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ORIGINAL ARTICLE

Processing and storage of apricots: effect on physicochemical and antioxidant properties

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Abstract The present study was carried out to evaluate the effect of processing methods and storage periods on the three apricot varieties viz. CITH-1, CITH-2 and New Castle. Apricots were processed by freezing and canning of pulp and drying of whole apricots. After processing these were analysed for various physicochemical and antioxidant properties for a storage period of 12 months at 4 month interval. The results for physicochemical properties like moisture content, TSS, total sugars and reducing sugars showed significant variation with respect to varieties and processing methods during storage. Apricots processed by canning showed highest retention of antioxidants in terms of TPC, FRAP, DPPH and metal chelating activity throughout storage period than that of frozen and dried one. CITH-2 processed by canning, freezing and drying method showed highest antioxidant properties than CITH-1 and New Castle. It can be concluded from the study that canning and freezing can preserve the apricot pulp for 12 months and significantly retain bioactive compounds.

Keywords Apricot · Processing · Storage · Physicochemical · Antioxidant

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Introduction

Fruits and vegetables are rich sources of several bioactive compounds which have many health promoting effects, in addition to vitamins and minerals (Singh et al. 2016). Apricot (*Prunus armeniaca* L.) has an important place in human nutrition, as it is a rich source of sugars, fibers, minerals, bioactive phytochemicals and vitamins like A, C, thiamine, riboflavin, niacin and pantothenic acid (Leccese et al. 2007). Among the phytochemicals, phenolics, carotenoids and antioxidants are important for their biological value. Sucrose, glucose, and fructose are the major sugar components (Akin et al. 2008). Carotenoids mainly include β-carotene, β-cryptoxanthin, lutein and γ-carotene. Phenolic characterization of the apricot fruits shows chlorogenic acid, neochlorogenic acid, protocatechuic acid, (+)-catechin, 3′-caffeoylquinic (or chlorogenic) acid, (−)-epicatechin, naringenin-7-glucoside (or prunin), quercetin-3-glucoside, quercetin-3-rhamnoglucoside (or rutin), and kaempferol-3-rutinoside (Erdogan-Orhanm and Kartal 2011). Apart from its nutritional characteristics, apricot fruit has also some pharmacological significance due to high amount of antioxidants. It is used as mild laxative, antipyretic, antiseptic, emetic and ophthalmic. Some studies have reported antimicrobial, antimutagenic, cardioprotective, hepatoprotective, anti-inflammatory and antinociceptive activities (Wani et al. 2015) of apricots. In India apricots are grown commercially in the hills of Himachal Pradesh, Jammu and Kashmir, Utter Pradesh and to a limited extent in the north eastern hills. Some apricots are being grown in dry temperate regions of Kinnaur and Lahaul Spiti in Himachal Pradesh and Ladakh in Jammu and Kashmir. Being perishable in nature, it has a short shelf-life of 4–5 days under ambient conditions. Its shelf-life is only about 2–3 weeks, even under low temperature

storage conditions (1 °C) and high relative humidity (90–95%) and can develop some physiological problems, including firm and juiceless flesh and internal browning (Wu et al. 2015). As known, the fruit of apricot is not only consumed fresh but also used to produce dried apricot, frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products, leather, bar etc. (Hacıseferogulları et al. 2007; Wani et al. 2016). During processing of the fruits various changes do occur in the pyhtochemical, nutritional and antioxidant value. Processing of fruit or vegetables can result in a significant reduction in phytochemical content. Conversely, in some cases, processing improves the stability of phytochemicals in processed food (Tiwari and Cummins 2013). Food processing such as heating or freezing can disrupt the cell membrane leading to the release of membrane-bound phytochemicals, which implies higher bioaccessibility (Leong and Oey 2012). The loss of nutrients in fruits and vegetables depends on the type of food, processing time, processing temperature and storage conditions (Murcia et al. 2001). Food product storage conditions, including storage time, temperature and light may have an influence on the retention of phytochemicals. Present study was carried out to investigate the effect of processing methods (freezing, canning and drying) and storage periods on physicochemical and antioxidant properties of three apricot cultivars.

Materials and methods

Chemicals and reagents

Standard chemicals and reagents used for various assays were procured from Hi-Media Laboratories Pvt. Ltd., Mumbai, India. All the chemicals were of analytical grade and of 99% purity.

Raw material

Three apricot varieties CITH-1, CITH-2 and New Castle studied in the present work were handpicked from the orchards of CITH (Central Institute of Temperate Horticulture) Rangreth, Srinagar. The apricot varieties were harvested at their commercial maturity stages in the month of July and brought to the Department of Food Science and Technology. The apricots were immediately sorted on basis of size, colour and maturity and then cleaned from dirt and dust with the tap water. The apricot varieties were separated into three lots to be processed by using preservation techniques of freezing, canning and drying.

