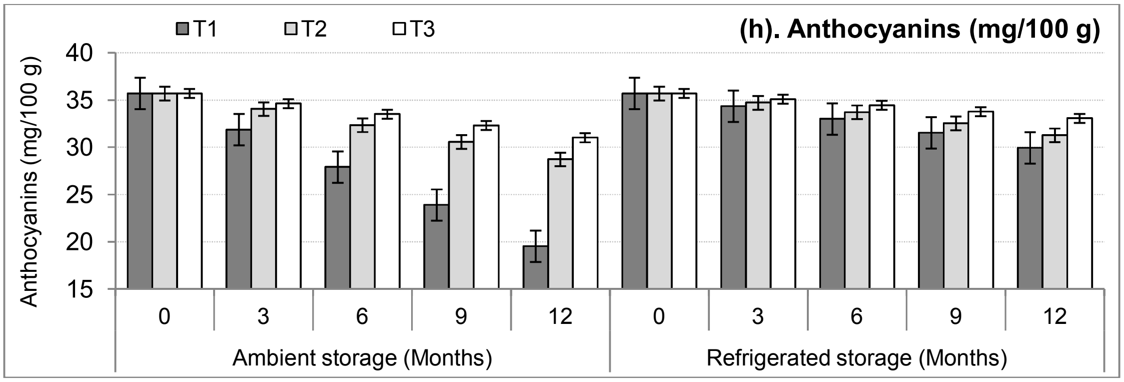
The colour scores of *anardana* exhibited significant decrease during storage which might be due to the loss of natural colour pigments including anthocyanins as a result of which judges awarded the lower scores to the product as compared to initial scores. Other reason could be the development of browning pigments due to NEB reactions. Significant decrease in texture score of *anardana* might be due to the absorption of moisture by the product leading to the softening of the product. The flavour scores of the *anardana* have decreased significantly during storage which could be due to the loss of various chemical constituents and changes in sugar-acid blend. The overall acceptability scores of *anardana* exhibited significant decrease during storage which might be due to reduction in colour intensity, distortion/disruption of texture and loss of flavour compounds of the product during storage. The sensory characteristics scores were retained maximum in ALPV could be due to the favourable conditions inside the pouch as a result of its better barrier properties to light, oxygen and moisture and thus helped the *anardana* to retain good colour, texture and flavour restricted the exchange of gases to preserve the flavour of the product and consequently retained the higher scores of overall acceptability of the product. Product stored under refrigerated temperature conditions retained maximum sensory scores as a result of controlled humidity conditions and slower rate of degradation reactions under low temperature conditions. The above results for the sensory characteristics are in accordance with the findings of Bhat et al. [23] in *anardana* packed in ALP under ambient and refrigerated temperature conditions, Sharma and Thakur [24] in *anardana* in ALP and PEP stored under ambient temperature conditions and Grande et al. [28] in *anardana* from Ganesh cultivar packed in polyethylene pouch stored under ambient temperature conditions.

