

# Nutritional characterization of apple as a function of genotype

Pushendra Kumar<sup>1</sup> · Shruti Sethi<sup>1</sup> · R. R. Sharma<sup>1</sup> · Surender Singh<sup>2</sup> ·  
Supradip Saha<sup>3</sup> · V. K. Sharma<sup>4</sup> · M. K. Verma<sup>5</sup> · Shashi Kumar Sharma<sup>6</sup>

Revised: 25 April 2018 / Accepted: 27 April 2018 / Published online: 9 May 2018  
© Association of Food Scientists & Technologists (India) 2018

**Abstract** Twenty two apple cultivars grown in Himachal Pradesh, India were harvested at commercial maturity and analysed for different physical (fruit weight, fruit dimensions, firmness, color) and nutritional attributes (ascorbic acid, antioxidant activity, total carotenoid, sugars, organic acids, phenolic compounds and minerals). Cultivar ‘Oregon Spur II’ was found to have maximum fruit size and weight while the least was observed for cultivar ‘Starkrimson’. Quantitative differences were found in the nutritional profile among the cultivars with respect to all the above attributes. The ascorbic acid content ranged between 19.38 mg 100 g<sup>-1</sup> (‘Well Spur’) and 32.08 mg 100 g<sup>-1</sup> (‘Starkrimson’) while the antioxidant activity varied between 2.64 μmol Trolox equivalent g<sup>-1</sup> (‘Granny Smith’) and 13.20 μmol Trolox equivalent g<sup>-1</sup> (‘Silver Spur’). The highest total carotenoid was found in ‘Red Chief’ (147.06 mg kg<sup>-1</sup>) while in ‘Early Red-I’ the total

carotenoid was only 29.03 mg kg<sup>-1</sup>. HPLC analysis for individual sugars, organic acids and phenolic compounds was carried out. Fructose (average 50.79 g L<sup>-1</sup>) was the most abundant sugar. Malic acid (average 6.03 mg L<sup>-1</sup>) predominated among the individual organic acids. Potassium (average 795.14 mg 100 g<sup>-1</sup>) and iron (average 2.04 μg g<sup>-1</sup>) were the predominant macro and micro elements, respectively. Chlorogenic acid was the major constituent among phenolic compounds.

**Keywords** Apple cultivars · Chemical composition · Malic acid · Phenolic compounds

## Introduction

Apple is the most popular temperate fruit in the world because of its crispy texture and sweet taste. India is the 5th largest producer of apples in the world, where it is commercially grown in states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Apples form an important part of human diet as they are a rich source of sugars, minerals, dietary fibre and functional compounds such as ascorbic acid and phenolics (Bondonno et al. 2017; Wu et al. 2007). The quality and consumer acceptability of apples is associated with their overall sensory appeal and chemical composition (Musacchi and Serra 2017; Alberti et al. 2017). Differences in the relative concentrations of individual components in different cultivars may occur depending on the fruit maturity, environmental factors, horticultural practices applied in the orchard and storage conditions (Musacchi and Serra 2017).

Sugars, organic acids and phenolic compounds, the major compounds in apple, impart taste characteristics, such as flavour, bitterness and astringency to the fruits

✉ Shruti Sethi  
docsethi@gmail.com

<sup>1</sup> Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India  
<sup>2</sup> Division of Microbiology, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India  
<sup>3</sup> Division of Agricultural Chemicals, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India  
<sup>4</sup> Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India  
<sup>5</sup> Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India  
<sup>6</sup> Regional Horticultural Research Station, Reckong Peo, Kinnaur, HP, India

(Mihailović et al. 2018). The sugar profiling of fruits can give valuable information on the quality of fruit juices extracted from them as it affects the sensory properties and nutritional value of the juices (Wu et al. 2007). The content of organic acids in the extracted apple juice not only influences the flavour but also the stability, nutritive value, acceptability and keeping quality of the juice. Besides their importance in flavour, acids are also important in the gelling property of pectin required in processed apple products. Phenolic compounds considered as anti-mutagenic, antioxidant, anti-inflammatory and anti-carcinogenic (Alberti et al. 2017), are associated with browning processes in apple, with a low level being more desirable. The type and concentration of phenolic compound in any fruit depends on its cultivar (Alberti et al. 2017; Ayaz and Kadioglu 1997). Furthermore, mineral composition of any fruit is equally important as minerals are considered essential in regulation of several body functions (Cindric et al. 2012). Some minerals may even affect the ripening behaviour and disease incidence in fruits.

Cultivar specific profiling of sugars, organic acids, phenolic compounds and minerals of apple cultivars grown in India have not been investigated till now. Hence, the present study was conducted to comprehensively analyze and compare the chemical composition of selected apple cultivars grown in Indian conditions. Based on the nutritional profiling, some of these cultivars may be found to be suitable for table consumption, juice production and/or for development of minimally processed apple slices.

## Materials and methods

### Sampling

Twenty two apple cultivars including five non-red viz., ‘Golden Delicious’, ‘Granny Smith’, ‘Winter Banana’, ‘Goldspur’ and ‘Starkspur Golden’ and seventeen red viz., ‘Royal Delicious’, ‘Top Red’, ‘Oregon Spur-II’, ‘Starkrimson’, ‘Well Spur’, ‘Red Chief’, ‘Super Chief’, ‘Red Gold’, ‘Royal Gala’, ‘Scarlet Spur-II’, ‘Scarlet Gala’, ‘Early Red-I’, ‘Gale Gala’, ‘Spartan’, ‘Vance Delicious’, ‘Silver Spur’ and ‘Red Delicious’ were procured from Horticulture Research Station, YSPUH&F, Seobagh, Kullu Valley, Himachal Pradesh, India. The orchard is located at a height of 1290 msl (31°58′56″ longitude and 77°7′48″ latitude). The apples were harvested in 2017 at commercial maturity, having starch pattern index (SPI) of 3.0. The starch pattern index (SPI) was determined according to the method of Fan et al. (1995) by immersing the cross section of apple in I<sub>2</sub>-KI solution. After harvesting and sorting, the fruits were packed in cartons, transported to New Delhi and stored at 2 °C with 80–90% relative humidity at the

Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi, for further observations. The physical and nutritional attributes were determined in 10 randomly selected fruits of each cultivar.

### Determination of physical attributes

#### *Fruit weight and dimensions*

Fruit weight was recorded with the help of an electronic balance (Make: Precisa 310 M, Adair Dutt & Co. Pvt Ltd., Calcutta). Measurement of the fruit dimensions of different cultivars of apple was done using a vernier calliper (Mityoto, Japan). To determine the average size of the fruits, three linear dimensions, namely length (L)—equivalent distance of the stem to the calyx, width (W)—the longest dimension perpendicular to L, and thickness (T)—the longest dimension perpendicular to L and W, were measured. The geometric mean diameter ( $D_g$ ) and arithmetic mean diameter ( $D_a$ ) were calculated using the following equations (Mohsenin 1986):

$$D_g = \sqrt[3]{LWT}$$

$$D_a = (L + W + T)/3$$

#### *Fruit firmness*

Fruit firmness (expressed in Newtons) was determined using a texture analyzer (model: TA+Di, Stable micro systems, UK) with a pre-test speed of 2 mm/sec and test speed of 0.5 mm/sec and was defined as maximum force attained during puncture by 2 mm probe upto a distance of 5 mm.

#### *Peel colour*

Peel colour was determined using Hunter Lab System (model: Miniscan XE PLUS). The colour value was expressed as L\*, a\* and b\* values where L\* is a measure of lightness, positive values of a\* indicate redness and negative values complement green. Positive values of b\* are the vector for yellowness and negative for blueness.