Freezing

The fruits to be frozen were destoned and the flesh was made into fine pulp using pulper (Bajaj). The pulp obtained was packed into plastic bags and kept for freezing in a deep freezer (Haier HCF, 345HTQ) and maintained at a temperature of − 18 °C.

Canning

For canning fruits were destoned and the flesh was made into fine pulp using pulper (Bajaj). The pulp obtained was filled into cans and processed at a temperature of 121 °C for 30 min. The cans were cooled to a temperature of 25 °C by tap water, dried and stored under ambient conditions for further studies.

Drying

For hot air drying, a laboratory convection tray-dryer (Labotech, BDI-51) was used. The apparatus include controllers for variable fan speed and heater. Samples of fresh apricot were separately placed on the steel sieved trays for increasing air passage from both surfaces which increases the effectiveness of drying. Initial moisture content of whole apricots was determined at 80 °C by gravimetric method. For drying, air temperature of 65 °C, RH of 70% and constant drying air velocity (1.07 ± 0.011 ms^{-1}) for 60 h were selected. Before drying, the dryer was run for 30 min to obtain steady-state conditions. After having reached a suitable dryness level, dried apricots were placed into polyethylene bags and stored under ambient conditions until subsequent analysis.

Evaluation of the processed apricots was done at an interval of 4 months during the storage period of 12 months. The processed products were evaluated for physicochemical, and antioxidant properties.

Proximate composition

Moisture content and total soluble solids (TSS)

Moisture content was determined as per the standard method of AOAC (2005). TSS was measured using a hand refractometer (Attago) and expressed as °Brix.

Titrable acidity

The acid content of the apricot samples was determined by titration method (Wani et al. 2016).

Total and reducing sugars

Total and reducing sugars were determined by the method of Miller (1959) using 3,5-dinitrosalicylic acid reagent (DNSA).

Total carotenoids

Total carotenoids as beta carotene equivalents were determined using the method of Kimura and Rodriguez-Amaya (2004).

Antioxidant activity

Preparation of extracts

Fifty gram homogenized sample of apricot was extracted three times using methanol. The extracts were combined and filtered through Whatmann filter paper no. 42, followed by centrifugation at 4 ± 1 °C for 20 min at 6500 rpm. The supernatants so collected were kept at 4 ± 1 °C for further analysis.

Total phenolic content

The total phenolic content was determined by the standard procedure of Singleton et al. (1999) using the Folin–Ciocalteu (FC) reagent.

DPPH radical scavenging activity

DPPH radical scavenging activity of extracts was measured according to the method of Brand-Williams et al. (1995) with some modifications (Mir et al. 2016).

Ferric reducing ability power (FRAP)

The FRAP assay was carried out as described by Benzie and Strain (1996) with slight modifications as described by Mir et al. (2016).

Metal chelating activity

Metal chelating activity was determined according to the method of Dinis et al. (1994).

Statistical analysis

All tests were done at least three times for each experimental condition and mean values are reported. Data were analyzed using general linear model (GLM) procedure of SPSS Statistics (v. 16, Inc., Chicago, IL) for two-way analyses of variance (ANOVA). Duncan's multiple range test ($P < 0.05$) was used to determine the differences between means. The statistical analysis for each parameter combines the data from three batches.

Results and discussion

Moisture content

Data pertaining to the effect of processing and variety on moisture content of apricots during storage of 12 months is presented in Table 1. Highest moisture content of 85.20% was observed in frozen CITH-2 at the 0 month of storage while as lowest (11.20%) was observed in dried CITH-2 apricots at 0 month of storage. Lesser moisture content in canned apricots is due to the small loss of water content during processing and in dried apricots there is considerable loss of moisture during drying which results in lowest moisture content. There is significant decrease in moisture during storage in frozen apricots, and a significant increase in dried apricots. However, changes in moisture content in canned apricots were non-significant. The changes in moisture content can be attributed to vapour pressure differential between apricots and the storage environment. In canned apricots, due to impermeability of metal to water vapour, changes in moisture content are non-significant. Amongst the varieties, CITH-2 showed the highest moisture content followed by CITH-1 while as New Castle showed the lowest moisture content in all the processing treatments and at all storage intervals. Skupien (2006) reported a linear decrease in moisture content of Spartan berries, jersey, blueray, and bluecrop berries during frozen storage of 12 months. Similar results have been reported by Sharma (2000).