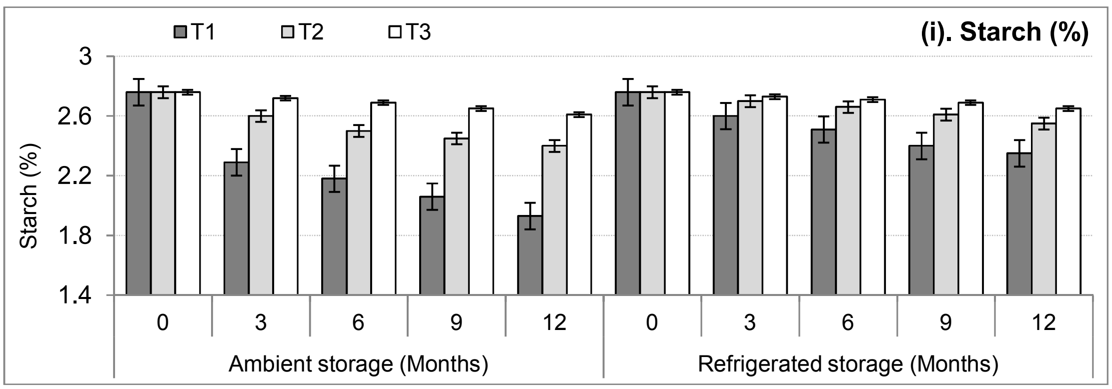


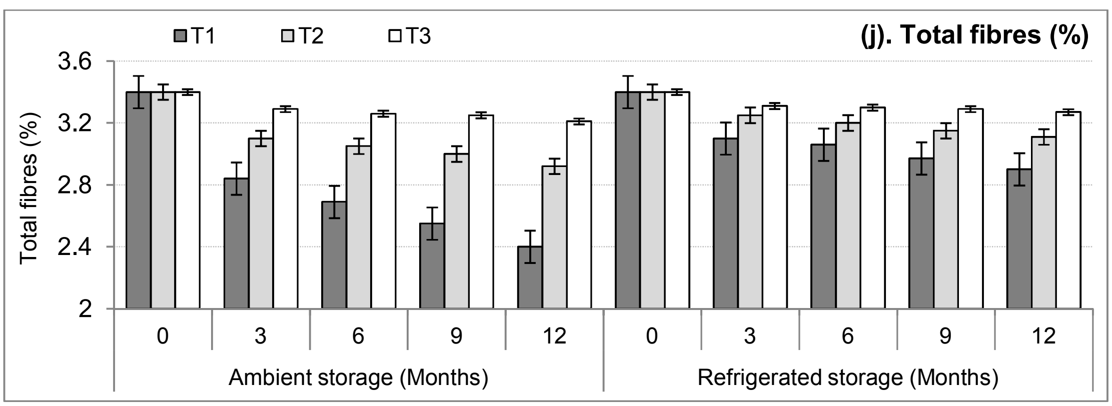


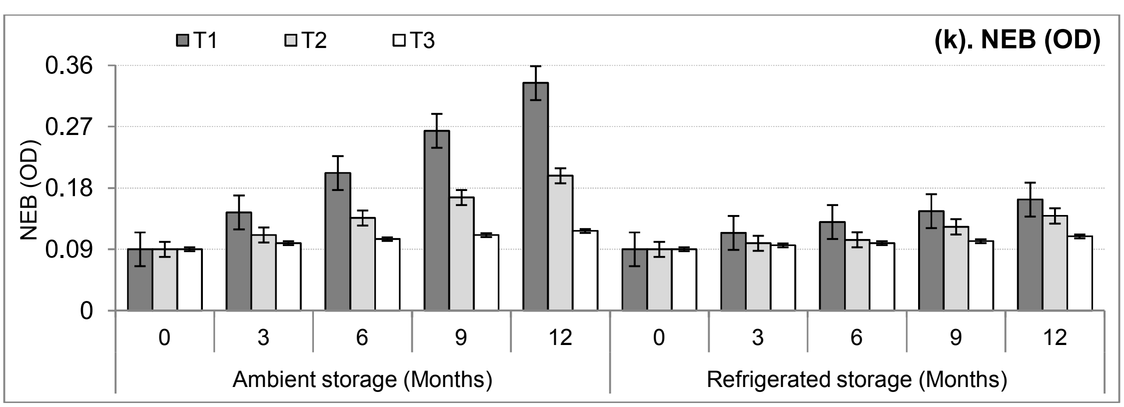



T1
T2
T3
(d). Titratable acidity (%)
Titratable acidity (%)
11.5
10.5
9.5
8.5
7.5
6.5
5.5
0
3
6
9
12
Ambient storage (Months)
Refrigerated storage (Months)
(e). Reducing sugars (%)
Reducing sugars (%)
26
25
24
23
22
(f). Total sugars (%)
Total sugars (%)
26
25
24
23
22
21
20
(g). Ascorbic acid (mg/100 g)
Ascorbic acid (mg/100 g)
15
12
9
6
3
0


(h). Anthocyanins (mg/100 g)
T1
T2
T3
Anthocyanins (mg/100 g)
40
35
30
25
20
15
0
3
6
9
12
Ambient storage (Months)
Refrigerated storage (Months)


(i). Starch (%)
T1
T2
T3
Starch (%)
3
2.6
2.2
1.8
1.4
0
3
6
9
12
Ambient storage (Months)
Refrigerated storage (Months)