### Estimation of nutritional attributes

*Soluble solid content (SSC), titratable acidity, total carotenoid, ascorbic acid content and antioxidant (AOX) activity*

The soluble solid content (SSC) of samples was estimated using hand refractometer (0–50 °B, ATAGO make) and

expressed as degree Brix ( $^{\circ}\text{B}$ ) at  $20^{\circ}\text{C}$ . Titratable acidity, ascorbic acid and total carotenoid content of the apple fruits were determined as per the standard procedures and denoted as percentage (%),  $\text{mg } 100 \text{ g}^{-1}$  pulp and  $\text{mg kg}^{-1}$ , respectively (Ranganna 1999). Antioxidant activity (AOX) in the apple fruits was determined by the cupric ion reducing antioxidant capacity (CUPRAC) method (Apak et al. 2004), and expressed as  $\mu\text{mol Trolox equivalent g}^{-1}$  FW. One mL each of copper (II) chloride, neocuproine and ammonium acetate buffer (pH 7) were mixed with the alcoholic extract of the sample (100  $\mu\text{L}$ ) and the developed colour was measured after 30 min of incubation in a spectrophotometer (Spectra Max M2, Molecular Devices, USA) at 450 nm.

#### *Sugars and organic acids*

The sugars and organic acids were estimated by high performance liquid chromatography (Wu et al. 2007). Fresh sample of apple fruit (5 g) was homogenized in distilled water and filtered through 0.45  $\mu\text{m}$  membrane filter. The filtrate was injected in HPLC for analysis. Standards of sugars and organic acids were procured from Sigma-Aldrich. Waters high performance liquid chromatography consisting of binary pump model 515, 2414 refractive index (RI) and 2998 photodiode array (PDA) detector was used for all analysis. Sugars and organic acids in aqueous phase were quantified by using Aminex HPX-87H (Bio-Rad Laboratories, Hercules, CA) column operated with 5 mM  $\text{H}_2\text{SO}_4$  as mobile phase at a flow rate of  $0.5 \text{ mL min}^{-1}$  with the oven temperature at  $50^{\circ}\text{C}$  using both detectors in series (PDA @ 210 nm). The concentration of sugars and organic acids in the apple cultivars were expressed as  $\text{g L}^{-1}$ .

#### *Phenolic compounds*

Extraction of phenolic compounds from fresh apples was carried out by following the procedure of Wu et al. (2007). Ten gram sample was extracted twice with 20 ml of ethyl acetate. The obtained fractions were pooled and evaporated to dryness and the residue was dissolved in 1.0 ml of methanol (HPLC grade). The resultant solution was filtered through a 0.45  $\mu\text{m}$  membrane filter prior to HPLC analysis. A 20  $\mu\text{L}$  volume of each sample was manually injected into the Water Alliance HPLC System (Waters Chromatography, Milford, MA). C18 column (5  $\mu\text{m}$ ,  $4.6 \times 250 \text{ mm}$ ) was used to estimate the individual phenolic components. The HPLC components include e2695 separation module and the 2996 photodiode array detector and the system was operated with Empower 2 Software (Waters Corporation). The mobile phase consisted of solvent A (water 0.1% formic acid), solvent B (acetonitrile

0.1% formic acid) with gradient programming of 100% A to 100% B and total run time of 55 min. and flow rate of  $0.5 \text{ mL min}^{-1}$ . The phenolic compounds peaks were detected at 280 nm, and expressed as  $\text{mL L}^{-1}$ .

#### *Macro and micro elements*

For estimation of macro and micro elements, fruit sample (1 g) was digested in a microwave digestion system (Anton Par: Multiwave ECO) with concentrated nitric acid (Suprapur grade, Merck, Germany) and diluted to 100 ml. The element concentrations were analyzed using ICP-MS with auto-sampling protocol (Perkin Elmer, Model: NexION 300 ICP-MS) and computed as  $\text{mg } 100 \text{ g}^{-1}$  for macro elements and  $\mu\text{g g}^{-1}$  for micro elements.

#### **Statistical analysis**

The results were statistically evaluated by one way analysis of variance (ANOVA). The data were expressed as mean  $\pm$  SEM of triplicate analysis. Significant difference amongst the means was determined by Duncan's Multiple Range Test.

## **Results and discussion**

### **Fruit weight, dimensions, firmness and peel colour**

Physical characteristics of horticultural produce are important parameters for design of grading, conveying, processing, and packaging systems (Tabatabaefar and Rajabipour 2005). Appearance of fruit is the first and one of the most purchasing driving trait that influence the consumers decision for consumption that is basically manifested by different external characteristics of fruit such as colour, size and shape. Dimensional attributes of various cultivars can be used in describing the fruit shape and cultivar descriptions (Beyer et al. 2002). Of the twenty two cultivars studied, more than 200 g fruit weight was observed for red cultivar 'Oregon Spur II' (202.68 g) which also had maximum geometric mean (77.23 mm) and arithmetic mean diameter (77.46 mm), indicating the bigger size of the fruits. In contrast, 'Starkrimson' had the least fruit weight (107.41 g), geometric mean (61.33 mm) and arithmetic mean diameter (61.74 mm) (Table 1). This variation in fruit weight might be due to varietal differences as every variety has specific shape, colour and size. Péroumal et al. (2017) have also reported that the average fruit weight of six mamey apple accessions significantly varied from one to another.

Fruit firmness is one of the most important quality characteristics of any fruit which governs the consumer