Total soluble solids

Total soluble solids varied significantly with variety, processing method and storage interval (Table 1). In frozen apricots and canned apricots TSS increased significantly over a storage period of 12 months. Highest TSS of 78.80% was recorded in dried New Castle apricots at 0 month of storage and lowest TSS of 11.60% was observed in frozen CITH-2 apricots at 0 month of storage. The increase may be attributed to conversion of complex carbohydrates into simpler ones. TSS decreased significantly in dried apricots which may be due to gain of moisture (dilution effect) and utilization of sugars in browning reactions. Amongst processing treatments, dried apricots showed the highest TSS followed by canned apricots while as frozen apricots showed the lowest. The highest TSS in dried apricots is due to loss of moisture (concentration effect) during drying and conversion of

Table 1 Effect of processing methods and storage on moisture (%) and TSS (°Bx) of apricot cultivars

Treatment	Variety	Moisture content (%)				TSS (°Bx)			
		Storage (months)				Storage (months)			
		0	4	8	12	0	4	8	12
Frozen	CITH-1	83.60 ± 0.43^{bcA}	82.70 ± 0.23^{bA}	82.20 ± 0.17^{bA}	81.90 ± 0.20^{bA}	12.70 ± 0.8^{aA}	13.40 ± 0.22^{aA}	13.80 ± 0.04^{aA}	13.90 ± 0.15^{aA}
	CITH-2	85.20 ± 0.09^{cA}	84.10 ± 0.21^{bcA}	83.50 ± 0.23^{bcA}	83.10 ± 0.41^{bA}	11.60 ± 0.7^{aA}	12.30 ± 0.13^{aA}	12.90 ± 0.08^{aA}	13.10 ± 0.22^{aA}
	New Castle	81.50 ± 0.23^{bA}	80.80 ± 0.06^{bA}	80.10 ± 0.01^{bcA}	79.70 ± 0.23^{bA}	13.50 ± 0.3^{aA}	14.20 ± 0.06^{aA}	14.70 ± 0.12^{aA}	15.0 ± 0.09^{aAB}
Canned	CITH-1	81.20 ± 0.19^{bA}	81.40 ± 0.18^{bA}	81.30 ± 0.33^{bA}	81.50 ± 0.06^{bA}	14.50 ± 0.1^{bA}	14.80 ± 0.03^{aA}	14.90 ± 0.11^{aA}	15.10 ± 0.32^{aA}
	CITH-2	83.10 ± 0.33^{bcA}	82.80 ± 0.12^{bA}	82.90 ± 0.14^{bA}	82.70 ± 0.03^{bA}	13.30 ± 0.1^{aA}	13.50 ± 0.09^{aA}	13.70 ± 0.13^{aA}	13.90 ± 0.17^{aA}
	New Castle	79.50 ± 0.26^{bA}	79.70 ± 0.04^{bA}	79.60 ± 0.21^{bA}	79.40 ± 0.17^{bA}	15.10 ± 0.8^{aA}	15.40 ± 0.02^{aA}	15.60 ± 0.09^{aA}	15.90 ± 0.01^{aA}
Dried	CITH-1	11.70 ± 0.02^{aA}	14.40 ± 0.08^{aB}	16.10 ± 0.16^{aC}	16.70 ± 0.05^{aC}	70.20 ± 0.5^{bB}	68.40 ± 0.16^{bAB}	67.50 ± 0.13^{bA}	66.70 ± 0.22^{bA}
	CITH-2	12.10 ± 0.18^{aA}	14.70 ± 0.15^{aAB}	16.50 ± 0.09^{aC}	17.10 ± 0.02^{aC}	69.80 ± 0.2^{bAB}	67.80 ± 0.07^{bA}	66.70 ± 0.40^{bA}	65.90 ± 0.18^{bA}
	New Castle	11.20 ± 0.01^{aA}	13.90 ± 0.03^{aAB}	15.60 ± 0.09^{aC}	16.20 ± 0.01^{aC}	71.80 ± 0.2^{bB}	70.01 ± 0.01^{bAB}	68.60 ± 0.06^{bA}	67.70 ± 0.03^{bA}

All values are mean ± standard deviation of three replicates (n = 3)

Means in the same column with different superscripts differ significantly: $^{*}P < 0.05$

Means with different superscripts in the same row indicate significant difference: $^{*}P < 0.05$

complex carbohydrates into simple and soluble forms due to high temperature. During canning, high temperature causes breakdown of complex substances into soluble forms resulting in higher TSS than frozen apricots. Vijayanand et al. (2015) also reported increase in TSS of canned mango products from Sindura, Mallika and Totapuri varieties during 2 months storage period. Similar findings have been observed by Mir et al. (2009) in sulphite treated dried apricots during 12 months storage.

Titrable acidity

There was significant variation in titrable acidity with respect to variety and processing method during storage of 12 months (Table 2). New Castle recorded the highest titrable acidity followed by CITH-1 and CITH-2 throughout the storage. Dried apricots showed highest acidity while as canned apricots showed the lowest. Highest acidity of 3.80% was recorded in dried New Castle apricots at 0 month of storage and lowest acidity of 0.82% was observed in frozen CITH-2 apricots at 0 month of storage. Titrable acidity increased significantly during storage of frozen apricots which may be attributed to the concentration effect due to moisture loss. There was a significant decrease in acidity during storage of canned and dried apricots. In canned apricots there occurs degradation of organic acids while as in dried apricots decrease is due to degradation and dilution effects due to moisture gain. Vijayanand et al. (2015) also reported slight decrease in acidity of canned mango slices during 2 months storage period at ambient temperature. Priya and Khatkar (2013) also observed significant decrease in titratable acidity of aonla preserves during storage period of 90 days. Similar results were obtained by Sharma (2000) and Akin et al. (2008).