(j). Total fibres (%)
T1
T2
T3
Total fibres (%)
3.6
3.2
2.8
2.4
2
0
3
6
9
12
Ambient storage (Months)
Refrigerated storage (Months)


(k). NEB (OD)
T1
T2
T3
NEB (OD)
0.36
0.27
0.18
0.09
0
0
3
6
9
12
Ambient storage (Months)
Refrigerated storage (Months)

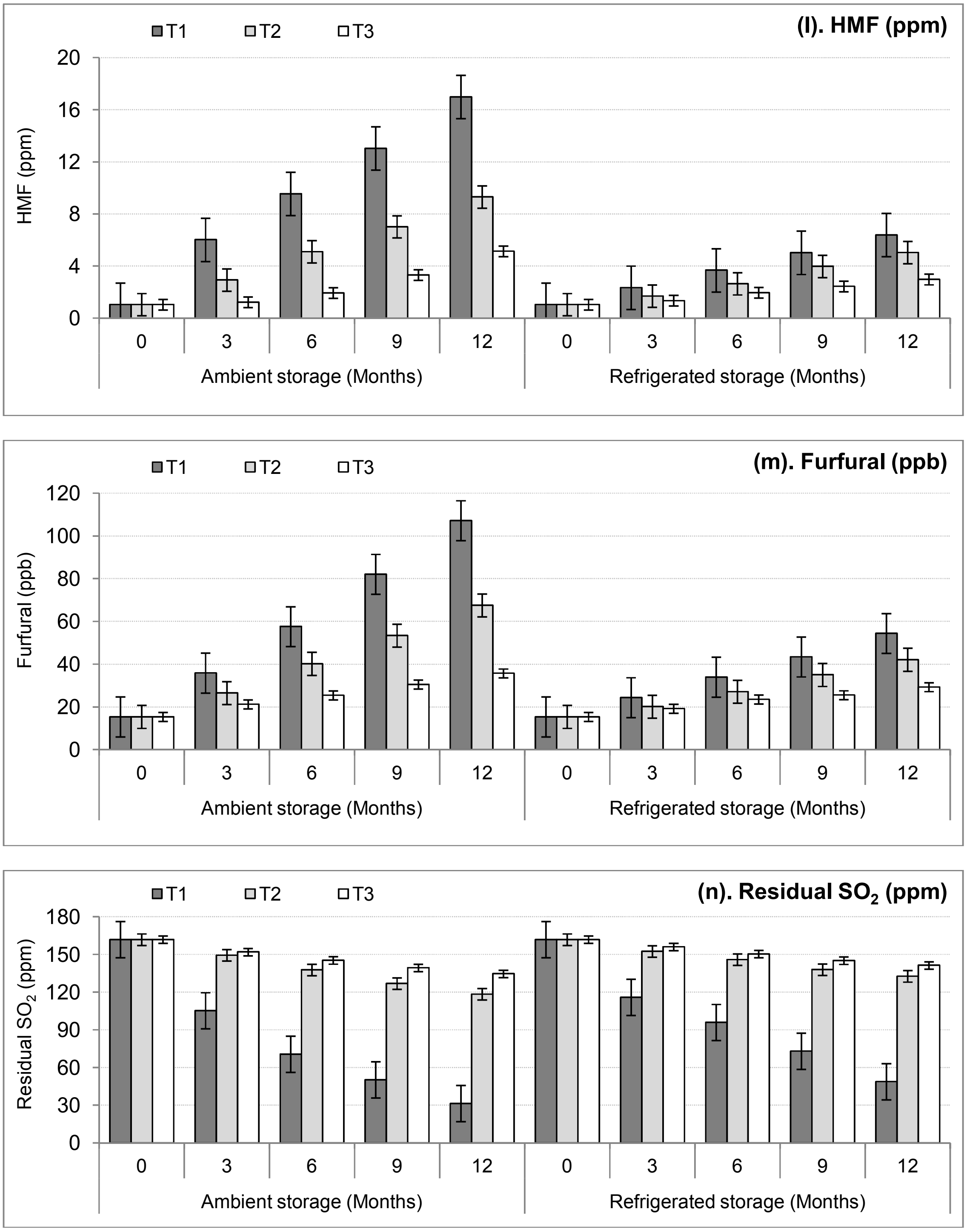
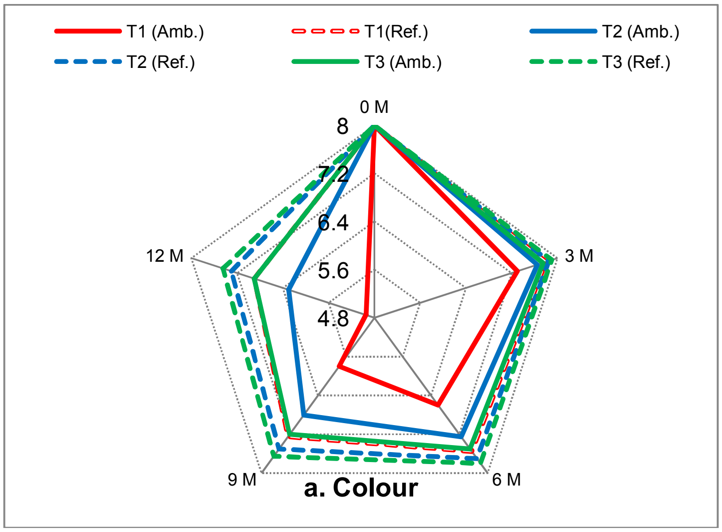
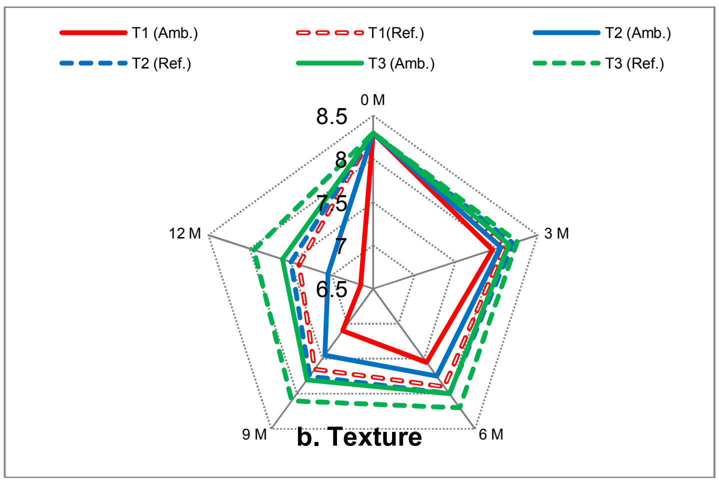
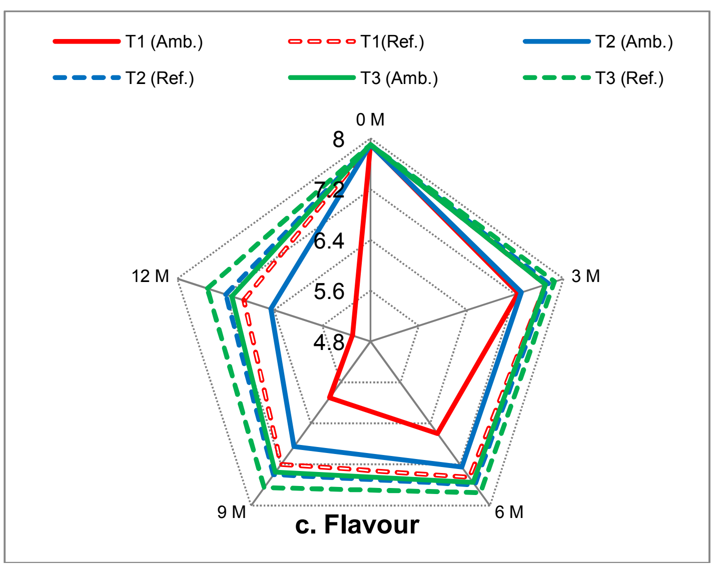