**Table 1** Physical attributes of different apple cultivars

Cultivar	Fruit weight (g)			Fruit dimension (mm)			Arithmetic mean diameter	Firmness (N)	Colour		
	Width	Length	Geometric mean diameter	Width	Length	Geometric mean diameter			L*	a*	b*
<i>Non-red cultivars</i>											
Golden Delicious	133.40 ± 1.84 <sup>k</sup>	69.71 ± 1.51 <sup>ih</sup>	66.17 ± 0.71 <sup>hij</sup>	66.35 ± 1.22 <sup>ihj</sup>	59.63 ± 0.34 <sup>g</sup>	66.17 ± 0.71 <sup>hij</sup>	66.35 ± 1.22 <sup>ihj</sup>	11.25 ± 0.08 <sup>edf</sup>	68.24 ± 1.10 <sup>c</sup>	- 8.76 ± 0.03 <sup>n</sup>	40.06 ± 0.48 <sup>c</sup>
Granny Smith	175.00 ± 3.07 <sup>d</sup>	73.86 ± 0.80 <sup>ed</sup>	71.05 ± 0.79 <sup>c</sup>	71.16 ± 0.80 <sup>d</sup>	65.76 ± 0.17 <sup>d</sup>	71.05 ± 0.79 <sup>c</sup>	71.16 ± 0.80 <sup>d</sup>	12.69 ± 0.10 <sup>b</sup>	61.72 ± 0.66 <sup>le</sup>	11.40 ± 0.05 <sup>o</sup>	41.17 ± 0.37 <sup>b</sup>
Winter Banana	131.24 ± 0.21 <sup>l</sup>	68.24 ± 1.08 <sup>ijk</sup>	65.04 ± 1.17 <sup>ikj</sup>	65.19 ± 0.63 <sup>ikj</sup>	59.08 ± 0.60 <sup>g</sup>	65.04 ± 1.17 <sup>ikj</sup>	65.19 ± 0.63 <sup>ikj</sup>	14.00 ± 0.24 <sup>a</sup>	74.87 ± 1.09 <sup>a</sup>	- 9.22 ± 0.07 <sup>n</sup>	39.70 ± 0.14 <sup>c</sup>
Goldspur	131.42 ± 1.38 <sup>lk</sup>	70.49 ± 0.78 <sup>ihg</sup>	67.01 ± 0.76 <sup>hifgi</sup>	67.18 ± 1.17 <sup>igh</sup>	60.56 ± 0.93 <sup>leg</sup>	67.01 ± 0.76 <sup>hifgi</sup>	67.18 ± 1.17 <sup>igh</sup>	10.90 ± 0.08 <sup>hgf</sup>	69.36 ± 0.94 <sup>c</sup>	- 8.03 ± 0.08 <sup>m</sup>	41.27 ± 0.26 <sup>b</sup>
Starkspur Golden	134.04 ± 2.25 <sup>k</sup>	71.79 ± 0.29 <sup>ehgf</sup>	68.54 ± 0.73 <sup>dfige</sup>	68.69 ± 0.85 <sup>eghf</sup>	62.48 ± 0.61 <sup>le</sup>	68.54 ± 0.73 <sup>dfige</sup>	68.69 ± 0.85 <sup>eghf</sup>	10.53 ± 0.06 <sup>hi</sup>	72.15 ± 0.82 <sup>b</sup>	- 9.21 ± 0.09 <sup>n</sup>	42.66 ± 0.52 <sup>a</sup>
<i>Red cultivars</i>											
Royal Delicious	165.32 ± 2.02 <sup>leg</sup>	76.42 ± 0.51 <sup>eb</sup>	73.58 ± 0.86 <sup>b</sup>	73.68 ± 0.40 <sup>c</sup>	68.21 ± 0.82 <sup>eb</sup>	73.58 ± 0.86 <sup>b</sup>	73.68 ± 0.40 <sup>c</sup>	10.72 ± 0.16 <sup>hgi</sup>	54.94 ± 0.06 <sup>h</sup>	15.20 ± 0.13 <sup>i</sup>	26.15 ± 0.07 <sup>i</sup>
Top Red	170.30 ± 2.48 <sup>d</sup>	78.50 ± 0.77 <sup>b</sup>	76.28 ± 0.52 <sup>a</sup>	76.34 ± 1.27 <sup>ba</sup>	72.02 ± 0.46 <sup>a</sup>	76.28 ± 0.52 <sup>a</sup>	76.34 ± 1.27 <sup>ba</sup>	12.64 ± 0.05 <sup>b</sup>	49.46 ± 0.39 <sup>ji</sup>	18.24 ± 0.26 <sup>bg</sup>	21.79 ± 0.27 <sup>kj</sup>
Oregon Spur II	202.68 ± 1.23 <sup>a</sup>	81.61 ± 0.15 <sup>a</sup>	77.23 ± 1.27 <sup>a</sup>	77.46 ± 0.24 <sup>a</sup>	69.17 ± 0.68 <sup>b</sup>	77.23 ± 1.27 <sup>a</sup>	77.46 ± 0.24 <sup>a</sup>	11.63 ± 0.13 <sup>d</sup>	45.69 ± 0.81 <sup>k</sup>	21.32 ± 0.21 <sup>f</sup>	18.30 ± 0.16 <sup>mm</sup>
Starkrimson	107.41 ± 1.70 <sup>n</sup>	66.61 ± 0.51 <sup>jk</sup>	61.33 ± 0.56 <sup>l</sup>	61.74 ± 0.55 <sup>l</sup>	51.99 ± 0.54 <sup>h</sup>	61.33 ± 0.56 <sup>l</sup>	61.74 ± 0.55 <sup>l</sup>	10.37 ± 0.15 <sup>i</sup>	54.31 ± 0.75 <sup>h</sup>	15.56 ± 0.29 <sup>j</sup>	22.60 ± 0.17 <sup>j</sup>
Well Spur	168.82 ± 1.99 <sup>e</sup>	72.50 ± 0.25 <sup>ef</sup>	70.11 ± 0.91 <sup>dce</sup>	70.19 ± 1.42 <sup>edf</sup>	65.57 ± 0.60 <sup>d</sup>	70.11 ± 0.91 <sup>dce</sup>	70.19 ± 1.42 <sup>edf</sup>	12.08 ± 0.22 <sup>c</sup>	55.52 ± 0.06 <sup>h</sup>	11.25 ± 0.06 <sup>j</sup>	27.06 ± 0.45 <sup>h</sup>
Red Chief	145.72 ± 0.84 <sup>j</sup>	73.09 ± 1.69 <sup>edf</sup>	70.43 ± 0.71 <sup>dc</sup>	70.52 ± 0.44 <sup>ed</sup>	65.39 ± 1.53 <sup>d</sup>	70.43 ± 0.71 <sup>dc</sup>	70.52 ± 0.44 <sup>ed</sup>	12.33 ± 0.18 <sup>eb</sup>	47.89 ± 0.85 <sup>j</sup>	18.00 ± 0.12 <sup>h</sup>	20.79 ± 0.06 <sup>l</sup>
Super Chief	151.06 ± 2.05 <sup>i</sup>	70.93 ± 0.74 <sup>hgf</sup>	68.08 ± 1.31 <sup>hdfige</sup>	68.20 ± 0.26 <sup>eghf</sup>	62.73 ± 0.48 <sup>e</sup>	68.08 ± 1.31 <sup>hdfige</sup>	68.20 ± 0.26 <sup>eghf</sup>	11.09 ± 0.15 <sup>esf</sup>	45.81 ± 0.13 <sup>k</sup>	22.08 ± 0.27 <sup>e</sup>	17.67 ± 0.25 <sup>n</sup>
Red Gold	159.66 ± 1.30 <sup>g</sup>	73.17 ± 0.95 <sup>edf</sup>	69.35 ± 0.78 <sup>dice</sup>	69.54 ± 0.39 <sup>egdf</sup>	62.29 ± 1.36 <sup>le</sup>	69.35 ± 0.78 <sup>dice</sup>	69.54 ± 0.39 <sup>egdf</sup>	10.92 ± 0.17 <sup>hgf</sup>	62.95 ± 1.12 <sup>e</sup>	7.32 ± 0.09 <sup>k</sup>	32.02 ± 0.25 <sup>f</sup>
Royal Gala	195.82 ± 4.10 <sup>b</sup>	72.86 ± 0.72 <sup>egf</sup>	70.32 ± 0.72 <sup>dc</sup>	70.40 ± 1.55 <sup>ed</sup>	65.49 ± 0.45 <sup>d</sup>	70.32 ± 0.72 <sup>dc</sup>	70.40 ± 1.55 <sup>ed</sup>	11.11 ± 0.01 <sup>egf</sup>	63.19 ± 0.32 <sup>e</sup>	27.45 ± 0.19 <sup>b</sup>	29.83 ± 0.21 <sup>g</sup>
Scarlet Spur-II	163.52 ± 1.43 <sup>fg</sup>	71.25 ± 0.56 <sup>hgf</sup>	68.23 ± 0.68 <sup>hdfige</sup>	68.35 ± 0.87 <sup>eghf</sup>	62.56 ± 0.49 <sup>le</sup>	68.23 ± 0.68 <sup>hdfige</sup>	68.35 ± 0.87 <sup>eghf</sup>	11.45 ± 0.13 <sup>ed</sup>	44.33 ± 0.64 <sup>k</sup>	24.39 ± 0.39 <sup>c</sup>	18.89 ± 0.14 <sup>m</sup>
Scarlet Gala	134.96 ± 1.36 <sup>k</sup>	69.77 ± 0.51 <sup>ih</sup>	67.07 ± 0.72 <sup>hifig</sup>	67.17 ± 0.78 <sup>igh</sup>	61.98 ± 0.40 <sup>le</sup>	67.07 ± 0.72 <sup>hifig</sup>	67.17 ± 0.78 <sup>igh</sup>	10.52 ± 0.23 <sup>hi</sup>	60.87 ± 0.83 <sup>f</sup>	27.94 ± 0.34 <sup>b</sup>	33.42 ± 0.21 <sup>e</sup>
Early Red-I	120.68 ± 1.01 <sup>m</sup>	65.92 ± 0.39 <sup>lk</sup>	64.68 ± 0.69 <sup>kl</sup>	64.71 ± 0.63 <sup>kl</sup>	62.28 ± 0.25 <sup>le</sup>	64.68 ± 0.69 <sup>kl</sup>	64.71 ± 0.63 <sup>kl</sup>	11.04 ± 0.13 <sup>gf</sup>	47.89 ± 0.69 <sup>j</sup>	18.00 ± 0.34 <sup>h</sup>	20.79 ± 0.20 <sup>l</sup>
Gale Gala	141.01 ± 2.21 <sup>k</sup>	70.60 ± 1.14 <sup>ihg</sup>	66.32 ± 1.25 <sup>higj</sup>	66.58 ± 1.07 <sup>ihj</sup>	58.53 ± 0.87 <sup>g</sup>	66.32 ± 1.25 <sup>higj</sup>	66.58 ± 1.07 <sup>ihj</sup>	11.46 ± 0.09 <sup>ed</sup>	38.52 ± 0.69 <sup>m</sup>	30.59 ± 0.42 <sup>a</sup>	15.76 ± 0.16 <sup>o</sup>
Spartan	157.35 ± 1.84 <sup>b</sup>	75.40 ± 0.67 <sup>cd</sup>	70.12 ± 0.52 <sup>dce</sup>	70.48 ± 0.16 <sup>ed</sup>	60.64 ± 0.95 <sup>leg</sup>	70.12 ± 0.52 <sup>dce</sup>	70.48 ± 0.16 <sup>ed</sup>	12.39 ± 0.05 <sup>cb</sup>	65.33 ± 0.51 <sup>d</sup>	- 2.51 ± 0.04 <sup>l</sup>	36.78 ± 0.17 <sup>d</sup>
Vance Delicious	166.48 ± 1.96 <sup>fe</sup>	68.42 ± 0.81 <sup>ij</sup>	67.92 ± 0.87 <sup>hfige</sup>	67.93 ± 0.68 <sup>ghf</sup>	66.94 ± 1.38 <sup>ed</sup>	67.92 ± 0.87 <sup>hfige</sup>	67.93 ± 0.68 <sup>ghf</sup>	10.44 ± 0.12 <sup>i</sup>	50.78 ± 0.45 <sup>i</sup>	18.70 ± 0.28 <sup>g</sup>	21.71 ± 0.07 <sup>k</sup>
Silver Spur	185.47 ± 1.91 <sup>c</sup>	80.23 ± 0.70 <sup>b</sup>	76.71 ± 0.60 <sup>b</sup>	76.86 ± 0.26 <sup>bc</sup>	70.12 ± 0.76 <sup>d</sup>	76.71 ± 0.60 <sup>b</sup>	76.86 ± 0.26 <sup>bc</sup>	10.32 ± 0.12 <sup>j</sup>	41.8 ± 0.61 <sup>l</sup>	23.55 ± 0.21 <sup>d</sup>	13.79 ± 0.29 <sup>p</sup>
Red Delicious	142.00 ± 2.99 <sup>k</sup>	64.13 ± 0.95 <sup>l</sup>	62.85 ± 0.52 <sup>lk</sup>	62.88 ± 0.55 <sup>lk</sup>	60.37 ± 0.60 <sup>fg</sup>	62.85 ± 0.52 <sup>lk</sup>	62.88 ± 0.55 <sup>lk</sup>	12.35 ± 0.11 <sup>cb</sup>	58.17 ± 0.63 <sup>g</sup>	11.57 ± 0.19 <sup>j</sup>	30.16 ± 0.66 <sup>g</sup>
Average	154.04 ± 1.11	71.98 ± 0.48	68.88 ± 0.48	69.03 ± 0.48	63.14 ± 0.45	68.88 ± 0.48	69.03 ± 0.48	11.47 ± 0.08	56.08 ± 0.41	11.91 ± 0.13	27.83 ± 0.17