Total sugars

Perusal of data pertaining to total sugars shows a significant difference in the varieties, processing methods and storage intervals (Table 2). Highest value for total sugars (30.50%) was recorded in dried New Castle apricots at 0 month of storage and lowest acidity of 2.50% was observed in frozen CITH-2 apricots at 0 month of storage. However value of 29% was observed in New Castle in dried apricots and a value of 3.20% was reported in CITH-2 frozen apricot after 12 month of storage. During storage of dried apricots, total sugars decreased significantly, and this may be attributed to moisture gain and utilization of sugars in browning reactions. In frozen and canned apricots, total sugars increased significantly during storage which may be due to conversion of complex carbohydrates into sugars. Amongst processing methods, frozen apricots

Table 2 Effect of processing methods and storage on titrable acidity (%) and total sugars (%) of apricot cultivars

Treatment	Variety	Acidity (%)				Total sugars (%)			
		Storage (months)				Storage (months)			
		0	4	8	12	0	4	8	12
Frozen	CITH-1	0.90 ± 0.1^{aA}	0.93 ± 0.03^{aA}	0.95 ± 0.09^{aA}	0.96 ± 0.12^{aA}	2.70 ± 0.03^{aA}	3.10 ± 0.06^{aA}	3.30 ± 0.23^{aA}	3.40 ± 0.13^{aA}
	CITH-2	0.85 ± 0.07^{aA}	0.87 ± 0.02^{aA}	0.90 ± 0.13^{aA}	0.92 ± 0.05^{aA}	2.50 ± 0.04^{aA}	2.90 ± 0.16^{aA}	3.10 ± 0.07^{aA}	3.20 ± 0.02^{aA}
	New Castle	1.05 ± 0.09^{aA}	1.09 ± 0.23^{aA}	1.11 ± 0.08^{aA}	1.12 ± 0.12^{aA}	2.90 ± 0.05^{aA}	3.40 ± 0.09^{aA}	3.70 ± 0.14^{aA}	3.90 ± 0.08^{aA}
Canned	CITH-1	0.84 ± 0.07^{aA}	0.81 ± 0.04^{aA}	0.78 ± 0.06^{aA}	0.77 ± 0.24^{aA}	4.80 ± 0.08^{bA}	5.40 ± 0.18^{bA}	5.70 ± 0.13^{bA}	5.90 ± 0.23^{bA}
	CITH-2	0.82 ± 0.03^{aA}	0.80 ± 0.06^{aA}	0.77 ± 0.13^{aA}	0.75 ± 0.16^{aA}	4.50 ± 0.21^{bA}	5.10 ± 0.06^{bA}	5.30 ± 0.09^{bA}	5.60 ± 0.15^{bA}
	New Castle	1.01 ± 0.09^{aA}	0.97 ± 0.02^{aA}	0.95 ± 0.17^{aA}	0.92 ± 0.27^{aA}	5.20 ± 0.06^{bA}	5.70 ± 0.03^{bA}	5.90 ± 0.01^{bA}	6.10 ± 0.18^{bA}
Dried	CITH-1	3.65 ± 0.07^{bA}	3.35 ± 0.23^{bA}	3.20 ± 0.13^{bA}	3.10 ± 0.06^{cA}	29.30 ± 0.17^{cA}	28.80 ± 0.28^{cA}	28.60 ± 0.09^{cA}	28.50 ± 0.16^{cA}
	CITH-2	3.40 ± 0.05^{bA}	3.15 ± 0.11^{bA}	3.05 ± 0.13^{bA}	2.95 ± 0.05^{bA}	28.60 ± 0.07^{cA}	28.30 ± 0.21^{cA}	28.00 ± 0.12^{cA}	27.80 ± 0.02^{cA}
	New Castle	3.80 ± 0.18^{bA}	3.45 ± 0.01^{bA}	3.30 ± 0.23^{bA}	3.15 ± 0.19^{cA}	30.50 ± 0.03^{cA}	30.10 ± 0.12^{cA}	29.10 ± 0.08^{cA}	29.00 ± 0.01^{cA}

All values are mean ± standard deviation of three replicates (n = 3)

Means in the same column with different superscripts differ significantly: $^{*}P < 0.05$

Means with different superscripts in the same row indicate significant difference: $^{*}P < 0.05$

showed the lowest total sugar content. Higher total sugar content in canned and dried apricots may be attributed to loss of water during processing and breakdown of complex carbohydrates into sugars. Total sugar content in the same range was reported by Ali et al. (2011) in fresh apricots. Doreyappa Gowda and Huddar (2004) also reported increase in total sugars of canned mango slices during storage. Similar trends for total sugar content were observed by Sharma (2000).