Fig. 3(a-n). Effect of storage on the physico-chemical characteristics of *anardana* prepared under solar tunnel drier

(T_1: Gunny bags, T_2: Aluminium laminated pouch and T_3: Aluminium laminated pouch with vacuum; Error bars indicates standard error of the average; a. Moisture, b. Water activity, c. TSS, d. Titratable acidity, e. Reducing sugars, f. Total sugars, g. Ascorbic acid, h. Anthocyanins, i. Starch, j. Total fibres, k. NEB, l. HMF, m. Furfural and n. Residual SO_2)


T1 (Amb.)
T1(Ref.)
T2 (Amb.)
T2 (Ref.)
T3 (Amb.)
T3 (Ref.)
0 M
3 M
6 M
9 M
12 M
8
7.2
6.4
5.6
4.8
a. Colour


T1 (Amb.)
T1(Ref.)
T2 (Amb.)
T2 (Ref.)
T3 (Amb.)
T3 (Ref.)
0 M
3 M
6 M
9 M
12 M
8.5
8
7.5
7
6.5
b. Texture


T1 (Amb.)
T1(Ref.)
T2 (Amb.)
T2 (Ref.)
T3 (Amb.)
T3 (Ref.)
0 M
3 M
6 M
9 M
12 M
8
7.2
6.4
5.6
4.8
c. Flavour

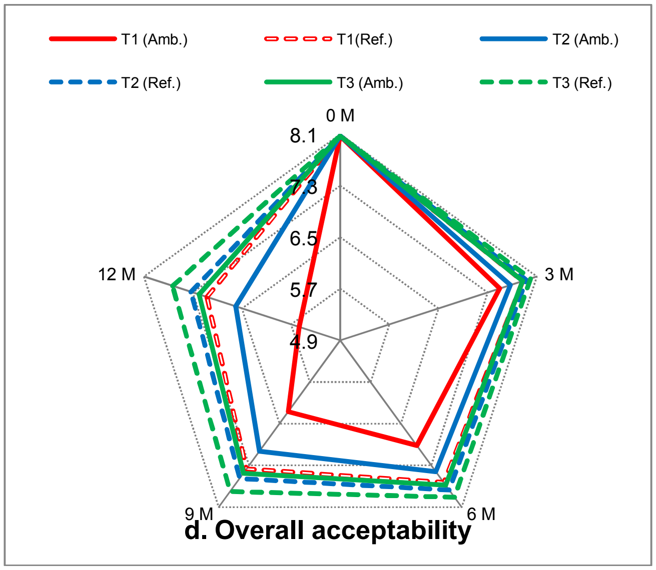


Fig. 4(a-d). Effect of storage on the sensory characteristics scores of *anardana* prepared under solar tunnel drier

(T_1: Gunny bags, T_2: Aluminium laminated pouch and T_3: Aluminium laminated pouch with vacuum; M: Months; Amb.: Ambient and Ref.: Refrigerated; a: Colour, b: Texture, c: Flavour and d. Overall acceptability)

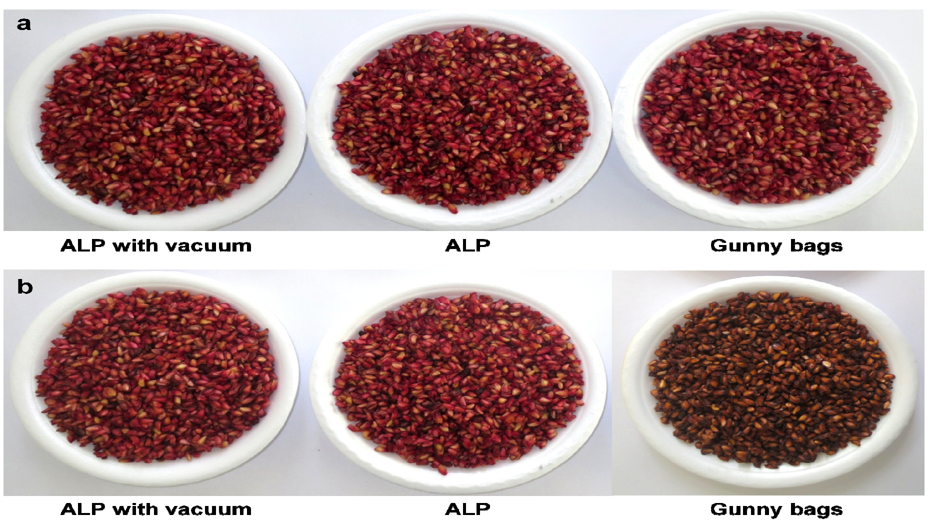


Fig. 5. Condition of *anardana* prepared under solar tunnel drier after 12 months of storage (a: Refrigerated storage and b: Ambient storage

(ALP: Aluminium laminated pouch)

4. CONCLUSION

The *anardana* prepared in solar tunnel drier can be stored safely for a period of 12 months under both storage conditions and packaging materials. The best quality of *anardana* was retained in ALP with vacuum which was stored under refrigerated storage conditions as compared to ALP and gunny bags. However, the *anardana* prepared in solar tunnel drier packed in gunny bags and stored under ambient temperature conditions turned brown at the end of storage period.