Results as mean ± SE of triplicate measurements. Means with same superscript in the same column are not significantly different

**Table 2** Composition of different apple cultivars

Cultivar	SSC (°B)	Titrateable acidity (% malic acid)	Ascorbic acid (mg 100 g <sup>-1</sup> )	Total antioxidant (µmole Trolox g <sup>-1</sup> )	Total carotenoids (mg kg <sup>-1</sup> )
<i>Non-red cultivars</i>					
Golden Delicious	13.50 ± 0.20 <sup>c</sup>	0.54 ± 0.00 <sup>fe</sup>	21.60 ± 0.33 <sup>h</sup>	6.45 ± 0.06 <sup>h</sup>	100.62 ± 0.75 <sup>d</sup>
Granny Smith	12.00 ± 0.08 <sup>g</sup>	0.54 ± 0.00 <sup>b</sup>	20.00 ± 0.17 <sup>i</sup>	2.64 ± 0.02 <sup>n</sup>	32.90 ± 0.11 <sup>p</sup>
Winter Banana	11.00 ± 0.11 <sup>h</sup>	0.67 ± 0.00 <sup>a</sup>	21.39 ± 0.27 <sup>h</sup>	10.57 ± 0.19 <sup>c</sup>	79.34 ± 0.46 <sup>h</sup>
Goldspur	11.00 ± 0.09 <sup>h</sup>	0.54 ± 0.00 <sup>c</sup>	20.19 ± 0.24 <sup>i</sup>	6.64 ± 0.08 <sup>g</sup>	42.57 ± 0.66 <sup>n</sup>
Starkspur Golden	12.50 ± 0.22 <sup>f</sup>	0.67 ± 0.00 <sup>ba</sup>	21.18 ± 0.25 <sup>h</sup>	6.01 ± 0.10 <sup>ij</sup>	44.51 ± 0.15 <sup>m</sup>
<i>Red cultivars</i>					
Royal Delicious	13.20 ± 0.17 <sup>dc</sup>	0.27 ± 0.00 <sup>j</sup>	21.18 ± 0.28 <sup>h</sup>	5.56 ± 0.08 <sup>kl</sup>	46.44 ± 0.60 <sup>l</sup>
Top Red	12.70 ± 0.08 <sup>fe</sup>	0.54 ± 0.00 <sup>e</sup>	25.37 ± 0.08 <sup>ed</sup>	7.11 ± 0.03 <sup>g</sup>	90.95 ± 0.91 <sup>e</sup>
Oregon Spur II	12.60 ± 0.02 <sup>fe</sup>	0.47 ± 0.00 <sup>hi</sup>	31.76 ± 0.70 <sup>a</sup>	7.35 ± 0.12 <sup>e</sup>	139.32 ± 1.24 <sup>b</sup>
Starkrimson	12.50 ± 0.12 <sup>f</sup>	0.56 ± 0.00 <sup>i</sup>	32.08 ± 0.38 <sup>a</sup>	5.71 ± 0.06 <sup>kl</sup>	46.44 ± 0.96 <sup>l</sup>
Well Spur	12.50 ± 0.09 <sup>f</sup>	0.59 ± 0.00 <sup>d</sup>	19.38 ± 0.28 <sup>i</sup>	5.97 ± 0.09 <sup>kj</sup>	83.21 ± 0.31 <sup>g</sup>
Red Chief	14.40 ± 0.12 <sup>b</sup>	0.42 ± 0.00 <sup>k</sup>	24.92 ± 0.31 <sup>e</sup>	9.33 ± 0.11 <sup>d</sup>	147.06 ± 0.75 <sup>a</sup>
Super Chief	13.20 ± 0.03 <sup>dc</sup>	0.52 ± 0.00 <sup>fe</sup>	23.77 ± 0.05 <sup>f</sup>	7.27 ± 0.08 <sup>f</sup>	38.70 ± 0.01 <sup>o</sup>
Red Gold	12.50 ± 0.14 <sup>f</sup>	0.27 ± 0.00 <sup>hi</sup>	19.82 ± 0.32 <sup>i</sup>	2.77 ± 0.02 <sup>m</sup>	48.38 ± 0.46 <sup>k</sup>
Royal Gala	14.30 ± 0.03 <sup>b</sup>	0.64 ± 0.00 <sup>j</sup>	26.18 ± 0.32 <sup>d</sup>	5.76 ± 0.07 <sup>kj</sup>	52.25 ± 0.32 <sup>j</sup>
Scarlet Spur-II	11.90 ± 0.04 <sup>g</sup>	0.48 ± 0.00 <sup>h</sup>	22.59 ± 0.43 <sup>g</sup>	6.21 ± 0.09 <sup>ih</sup>	108.36 ± 1.15 <sup>c</sup>
Scarlet Gala	13.20 ± 0.16 <sup>dc</sup>	0.51 ± 0.00 <sup>l</sup>	25.20 ± 0.20 <sup>e</sup>	9.40 ± 0.06 <sup>c</sup>	87.08 ± 0.88 <sup>f</sup>
Early Red-I	11.10 ± 0.01 <sup>h</sup>	0.27 ± 0.00 <sup>hg</sup>	21.60 ± 0.40 <sup>h</sup>	11.58 ± 0.14 <sup>b</sup>	29.03 ± 0.29 <sup>o</sup>
Gale Gala	16.10 ± 0.11 <sup>a</sup>	0.62 ± 0.00 <sup>m</sup>	27.17 ± 0.26 <sup>c</sup>	5.11 ± 0.06 <sup>l</sup>	38.70 ± 0.52 <sup>o</sup>
Spartan	11.90 ± 0.07 <sup>g</sup>	0.27 ± 0.00 <sup>h</sup>	28.80 ± 0.41 <sup>b</sup>	6.69 ± 0.08 <sup>g</sup>	59.99 ± 0.90 <sup>i</sup>
Vance Delicious	12.90 ± 0.16 <sup>de</sup>	0.54 ± 0.00 <sup>f</sup>	28.24 ± 0.29 <sup>b</sup>	6.43 ± 0.07 <sup>h</sup>	79.34 ± 0.36 <sup>h</sup>
Silver Spur	12.10 ± 0.09 <sup>g</sup>	0.47 ± 0.00 <sup>i</sup>	27.09 ± 0.08 <sup>c</sup>	13.20 ± 0.17 <sup>a</sup>	38.70 ± 0.56 <sup>o</sup>
Red Delicious	10.00 ± 0.08 <sup>i</sup>	0.27 ± 0.00 <sup>g</sup>	21.60 ± 0.08 <sup>h</sup>	8.24 ± 0.11 <sup>e</sup>	42.57 ± 0.23 <sup>n</sup>
Average	12.60 ± 0.06	0.39 ± 0.00	24.14 ± 0.18	7.09 ± 0.05	67.11 ± 0.382