Reducing sugars

Reducing sugars showed similar trends as reported for total sugars (Table 3). Analysis of data shows that highest reducing sugars were reported in New Castle followed by CITH-1 and CITH-2 in all the processing methods. For reducing sugars the highest value of 14.43% was recorded for dried New Castle at the beginning of storage, while as lowest value of 0.88% was reported in CITH-2 at the beginning of storage. At the end of storage value of 12.90% was reported for dried New-Castle and for frozen CITH-2 value of 1.95% was observed. Amongst various processing methods dried New Castle apricots showed highest reducing sugars (12.90%) followed by canned (4.10%) and frozen apricots (1.95%) at the end of storage. Higher values for dried may be due to loss of moisture resulting in concentration of the solid matter and effect of higher temperature on conversion reactions. There was a continuous decrease in reducing sugars in dried apricots during storage of 12 months and reasons for the decrease may be their utilization in browning reactions and dilution effects of moisture gain. In canned and frozen apricots breakdown of complex carbohydrates and non-reducing sugars may be responsible for the increase in reducing sugars. Ali et al. (2011) reported reducing sugars in similar range for apricots grown in Pakistan. Similar increase in reducing sugars of canned mango slices was reported in processed mango products during storage by Vijayanand et al. (2015) during 2 months storage period. The results were also in conformity with the findings reported earlier. They noticed a marked increase in reducing sugar content of aonla preserves was noticed during 90 days storage period (Damame et al. 2002; Sharma 2000).

Total carotenoids

The effect of different processing methods and storage periods on total carotenoids is given in Table 3. Total carotenoids significantly decreased during processing and storage in all apricot varieties. Lowest carotenoid value was reported in dried apricots New Castle (5.15 mg/100 g FW) while as frozen apricots CITH-2 showed the highest content of carotenoids (12.75 mg/100 g FW) at the

Table 3 Effect of processing methods and storage on reducing sugars (%) and beta carotene (mg/100 g FW) and of apricot cultivars

Treatment	Variety	Reducing sugars (%)				Beta carotene (mg/100 g DW)			
		Storage (months)				Storage (months)			
		0	4	8	12	0	4	8	12
Frozen	CITH-1	0.93 ± 0.03^{aA}	1.10 ± 0.02^{aA}	1.30 ± 0.05^{aA}	1.40 ± 0.26^{aAB}	9.80 ± 0.9^{dC}	8.60 ± 0.06^{cC}	6.75 ± 0.07^{bcB}	4.80 ± 0.14^{bA}
	CITH-2	0.88 ± 0.14^{aA}	0.94 ± 0.16^{aA}	1.19 ± 0.01^{aA}	1.52 ± 0.04^{aAB}	12.75 ± 0.01^{eBC}	11.40 ± 0.16^{dB}	9.65 ± 0.09^{dA}	7.30 ± 0.18^{dA}
	New Castle	1.03 ± 0.11^{aA}	1.40 ± 0.03^{aA}	1.70 ± 0.24^{aAB}	1.95 ± 0.02^{aAB}	11.45 ± 0.12^{eC}	10.25 ± 0.23^{dC}	8.40 ± 0.18^{dB}	6.15 ± 0.07^{cA}
Canned	CITH-1	2.84 ± 0.03^{bA}	3.40 ± 0.17^{bA}	3.75 ± 0.07^{bB}	3.96 ± 0.12^{bB}	7.20 ± 0.08^{cD}	5.65 ± 0.07^{abC}	4.15 ± 0.25^{aB}	2.80 ± 0.34^{aA}
	CITH-2	2.41 ± 0.13^{bA}	3.10 ± 0.09^{bAB}	3.39 ± 0.09^{bB}	3.76 ± 0.10^{bB}	11.90 ± 0.07^{eC}	10.20 ± 0.17^{dC}	8.35 ± 0.01^{dB}	6.25 ± 0.13^{cA}
	New Castle	3.21 ± 0.19^{cA}	3.78 ± 0.21^{bA}	3.97 ± 0.15^{bAB}	4.10 ± 0.29^{bB}	9.15 ± 0.23^{dD}	7.45 ± 0.04^{cC}	5.60 ± 0.07^{bB}	3.90 ± 0.16^{aA}
Dried	CITH-1	12.33 ± 0.3^{dB}	12.01 ± 0.34^{cAB}	11.60 ± 0.19^{cA}	11.10 ± 0.07^{cA}	4.50 ± 0.05^{aAB}	3.80 ± 0.12^{aA}	3.45 ± 0.19^{aA}	3.10 ± 0.09^{aA}
	CITH-2	11.62 ± 0.9^{dB}	11.30 ± 0.02^{cAB}	11.00 ± 0.07^{cA}	10.45 ± 0.01^{cA}	5.95 ± 0.13^{abAB}	5.10 ± 0.08^{abA}	4.70 ± 0.32^{aA}	4.25 ± 0.27^{bA}
	New Castle	14.43 ± 0.0^{eB}	13.14 ± 0.29^{dA}	13.10 ± 0.06^{dA}	12.90 ± 0.05^{dA}	5.15 ± 0.03^{aAB}	4.75 ± 0.06^{aA}	4.20 ± 0.02^{aA}	3.97 ± 0.18^{aA}