CONSENT

Informed consent was obtained from all individual participants involved in the study for sensory analysis.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ercisli S, Gadze J, Agar G, Yildirim N, Hizarci Y. Genetic relationships among wild pomegranate (*Punica granatum*) genotypes from Coruh Valley in Turkey. Genetics and Molecular Research. 2011; 10(1):459-464. Available:https://www.doi.org/0.4238/vol10-1gmr1155
2. Morton J. Pomegranate. In: Fruits of warm climates. Julia F. Morton, Miami, FL. 1987; 352-355.
3. Holland D, Hatip K, Bar-Yaakov I. Pomegranate: Botany, Horticulture and Breeding. In: Janik J, editor. Horticultural Reviews. John Wiley & Sons Inc. NJ, USA; 2009:127-191. Available:https://doi.org/10.1002/9780470593776.ch2
4. Usanmaz S, Kahramanoğlu I, Yılmaz N. Yield and pomological characteristics of three pomegranate (*Punica granatum* L) cultivars: Wonderful, Acco and Herskovitz. American Journal of Agriculture and Forestry. 2014;2(3):61-65. Available:https://doi.org/10.11648/j.ajaf.20140203.12
5. Levin GM. Pomegranate (1st Edn). Third Millennium Publishing, East Libra Drive Tempe, AZ. 2006:1-129.
6. Mishra G, Sharma G, Taria S, Lata S, Negi D. Determination of pollen viability of wild pomegranate accessions in the mid-hill zone of Himachal Pradesh. International Journal of Farm Sciences. 2016;6:105-110.
7. Thakur NS, Dhaygude GS, Gupta, A. Physico-chemical characteristics of wild pomegranate fruits in different locations of Himachal Pradesh. International Journal of Farm Sciences. 2011;1(2):37-44.
8. Thakur A, Thakur NS, Hamid, Kumar, P. Studies on physico-chemical and antioxidant properties of wild pomegranate fruits in different locations of Himachal Pradesh, India. International Journal of Current Microbiology and Applied Sciences. 2018;7(8):2842-2850. Available:https://www.doi.org/10.20546/ijcmas.2018.708.299
9. Viuda-Martos, M, Fernández-López J, Pérez-Álvarez JA. Pomegranate and its many functional components as related to human health: a review. Comprehensive Reviews in Food Science and Food Safety. 2010;9(6):635-654. Available:https://www.doi.org/10.1111/j.1541-4337.2010.00131.x
10. Sreekumar S, Sithul H, Muraleedharan P, Azeez JM and Sreeharshan S. Pomegranate fruit as a rich source of biologically active compounds. BioMed Research International; 2014. Article ID 686921. Available:https://doi.org/10.1155/2014/686921
11. Mageid MMAE, Salama NAR, Saleh MAM, Abo-Taleb HM. Evaluation of antdiabetic, hypocholesterolemic of pomegranate (*Punica granatum* L.) juice powders and peel powder extracts in male albino rats. Journal of Pharmacy and Biological Sciences. 2016;11:53-64.
12. Kalaycioglu Z, Erim FB. Total phenolic contents, antioxidant activities, and bioactive ingredients of juices from pomegranate cultivars worldwide. Food Chemistry. 2017;221:496-507. Availablehttps://www.doi.org/10.1016/j.foodchem.2016.10.084
13. Kashyap P, Anand S, Thakur A. Evaluation of antioxidant and antimicrobial activity of *Rhododendron arboreum* flowers extract. International Journal of Food and Fermentation Technology. 2017;7(1):123-128. Available:https://www.doi.org/10.5958/2277-9396.2017.00013.7
14. Thakur A, Joshi VK, Thakur NS. Immunology and its relation with food components: an overview. International Journal of Food and Fermentation Technology. 2019;9(1):1-16. Available:https://www.doi.org/10.30954/2277-9396.01.2019.3
15. Kingsly ARP, Singh DB, Manikantan MR, Jain RK. Moisture dependent physical properties of dried pomegranate seeds (*anardana*). Journal of Food Engineering. 2006;75:492-496.