Results as mean ± SE of triplicate measurements. Means with same superscript in the same column are not significantly different

acceptability. Harker et al. (2008) have reported that acceptability of firmer apple fruits is always better. In the present work, a variation in fruit firmness amongst the apple cultivars was observed, which ranged from 10.32 N in red coloured big sized fruits of ‘Silver Spur’ to 14.0 N in non-red coloured ‘Winter Banana’ (Table 1). Average firmness of the twenty two cultivars was found to be 11.47 N. This variation in fruit firmness may due to different factors as the range of fruit firmness depends on variety, location, maturity stage and environmental factors (Ornelas-Paz et al. 2018; Musacchi and Serra 2017).

Skin colour in apple industry is fundamental as a sorting criterion for various genotypes. The colour of apple skin from green, yellow and red contributes to distinguish the genotypes. Commonly, the red colour is preferred while bright red apples and new alternative colours are recently receiving the consumer attention. In the present study, the intensity of red peel colour was higher in Gala cultivars (Hunter ‘a\*’ value ranging from 27.45 to 30.59), giving them an edge over sensory appeal in comparison to other cultivars Table 1). Some non-red apple varieties such as

‘Golden Delicious (Hunter ‘b\*’ value = 40.06) and ‘Granny Smith’ (Hunter ‘b\*’ value = 41.17) exhibited higher hunter ‘b\*’ values, representing yellow and/or green colour. Other varieties have shown differed Hunter a\*/b\* values, giving different shades of colour. Such difference in peel colour of the studied apple cultivars may be due genotypic variations and composition of pigments in respective varieties (Ma et al. 2017).

#### Soluble solid content and titrateable acidity of the apple cultivars

Soluble solid content (SSC) comprises majorly of sugars followed by acids, vitamins and some minerals that are soluble in water. It is an important integrated index to assess the quality and sweetness of fruits that is pivotal for consumer acceptance. The soluble solid content (SSC) of the apple cultivars ranged from 10 °Brix (‘Red Delicious’) to 16.1 °Brix (‘Gale Gala’). In an earlier study, Jan et al. (2012) have reported lower soluble solid content for the five apple cultivars they studied with values in the range of



11.24–11.79%. Ma et al. (2017) also described genotype differences to be the main factor determining the soluble solid content in kiwifruits. The most popular and widely grown apple cultivars in India, ‘Golden Delicious’ (13.5 °Brix) and ‘Royal Delicious’ (13.2 °Brix) recorded good soluble solid content (Table 2).

Titrateable acidity in fruits governs the overall taste of the fruit. A wide variation in titrateable acidity was observed with higher values in all non-red cultivars. The maximum titrateable acidity was recorded in non-red cultivars, ‘Winter Banana’ and ‘Starkspur Golden’ (0.67%) while minimum was observed in red cultivars, ‘Royal Delicious’, ‘Red Gold’, ‘Early Red-I’, ‘Spartan’ and ‘Red Delicious’ (0.27%) (Table 2). Average titrateable acidity of the twenty two cultivars was 0.39%. A range of 0.50–0.56% titrateable acidity has been previously reported in apples by Jan et al. (2012). Cultivars possessing high SSC and acidity can be considered good for apple juice concentrate production as reported by Wu et al. (2007).

#### Ascorbic acid, antioxidant (AOX) activity and total carotenoid

Ascorbic acid (vitamin C) is an important quality characteristic of apple fruit, specially desired for its antioxidant properties (Lata and Tomala 2007). The maximum ascorbic acid content was recorded in red cultivars, ‘Starkrimson’ (32.08 mg 100 g<sup>-1</sup>) and ‘Oregon Spur II’ (31.76 mg 100 g<sup>-1</sup>) whereas the least ascorbic acid was recorded in ‘Well Spur’ (19.38 mg 100 g<sup>-1</sup>) (Table 2). Our data on this attribute are lower than those reported by Jan et al. (2012) and have wider range than those reported by Joshi et al. (2007) who reported ascorbic acid in the range of 14.3–45.9 mg 100 g<sup>-1</sup> and 10.27–12.49 mg 100 g<sup>-1</sup>, respectively in apples. This deviation in the values of ascorbic acid may be due to fact that we analyzed different varieties than those studied by them.

A great variability in antioxidant (AOX) activity existed among the studied apple cultivars, the maximum being in red cultivar, ‘Silver Spur’ (13.20 µmol Trolox equivalent g<sup>-1</sup>) and the minimum in non-red cultivar, ‘Granny Smith’ (2.64 µmol Trolox equivalent g<sup>-1</sup>). In a similar study, Wang et al. (2015) reported that the antioxidant activity was significantly higher for red-fleshed genotypes than for white-fleshed genotypes. Similarly, a wider range of AOX activity (7.7–22.6 µmol Trolox equivalent g<sup>-1</sup>) has been reported by Joshi et al. (2007) in apple cultivars. The difference observed among the genotypes studied in terms of antioxidant activity may probably be due to plant genotype because all plants were grown in the same location using similar horticultural practices.

The apple cultivars varied in total carotenoid content, the maximum being in red cultivar, ‘Red Chief’

(147.06 mg kg<sup>-1</sup>) and lower in ‘Early Red-I’ (29.03 mg kg<sup>-1</sup>), ‘Granny Smith’ (32.90 mg kg<sup>-1</sup>), ‘Super Chief’, ‘Gale Gala’ and ‘Silver Spur’ (38.70 mg kg<sup>-1</sup>) (Table 2). A high level of variability existed with respect to total carotenoids, which could be due to genetic differences among the cultivars. Earlier, Delgado-Pelayo et al. (2014) and Péroumal et al. (2017) have reported a similar variation in the total carotenoid content among different apple accessions.

#### Sugar and organic acid profiling

The quantity of sugars and organic acids in fruits is influenced by the genotype (Wu et al. 2007) and also by environmental factors and horticultural practices followed in the orchards (Hudina and Stampar 2006). Further, the sugar profiling of fruits is important as it governs the sensory properties and nutritional value of fruits. A great variation in terms of individual sugars was observed among the studied apple cultivars (Table 3). The predominant monosaccharide was found to be fructose that ranged between 10.85 and 67.55 g L<sup>-1</sup>. All analyzed apple cultivars showed a higher concentration of fructose as compared to sucrose and glucose. As suggested by Hecke et al. (2006), this may favour the intake of apples by diabetic patients, since high fructose level keeps the level of blood sugar constant. Earlier, Zhang et al. (2010) have also reported presence of fructose, glucose, sucrose along with sorbitol in apple fruits. Sucrose was observed to be present in small amount with an average of 20.40 g L<sup>-1</sup>. The highest contents were recorded in non-red cultivar ‘Granny Smith’ (48.90 g L<sup>-1</sup>) and lowest in red cultivar ‘Royal Delicious’ (9.85 g L<sup>-1</sup>) (Table 3). Recently, Mpaia et al. (2018) have also reported a wide variation in composition of sugars in eleven Kei-apple fruit accessions. In this study, we used twenty two apple cultivars that were grown at the same location with similar horticultural practices. The variation in sugars demonstrated that a genetic variability existed among the cultivars that might have contributed to the differences in the synthesis of sugars in these apple cultivars.