All values are mean ± standard deviation of three replicates (n = 3)

Means in the same column with different superscripts differ significantly: $^{*}P < 0.05$

Means with different superscripts in the same row indicate significant difference: $^{*}P < 0.05$

0 month of storage. Till the end of storage period of 12 months, the value of carotenoids in case of CITH-1 canned was (2.80 mg/100 g FW) and in case of CITH-2 frozen was (7.30 mg/100 g FW). The decrease may be attributed to 5, 8 epoxidation and cis-isomerisation. Similar results for decrease in carotenoids during thermal processing and drying have been reported by Beyers et al. (1979) in canned papaya and lichi, Rattanathanalerk et al. (2009) in heat treated pine apple juice, Saxena et al. (2010) in hot air dried jackfruit, Chen et al. (2007) in hot air dried mango. The degradation during canning is lesser than drying because air is removed during canning which gives more stability to carotenoids as compared to drying. Among varieties CITH-2 reported the highest carotenoid content followed by New Castle and CITH-1.

Total phenolics

Processing method, storage period and variety significantly influences total phenolic content (Table 4). On fresh weight basis, dried apricots CITH-1 reported the lowest phenolic content (180 mg GAE/kg FW) while as canned CITH-2 reported the highest (375 mg GAE/kg FW) at the 0 month of storage. The decrease in TPC at the 12 month of storage in case of CITH-1 dried was (105 mg GAE/kg FW), however CITH-2 canned retained value of (235 mg GAE/kg FW). The TPC value showed significant decrease throughout storage period in all varieties of apricots irrespective of method of processing employed. The content of phytochemicals after processing is a net result of phenomena like extractability, degradation and leaching. In canned apricots, factors like inactivation of PPO, enhanced leaching of soluble compounds and release of bound phenolics due to cell damage result in higher phenolic content than frozen apricots. Further, exclusion of oxygen in canned pulp helps in prevention of oxidative degradation of phenolics which is not the case with frozen and dried samples. In the present study, no canning medium was used and solids and liquids were combined in slurry before the extraction process. This procedure retained all the bioactive compounds that otherwise may have been lost into the medium. Similar results were reported for anthocyanin content of summer fruits and vegetables by Leong and Oey (2012). However there are numerous studies which show contradictory results. Hoffmann-Ribani et al. (2009) in pasteurized juice/pulp of acerola; Kim et al. (2009) in hot water treatment of mango; Aramwit et al. (2010) in mulberry fruit extract. Degradation of phenolic compounds occurs in presence of heat and oxygen during drying. Degradation is primary caused by oxidation, cleavage of covalent bonds on enhanced oxidation reactions (Rawson et al. 2013; Tiwari et al. 2011).

Table 4 Effect of processing methods and storage on total phenolic content (mg/100 g FW) and FRAP (mmol Fe^{2+}/100 g *FW*) of apricot cultivars