Available:https://doi.org/10.1016/j.jfoodeng.2005.04.033
16. Thakur A, Thakur NS, Hamid, Chauhan M, Sharma C. Comparison of quality of *anardana* (dried arils) prepared in mechanical cabinet and solar tunnel drier from wild pomegranate (*Punica granatum* L.) fruits procured from different locations of Himachal Pradesh, India. Journal of Applied and Natural Science. 2020;12(2):71-78. Available:https://doi.org/10.31018/jans.v12i2.2247
17. Bakshi P, Bhushan B, Wali VK, Bakshi M, Sharma A, Bhat DJ. Standardization of drying method and organoleptic evaluation of wild pomegranate (*anardana*) seeds. World Journal of Agricultural Sciences. 2013;9(5):397-400. Available:https://www.doi.org/10.5829/idosi.wjas.2013.9.5.1750
18. Thakur NS, Bhat MM, Rana N, Joshi VK. Standardization of pre-treatments for the preparation of dried arils from wild pomegranate. Journal of Food Science and Technology. 2010;47(6):620-625. Available:https://www.doi.org/10.1007/s13197-010-0091-4
19. Ranganna S. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. Tata McGraw Hill, pub. Co. Ltd., New Delhi; 2009.
20. Gould WA. Food Quality Assurance. AVI Publishing Company, Westport, Connecticut, New York; 1978.
21. Amerine MA, Pangborn RM, Roessler EB. Principles of Sensory Evaluation of Food. Academic Press, London; 1965.
22. Kumar V, Kushwaha R, Goyal A, Tanwar B, Kaur J. Process optimization for the preparation of antioxidant rich ginger candy using beetroot pomace extract. Food Chemistry. 2018;245:168-177. Available:https://www.doi.org/10.1016/j.foodchem.2017.10.089
23. Bhat MM, Thakur NS, Jindal N. Studies on the effect of drying methods and packaging on quality and shelf life of dried wild pomegranate arils. Asian Journal of Dairy and Food Research. 2014;33:18-24. Available:https://www.doi.org/10.5958/j.0976-0563.33.1.005
24. Sharma A, Thakur NS. Influence of active packaging on quality attributes of dried wild pomegranate (*Punica granatum* L.) arils during storage. Journal of Applied and Natural Science. 2016;8:398-404.
25. Sharma SR, Bhatia S, Arora S, Mittal TC, Gupta SK. Effect of storage conditions and packaging material on quality of *anardana*. International Journal of Advanced Engineering Technology. 2013;6(5):2179-2186.
26. Dak M, Sagar VR, Jha SK. Shelf-life and kinetics of quality change of dried pomegranate arils in flexible packaging. Food Packaging and Shelf Life. 2014;2:1-6.
27. Singh DB, Kingsly ARP. Effect of convective drying on quality of *anardana*. Indian Journal of Horticulture. 2008;65(4):413-416.
28. Grande VK, Masalkar SD, Gaikand RS, Patil RS. Studies on preparation and storage of *anardan*a. Agriculture Science Digest. 2004;24:283-285.
29. Gregory III, JF. Vitamins. In: Fennema OR, editor. Food Chemistry. Marcel Dekker, New York; 1996:559-567.
30. Bolin HR, Steele, RJ. Non-enzymatic browning in dried apples during storage. Journal of Food Science. 1987;52:1654-1657.
31. Mahadeviah MO. Modern trend in food packaging for globalization. Indian Food Packer. 1999;53:44-48.
32. Murkovic M, Pichler N. Analysis of 5-hydroxymethylfurfual in coffee, dried fruits and urine. Molecular Nutrition and Food Research. 2006;50:842-846.
33. Sen F, Ozgen M, Asma, BM, Aksoy U. Quality and nutritional property changes in stored dried apricots fumigated by sulfur dioxide. Horticulture, Environment and Biotechnology. 2015;56:200-206.

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