Besides sugars, the organic acids present in the fruits also influence their taste and the consumption pattern. Low acidic fruits with appreciable sweetness are good for fresh consumption. Among the studied apple cultivars, all the non-red cultivars had a higher level of organic acids, with malic acid being the most predominant, followed by succinic acid and traces of citric and acetic acid (Table 3). Wu et al. (2007) have also reported the presence of malic, succinic and citric acid in apples. In the cultivars we studied, malic acid ranged from 4.40 g L<sup>-1</sup> (‘Red Gold’) to 9.50 g L<sup>-1</sup> (‘Starkspur Golden’) whereas succinic acid was found to be absent in cultivar ‘Starkspur Golden’ and maximum (5.10 g L<sup>-1</sup>) in ‘Red Delicious’ (Table 3).

**Table 3** Sugar content (g L<sup>-1</sup>) and organic acids in different apple cultivars

Cultivar	Sugars			Organic acids			
	Glucose	Fructose	Sucrose	Malic acid	Succinic acid	Citric acid	Acetic acid
<i>Non-red cultivars</i>							
Golden delicious	9.50 ± 0.11 <sup>j</sup>	49.10 ± 0.41 <sup>f</sup>	26.00 ± 0.18 <sup>e</sup>	6.50 ± 0.03 <sup>d</sup>	0.90 ± 0.01 <sup>h</sup>	–	–
Granny Smith	10.50 ± 0.14 <sup>h</sup>	10.85 ± 0.18 <sup>k</sup>	48.90 ± 0.59 <sup>a</sup>	6.60 ± 0.05 <sup>d</sup>	3.35 ± 0.03 <sup>b</sup>	5.10 ± 0.08 <sup>b</sup>	0.65 ± 0.00 <sup>a</sup>
Winter Banana	10.05 ± 0.08 <sup>i</sup>	52.30 ± 0.40 <sup>e</sup>	14.05 ± 0.09 <sup>g</sup>	8.25 ± 0.06 <sup>b</sup>	1.10 ± 0.01 <sup>g</sup>	–	–
Goldspur	22.50 ± 0.47 <sup>b</sup>	54.60 ± 0.13 <sup>d</sup>	12.75 ± 0.06 <sup>g</sup>	7.20 ± 0.08 <sup>c</sup>	0.85 ± 0.01 <sup>ih</sup>	–	–
Starkspur Golden	9.85 ± 0.09 <sup>ij</sup>	65.55 ± 1.17 <sup>b</sup>	22.30 ± 0.27 <sup>f</sup>	9.50 ± 0.11 <sup>a</sup>	0.00 ± 0.00 <sup>l</sup>	–	–
<i>Red cultivars</i>							
Royal Delicious	17.00 ± 0.15 <sup>c</sup>	48.05 ± 0.41 <sup>f</sup>	9.85 ± 0.10 <sup>l</sup>	5.50 ± 0.06 <sup>hgi</sup>	0.15 ± 0.00 <sup>k</sup>	–	–
Top Red	24.40 ± 0.49 <sup>g</sup>	56.60 ± 0.43 <sup>c</sup>	17.80 ± 0.34 <sup>ih</sup>	6.10 ± 0.04 <sup>e</sup>	1.10 ± 0.02 <sup>gf</sup>	–	–
Oregon Spur II	25.15 ± 0.44 <sup>ih</sup>	58.15 ± 1.06 <sup>h</sup>	17.90 ± 0.16 <sup>ih</sup>	5.90 ± 0.10 <sup>f</sup>	1.45 ± 0.01 <sup>e</sup>	–	–
Starkrimson	21.35 ± 0.26 <sup>fe</sup>	51.40 ± 0.30 <sup>h</sup>	16.75 ± 0.36 <sup>ihj</sup>	5.35 ± 0.08 <sup>i</sup>	1.15 ± 0.01 <sup>f</sup>	–	–
Well Spur	16.80 ± 0.17 <sup>d</sup>	47.85 ± 0.94 <sup>g</sup>	17.15 ± 0.16 <sup>ihj</sup>	5.50 ± 0.06 <sup>hgi</sup>	1.55 ± 0.01 <sup>d</sup>	–	–
Red Chief	20.45 ± 0.17 <sup>d</sup>	57.55 ± 1.09 <sup>h</sup>	24.80 ± 0.31 <sup>e</sup>	5.70 ± 0.03 <sup>g</sup>	1.45 ± 0.02 <sup>e</sup>	–	–
Super Chief	26.70 ± 0.26 <sup>m</sup>	57.05 ± 0.73 <sup>c</sup>	17.05 ± 0.23 <sup>ihj</sup>	4.90 ± 0.04 <sup>j</sup>	1.40 ± 0.02 <sup>e</sup>	–	–
Red Gold	12.50 ± 0.11 <sup>e</sup>	52.20 ± 0.40 <sup>e</sup>	29.90 ± 0.29 <sup>c</sup>	4.40 ± 0.05 <sup>l</sup>	0.55 ± 0.00 <sup>j</sup>	–	–
Royal Gala	16.85 ± 0.09 <sup>k</sup>	52.05 ± 0.52 <sup>h</sup>	19.55 ± 0.17 <sup>k</sup>	5.55 ± 0.06 <sup>hg</sup>	1.40 ± 0.01 <sup>e</sup>	–	–
Scarlet spur-II	20.40 ± 0.12 <sup>c</sup>	48.00 ± 0.41 <sup>g</sup>	23.15 ± 0.27 <sup>f</sup>	4.65 ± 0.06 <sup>k</sup>	1.60 ± 0.02 <sup>d</sup>	–	–
Scarlet Gala	25.90 ± 0.25 <sup>c</sup>	67.55 ± 0.20 <sup>a</sup>	10.95 ± 0.08 <sup>h</sup>	6.05 ± 0.11 <sup>fe</sup>	1.55 ± 0.03 <sup>d</sup>	–	–
Early Red-I	13.00 ± 0.02 <sup>d</sup>	54.30 ± 0.62 <sup>d</sup>	14.10 ± 0.20 <sup>g</sup>	6.10 ± 0.04 <sup>e</sup>	1.05 ± 0.01 <sup>g</sup>	–	–
Gale Gala	11.40 ± 0.12 <sup>l</sup>	51.65 ± 0.87 <sup>h</sup>	23.90 ± 0.17 <sup>f</sup>	5.90 ± 0.02 <sup>f</sup>	0.80 ± 0.00 <sup>i</sup>	–	–
Spartan	10.00 ± 0.15 <sup>i</sup>	48.10 ± 0.34 <sup>f</sup>	14.65 ± 0.09 <sup>g</sup>	6.00 ± 0.07 <sup>fe</sup>	1.85 ± 0.03 <sup>c</sup>	–	–
Vance Delicious	24.50 ± 0.21 <sup>d</sup>	59.90 ± 0.78 <sup>h</sup>	22.20 ± 0.23 <sup>f</sup>	5.40 ± 0.05 <sup>hi</sup>	1.85 ± 0.00 <sup>c</sup>	–	–
Silver Spur	23.25 ± 0.28 <sup>f</sup>	54.85 ± 0.59 <sup>dc</sup>	19.85 ± 0.19 <sup>k</sup>	6.05 ± 0.02 <sup>fe</sup>	1.90 ± 0.00 <sup>c</sup>	–	–
Red Delicious	23.00 ± 0.18 <sup>a</sup>	19.65 ± 0.24 <sup>j</sup>	25.20 ± 0.36 <sup>d</sup>	5.50 ± 0.02 <sup>hgi</sup>	5.10 ± 0.05 <sup>a</sup>	11.00 ± 0.10 <sup>a</sup>	–
Average	17.96 ± 0.13	50.79 ± 0.36	20.40 ± 0.14	6.03 ± 0.03	1.46 ± 0.01	0.73 ± 0.01	0.03 ± 0.00

Results as mean ± SE of triplicate measurements. Means with same superscript in the same column are not significantly different

**Mineral analysis**

Apples are considered a good source of dietary minerals. Among the major elements studied in different cultivars of apple fruits, K was the most abundant with an overall mean concentration of 795.14 mg 100 g<sup>-1</sup> (Table 4). Maximum potassium concentration was observed in ‘Scarlet Gala’ (1142 mg 100 g<sup>-1</sup>) and minimum in ‘Winter Banana’ (550 mg 100 g<sup>-1</sup>). Earlier, Horsley et al. (2014) have reported a higher concentration of potassium in apple cultivars, however in contrast, Joshi et al. (2007) have reported a lower concentration (700 mg 100 g<sup>-1</sup>). The sodium, calcium and magnesium concentrations among different apple cultivars fell in the range of 9.70–70.20 mg 100 g<sup>-1</sup>, 14.20–90.37 mg 100 g<sup>-1</sup> and 15.98–31.12 mg 100 g<sup>-1</sup>, respectively (Table 4). The average values for Na (23.70 mg/100 g<sup>-1</sup>) in this study were higher than those reported by Fazli and Fazli (2014) and Ornelas-Paz et al.