Treatment	Variety	Total phenolic content (mg GAE/kg FW)				FRAP (mmol Fe^{2+}/100 g FW)			
		Storage (months)				Storage (months)			
		0	4	8	12	0	4	8	12
Frozen	CITH-1	245 ± 0.43^{bD}	220 ± 0.21^{bC}	185 ± 0.52^{abB}	140 ± 0.42^{abA}	2.43 ± 0.25^{aBC}	2.18 ± 0.17^{aB}	1.88 ± 0.23^{aA}	1.63 ± 0.13^{aA}
	CITH-2	335 ± 0.35^{dD}	310 ± 0.42^{cC}	260 ± 0.32^{cB}	215 ± 0.33^{cA}	2.71 ± 0.22^{aD}	2.42 ± 0.22^{aBC}	2.12 ± 0.14^{aB}	1.86 ± 0.10^{aA}
	New Castle	275 ± 0.32^{cD}	235 ± 0.41^{bC}	195 ± 0.42^{abB}	150 ± 0.43^{bA}	2.55 ± 0.12^{aBC}	2.21 ± 0.26^{aB}	1.93 ± 0.12^{aA}	1.71 ± 0.22^{aA}
Canned	CITH-1	280 ± 0.43^{cD}	235 ± 0.36^{bC}	195 ± 0.63^{abB}	155 ± 0.44^{bA}	2.92 ± 0.23^{abC}	2.65 ± 0.17^{abAB}	2.28 ± 0.24^{abA}	2.15 ± 0.17^{bA}
	CITH-2	375 ± 0.44^{dD}	330 ± 0.63^{cC}	280 ± 0.44^{cB}	235 ± 0.53^{cA}	3.260 ± 0.14^{bC}	2.92 ± 0.19^{bB}	2.66 ± 0.11^{bcA}	2.35 ± 0.16^{bcA}
	New Castle	320 ± 0.26^{dD}	295 ± 0.42^{cC}	240 ± 0.34^{cB}	130 ± 0.47^{aA}	3.02 ± 0.16^{bBC}	2.81 ± 0.12^{bB}	2.47 ± 0.15^{bA}	2.20 ± 0.11^{bA}
Dried	CITH-1	180 ± 0.53^{aD}	145 ± 0.32^{aC}	120 ± 0.47^{aB}	105 ± 0.42^{aA}	2.76 ± 0.10^{aBC}	2.58 ± 0.16^{abAB}	2.37 ± 0.22^{abA}	1.94 ± 0.18^{abA}
	CITH-2	210 ± 0.55^{abD}	165 ± 0.21^{aC}	145 ± 0.18^{aB}	125 ± 0.41^{aA}	2.94 ± 0.21^{abBC}	2.77 ± 0.10^{bAB}	2.54 ± 0.17^{bA}	2.25 ± 0.15^{bA}
	New Castle	195 ± 0.17^{aD}	155 ± 0.23^{aC}	140 ± 0.43^{aB}	110 ± 0.55^{aA}	2.82 ± 0.15^{abBC}	2.64 ± 0.17^{abB}	2.39 ± 0.11^{abA}	2.12 ± 0.12^{bA}

All values are mean ± standard deviation of three replicates (n = 3)

Means in the same column with different superscripts differ significantly: $^{*}P < 0.05$

Means with different superscripts in the same row indicate significant difference: $^{*}P < 0.05$

FRAP

Data pertaining to Ferric Reducing Antioxidant power of three apricot varieties processed by the methods of freezing, canning and drying and stored for a period of 12 months is presented in Table 4. Lowest FRAP value was reported in frozen CITH-1(2.43 mmol Fe^{2+}/100 g FW) while as CITH-2 canned showed the highest FRAP value of (3.26 mmol Fe^{2+}/100 g FW) during 0 month of storage. At the 12 month of storage the value of (1.63 mmol Fe^{2+}/100 g FW) was reported in CITH-1 frozen apricot and the value of (2.35 mmol Fe^{2+}/100 g *FW*) was recorded for CITH-2 dried apricot. Canned apricots showed higher FRAP value than frozen and dried apricots. Though there is degradation of bioactive compounds responsible for antioxidant activity, several factors result in increase in antioxidant activity. Enhanced leaching of soluble compounds, release of bound bioactives and conversion of native phytochemical substances into more active ones increase antioxidant activity. In dried apricots, there is generation of chemical species with antioxidant properties; degradation is more pronounced than canned apricots due to availability of oxygen during drying process. There is a steady decrease in antioxidant activity during storage of 12 months in all types of processed apricots. FRAP values in the similar range for apricots have been reported by Reddy et al. (2010) and Leong and Oey (2012).

DPPH radical scavenging activity

Scavenging activity of DPPH radicals varied significantly with variety, processing method and storage of 12 months (Table 5). The results obtained for DPPH radical scavenging activity for all varieties showed a significant decrease throughout storage in all processing methods. The highest radical scavenging activity was recorded in case of canned CITH-2 (46.45%) and lowest activity was observed in frozen CITH-1 (32.21%) at the beginning of storage. At the 12 month of storage lowest radical scavenging activity was recorded in frozen CITH-1 (21.40%) while highest scavenging activity was recorded in canned CITH-2 (37.42%). There are natural variations within varieties in terms of phytochemical profile. Among processing methods, canned apricots showed the maximum activity followed by dried apricots while frozen apricots showed the minimum. All processed apricot varieties showed a significant decrease in DPPH radical scavenging activity during the storage period of 12 months. During canning there is release of bound bioactive compounds and enhanced leaching as a result of tissue damage, which can be responsible for higher activity despite degradation losses of radical scavenging species at high temperature.