(2018), however the concentrations of calcium (14.20–90.37 mg 100 g<sup>-1</sup>) and magnesium (15.98–29.54 mg 100 g<sup>-1</sup>) recorded by us, were comparable with the data reported earlier by Joshi et al. (2007) and Ornelas-Paz et al. (2018) in apple fruits.

The micro elements also support many important functions in the human body. The average concentrations of investigated micro elements in the 22 apple cultivars were: Fe (2.04 µg g<sup>-1</sup>), Zn (0.64 µg g<sup>-1</sup>), Mn (0.16 µg g<sup>-1</sup>) and Cu (0.12 µg g<sup>-1</sup>) (Table 4). Among different apple cultivars studied, maximum Fe (6.14 µg g<sup>-1</sup>), Zn (2 µg g<sup>-1</sup>), Mn (0.28 µg g<sup>-1</sup>) and Cu (0.22 µg g<sup>-1</sup>) concentrations were recorded in ‘Red Chief’, ‘Scarlet Spur-II’, ‘Starkrimson’ and ‘Early Red-I’, respectively (Table 4). As far as the concentrations of the micro elements are concerned, our results are comparable with those demonstrated for apple fruits by Manzoor et al. (2012) and Ornelas-Paz et al. (2018).

**Table 4** Minerals content in different apple cultivars

Cultivar	Macro-elements (mg 100 g <sup>-1</sup> )				Micro-elements (µg g <sup>-1</sup> )			
	Na	K	Ca	Mg	Fe	Zn	Mn	Cu
<i>Non-red cultivars</i>								
Golden delicious	54.50 ± 0.59 <sup>c</sup>	936.00 ± 11.00 <sup>c</sup>	15.74 ± 0.14 <sup>n</sup>	17.37 ± 0.34 <sup>kj</sup>	1.27 ± 0.01 <sup>i</sup>	0.51 ± 0.02 <sup>ik</sup>	0.13 ± 0.00 <sup>k</sup>	0.07 ± 0.00 <sup>p</sup>
Granny Smith	11.40 ± 0.14 <sup>k</sup>	674.00 ± 12.26 <sup>k</sup>	14.94 ± 0.24 <sup>o</sup>	21.22 ± 0.32 <sup>ef</sup>	1.10 ± 0.00 <sup>j</sup>	0.77 ± 0.00 <sup>d</sup>	0.12 ± 0.00 <sup>lm</sup>	0.11 ± 0.00 <sup>i</sup>
Winter Banana	16.30 ± 0.18 <sup>l</sup>	550.00 ± 4.39 <sup>m</sup>	18.07 ± 0.17 <sup>l</sup>	17.23 ± 0.21 <sup>k</sup>	0.93 ± 0.02 <sup>k</sup>	0.25 ± 0.00 <sup>n</sup>	0.08 ± 0.00 <sup>o</sup>	0.09 ± 0.01 <sup>m</sup>
Goldspur	9.90 ± 0.11 <sup>l</sup>	1047.00 ± 16.44 <sup>b</sup>	15.94 ± 0.17 <sup>n</sup>	18.13 ± 0.21 <sup>ij</sup>	1.13 ± 0.00 <sup>j</sup>	0.50 ± 0.00 <sup>k</sup>	0.20 ± 0.01 <sup>d</sup>	0.14 ± 0.00 <sup>e</sup>
Starkspur Golden	70.20 ± 0.58 <sup>a</sup>	753.00 ± 8.69 <sup>jh</sup>	21.01 ± 0.44 <sup>i</sup>	21.82 ± 0.25 <sup>f</sup>	1.12 ± 0.00 <sup>j</sup>	0.61 ± 0.01 <sup>g</sup>	0.15 ± 0.00 <sup>j</sup>	0.13 ± 0.00 <sup>g</sup>
<i>Red cultivars</i>								
Royal Delicious	19.30 ± 0.30 <sup>g</sup>	618.00 ± 5.31 <sup>l</sup>	19.94 ± 0.11 <sup>k</sup>	21.41 ± 0.28 <sup>f</sup>	1.26 ± 0.00 <sup>j</sup>	0.86 ± 0.00 <sup>b</sup>	0.16 ± 0.00 <sup>ih</sup>	0.08 ± 0.00 <sup>n</sup>
Top Red	57.00 ± 0.53 <sup>b</sup>	868.00 ± 5.62 <sup>d</sup>	26.39 ± 0.14 <sup>f</sup>	23.86 ± 0.29 <sup>d</sup>	1.55 ± 0.00 <sup>h</sup>	0.82 ± 0.00 <sup>c</sup>	0.13 ± 0.00 <sup>ik</sup>	0.12 ± 0.00 <sup>h</sup>
Oregon Spur II	19.40 ± 0.12 <sup>g</sup>	810.00 ± 4.14 <sup>e</sup>	19.55 ± 0.05 <sup>k</sup>	21.89 ± 0.25 <sup>f</sup>	1.31 ± 0.01 <sup>i</sup>	0.53 ± 0.00 <sup>ij</sup>	0.16 ± 0.00 <sup>h</sup>	0.09 ± 0.00 <sup>k</sup>
Starkrimson	41.20 ± 0.30 <sup>d</sup>	696.00 ± 12.75 <sup>k</sup>	42.21 ± 0.20 <sup>c</sup>	31.12 ± 0.24 <sup>a</sup>	2.56 ± 0.02 <sup>d</sup>	0.80 ± 0.01 <sup>c</sup>	0.28 ± 0.00 <sup>a</sup>	0.09 ± 0.00 <sup>ik</sup>
Well Spur	19.60 ± 0.17 <sup>g</sup>	739.00 ± 7.90 <sup>j</sup>	22.37 ± 0.18 <sup>h</sup>	20.47 ± 0.25 <sup>g</sup>	1.28 ± 0.01 <sup>i</sup>	0.72 ± 0.00 <sup>e</sup>	0.17 ± 0.00 <sup>g</sup>	0.16 ± 0.00 <sup>c</sup>
Red Chief	17.60 ± 0.01 <sup>h</sup>	769.00 ± 3.38 <sup>gh</sup>	17.55 ± 0.17 <sup>ml</sup>	21.23 ± 0.17 <sup>gf</sup>	6.14 ± 0.12 <sup>a</sup>	0.13 ± 0.00 <sup>o</sup>	0.17 ± 0.01 <sup>g</sup>	0.15 ± 0.00 <sup>d</sup>
Super Chief	11.70 ± 0.12 <sup>k</sup>	887.00 ± 12.09 <sup>d</sup>	23.01 ± 0.04 <sup>g</sup>	23.30 ± 0.28 <sup>cd</sup>	1.80 ± 0.02 <sup>gf</sup>	0.54 ± 0.00 <sup>j</sup>	0.14 ± 0.00 <sup>j</sup>	0.11 ± 0.02 <sup>j</sup>
Red Gold	19.80 ± 0.29 <sup>g</sup>	782.00 ± 2.87 <sup>fg</sup>	28.95 ± 0.15 <sup>e</sup>	26.42 ± 0.35 <sup>c</sup>	2.53 ± 0.01 <sup>d</sup>	0.51 ± 0.00 <sup>ik</sup>	0.23 ± 0.00 <sup>b</sup>	0.12 ± 0.00 <sup>h</sup>
Royal Gala	10.30 ± 0.08 <sup>l</sup>	754.00 ± 8.01 <sup>ih</sup>	55.17 ± 0.25 <sup>b</sup>	15.98 ± 0.14 <sup>l</sup>	1.54 ± 0.00 <sup>h</sup>	0.58 ± 0.00 <sup>h</sup>	0.12 ± 0.00 <sup>lm</sup>	0.09 ± 0.00 <sup>lm</sup>
Scarlet Spur-II	11.30 ± 0.10 <sup>k</sup>	614.00 ± 6.96 <sup>l</sup>	31.98 ± 0.40 <sup>d</sup>	29.54 ± 0.50 <sup>b</sup>	3.52 ± 0.04 <sup>c</sup>	2.00 ± 0.01 <sup>a</sup>	0.22 ± 0.00 <sup>c</sup>	0.18 ± 0.00 <sup>b</sup>
Scarlet Gala	9.70 ± 0.09 <sup>l</sup>	1142.00 ± 19.10 <sup>a</sup>	14.20 ± 0.05 <sup>p</sup>	17.73 ± 0.17 <sup>ki</sup>	1.82 ± 0.00 <sup>gf</sup>	0.66 ± 0.00 <sup>f</sup>	0.11 ± 0.00 <sup>n</sup>	0.09 ± 0.00 <sup>m</sup>
Early Red-I	23.30 ± 0.21 <sup>f</sup>	778.00 ± 10.82 <sup>feh</sup>	16.99 ± 0.28 <sup>m</sup>	19.46 ± 0.17 <sup>h</sup>	2.31 ± 0.01 <sup>e</sup>	0.65 ± 0.00 <sup>f</sup>	0.14 ± 0.00 <sup>j</sup>	0.22 ± 0.00 <sup>a</sup>
Gale Gala	11.70 ± 0.10 <sup>k</sup>	748.00 ± 1.63 <sup>ij</sup>	21.04 ± 0.21 <sup>i</sup>	17.55 ± 0.25 <sup>ki</sup>	1.87 ± 0.00 <sup>f</sup>	0.51 ± 0.00 <sup>ik</sup>	0.22 ± 0.00 <sup>c</sup>	0.14 ± 0.00 <sup>f</sup>
Spartan	33.10 ± 0.49 <sup>e</sup>	795.00 ± 9.14 <sup>e</sup>	22.38 ± 0.13 <sup>h</sup>	18.71 ± 0.26 <sup>ih</sup>	1.78 ± 0.02 <sup>g</sup>	0.38 ± 0.00 <sup>m</sup>	0.19 ± 0.00 <sup>f</sup>	0.15 ± 0.00 <sup>d</sup>
Vance Delicious	22.80 ± 0.27 <sup>f</sup>	886.00 ± 4.36 <sup>d</sup>	90.37 ± 0.15 <sup>a</sup>	29.25 ± 0.43 <sup>b</sup>	4.33 ± 0.02 <sup>b</sup>	0.87 ± 0.01 <sup>b</sup>	0.19 ± 0.00 <sup>e</sup>	0.11 ± 0.00 <sup>i</sup>
Silver Spur	18.10 ± 0.24 <sup>h</sup>	872.00 ± 7.75 <sup>d</sup>	21.74 ± 0.07 <sup>i</sup>	23.40 ± 0.24 <sup>ed</sup>	2.33 ± 0.03 <sup>c</sup>	0.40 ± 0.00 <sup>m</sup>	0.12 ± 0.00 <sup>lm</sup>	0.12 ± 0.00 <sup>i</sup>
Red Delicious	13.30 ± 0.10 <sup>j</sup>	775.00 ± 10.56 <sup>gh</sup>	20.94 ± 0.16 <sup>i</sup>	22.93 ± 0.26 <sup>e</sup>	1.32 ± 0.00 <sup>j</sup>	0.45 ± 0.00 <sup>j</sup>	0.16 ± 0.00 <sup>ih</sup>	0.08 ± 0.00 <sup>o</sup>
Average	23.70 ± 0.16	795.14 ± 5.47	26.39 ± 0.11	21.82 ± 0.16	2.04 ± 0.01	0.64 ± 0.00	0.16 ± 0.00	0.12 ± 0.00