Table 5 Effect of processing methods and storage on DPPH (% inhibition) and metal chelation (%) of apricot cultivars

Treatment	Variety	DPPH (%)				Metal chelation (%)			
		Storage (months)				Storage (months)			
		0	4	8	12	0	4	8	12
Frozen	CITH-1	32.21 ± 0.23^{aD}	27.24 ± 0.36^{aC}	24.22 ± 0.57^{aB}	21.40 ± 0.64^{aA}	56.14 ± 0.23^{aD}	51.24 ± 0.22^{aC}	47.55 ± 0.06^{aB}	44.10 ± 0.47^{aA}
	CITH-2	41.20 ± 0.91^{eD}	35.09 ± 0.50^{dC}	32.24 ± 0.49^{dB}	28.22 ± 0.47^{cA}	63.78 ± 0.14^{cdD}	57.85 ± 0.37^{eC}	54.16 ± 0.08^{dB}	51.52 ± 0.24^{dA}
	New Castle	36.00 ± 0.66^{cD}	32.44 ± 0.72^{cBC}	30.18 ± 0.37^{cB}	25.14 ± 0.16^{bA}	60.23 ± 0.25^{bD}	54.63 ± 0.38^{cC}	49.73 ± 0.11^{bB}	46.37 ± 0.34^{bA}
Canned	CITH-1	35.24 ± 0.61^{bD}	32.21 ± 0.25^{cBC}	30.51 ± 0.42^{cB}	27.21 ± 0.89^{cA}	57.72 ± 0.33^{aD}	52.81 ± 0.18^{abC}	48.18 ± 0.30^{aB}	45.59 ± 0.29^{abA}
	CITH-2	46.45 ± 0.40^{fD}	42.18 ± 0.40^{fC}	39.43 ± 0.55^{efAB}	37.42 ± 0.32^{gA}	66.14 ± 0.13^{eD}	62.13 ± 0.17^{gC}	59.27 ± 0.32^{fB}	55.73 ± 0.25^{eA}
	New Castle	39.33 ± 0.58^{dD}	36.08 ± 0.48^{dC}	33.33 ± 1.19^{dAB}	31.14 ± 0.77^{eA}	62.51 ± 0.32^{cD}	55.74 ± 0.23^{dC}	50.96 ± 0.31^{bB}	48.28 ± 0.17^{cA}
Dried	CITH-1	33.12 ± 0.12^{aC}	30.07 ± 0.32^{bB}	28.21 ± 1.01^{bA}	26.11 ± 0.26^{bA}	57.08 ± 0.26^{aD}	53.30 ± 0.15^{bC}	$51.22 \pm 0.17b^{cB}$	48.40 ± 0.54^{cA}
	CITH-2	43.31 ± 0.42^{eC}	39.22 ± 0.33^{eB}	37.34 ± 0.73^{eB}	33.12 ± 0.22^{efA}	64.34 ± 0.24^{dD}	59.63 ± 0.17^{fC}	56.17 ± 0.16^{eB}	52.14 ± 0.21^{dA}
	New Castle	37.18 ± 0.63^{cD}	35.32 ± 0.17^{dC}	32.20 ± 0.66^{dB}	29.20 ± 0.87^{dA}	60.91 ± 0.20^{bD}	57.21 ± 0.16^{eC}	54.83 ± 0.24^{dB}	51.60 ± 0.18^{dA}

All values are mean ± standard deviation of three replicates (n = 3)

Means in the same column with different superscripts differ significantly: $^{*}P < 0.05$

Means with different superscripts in the same row indicate significant difference: $^{*}P < 0.05$

Although there is loss of phytochemicals at high temperature and in presence of oxygen during drying, formation of melanoidins, which show radical scavenging properties, result in higher activity than frozen apricots. Carotenoids undergo isomerization resulting predominantly cis-form which has greater radical scavenging property. Several studies have reported results in agreement with our findings (Madrau et al. 2009; Touati et al. 2013). Madrau et al. (2009) similarly determined increased antioxidant activity values in dried apricots.

Metal chelating activity

Metal species like Fe^{2+} can facilitate lipid peroxidation and generation of ROS, hence ability to chelate such metals can be a valuable antioxidant capacity. Among the studied varieties, CITH-2 canned showed highest value of 51.52% and lowest value for the metal chelating activity was recorded in dried CITH-1 (57.08%) at the 0 month of storage. At the end of storage period (12 month), highest value for metal chelating activity was recorded CITH-2 (55.73%) and lowest value for chelating activity was recorded in CITH-1 frozen (44.10%). Metal chelating activity followed the same decreasing trend as was recorded for DPPH radical activity during storage. Several factors act together during processing and resultant antioxidant activities are obtained. There is degradation of bioactive substances like ascorbic acid, polyphenols and carotenoids by different mechanisms like oxidation, isomerization and ring cleavage. Simultaneously enhanced leaching, release of bound substances, generation of novel chemical species with bioactivity enhance the antioxidant potential. Degradations are governed by processing conditions like temperature, availability of oxygen etc. During canning, although there is high temperature but exclusion of oxygen results in lesser degradation than drying. However, drying results in generation of metal chelating species. There is continuous decrease in antioxidant activity during storage in all processed apricots. Touati et al. (2013) have reported similar results.

Conclusion

The study reveals that apricot pulp is suitable for processing by freezing and canning. These processed products can be utilized by the industry as raw material during the period of year when fresh apricots are not available. Apricot pulp retains most of its nutritional and antioxidant properties during processing and storage up to 12 months.

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