Results as mean ± SE of triplicate measurements. Means with same superscript in the same column are not significantly different



**Table 5** Phenolic compounds (mg L<sup>-1</sup>) content in different cultivars

Cultivar	Chlorogenic acid	Coumaric acid	Phloridzindihydrate	Rutin	Catechin	3-hydroxy cinnamic acid	Total
<i>Non-red cultivars</i>							
Golden delicious	53.29 ± 0.47 <sup>d</sup>	3.58 ± 0.03 <sup>j</sup>	4.72 ± 0.00 <sup>p</sup>	TR	TR	0.53 ± 0.00 <sup>c</sup>	62.11
Granny Smith	3.69±0.06 <sup>m</sup>	2.06±0.02 <sup>m</sup>	22.11±0.12 <sup>k</sup>	TR	TR	TR	27.89
Winter Banana	163.97±1.79 <sup>a</sup>	9.32±0.10 <sup>a</sup>	18.68±0.24 <sup>l</sup>	TR	TR	0.74±0.00 <sup>a</sup>	192.70
Goldspur	8.00±0.10 <sup>k</sup>	1.11±0.01 <sup>o</sup>	2.05±0.00 <sup>q</sup>	0.46±0.00 <sup>e</sup>	TR	TR	11.60
Starkspur Golden	67.76±0.36 <sup>b</sup>	5.11±0.04 <sup>e</sup>	13.23±0.20 <sup>n</sup>	0.30±0.00 <sup>f</sup>	TR	0.66±0.00 <sup>b</sup>	87.06
<i>Red cultivars</i>							
Royal Delicious	17.88 ± 0.40 <sup>h</sup>	5.76 ± 0.06 <sup>c</sup>	46.21 ± 0.12 <sup>c</sup>	TR	TR	TR	69.84
Top Red	8.89±0.04 <sup>k</sup>	3.39±0.04 <sup>k</sup>	24.94±0.31 <sup>j</sup>	TR	TR	TR	37.22
Oregon Spur II	7.75±0.09 <sup>k</sup>	9.32±0.01 <sup>a</sup>	30.46±0.40 <sup>g</sup>	TR	TR	TR	
Starkrimson	40.48±0.49 <sup>e</sup>	6.08±0.06 <sup>b</sup>	38.39±0.26 <sup>d</sup>	0.50±0.00 <sup>b</sup>	TR	TR	85.45
Well Spur	15.17±0.18 <sup>i</sup>	4.03±0.04	35.23±0.24 <sup>f</sup>	TR	TR	TR	54.43
Red Chief	27.23±0.28 <sup>f</sup>	5.70±0.07 <sup>c</sup>	65.34±0.26 <sup>b</sup>	0.29±0.00 <sup>g</sup>	42.44±0.51 <sup>b</sup>	TR	140.99
Super Chief	15.44±0.02 <sup>i</sup>	3.82±0.04 <sup>i</sup>	35.60±0.40 <sup>f</sup>	0.21±0.00 <sup>b</sup>	TR	TR	55.07
Red Gold	10.34 ± 0.09 <sup>j</sup>	1.01 ± 0.00 <sup>o</sup>	16.85 ± 0.19 <sup>m</sup>	TR	TR	TR	
Royal Gala	17.99±0.09 <sup>h</sup>	4.92±0.06 <sup>f</sup>	5.67±0.01 <sup>o</sup>	TR	TR	0.25±0.00 <sup>e</sup>	28.81
Scarlet Spur-II	18.83±0.13 <sup>h</sup>	4.74±0.05 <sup>g</sup>	29.87±0.17 <sup>hg</sup>	0.32±0.00 <sup>e</sup>	TR	0.18±0.00 <sup>f</sup>	53.93
Scarlet Gala	5.44±0.06 <sup>l</sup>	1.90±0.00 <sup>n</sup>	4.40±0.04 <sup>p</sup>	TR	TR	0.11±0.00 <sup>b</sup>	11.85
Early Red-I	7.75±0.09 <sup>k</sup>	3.00±0.03 <sup>l</sup>	37.48±0.46 <sup>e</sup>	0.43±0.00 <sup>d</sup>	45.71±0.70 <sup>a</sup>	TR	
Gale Gala	7.74±0.09 <sup>k</sup>	1.99±0.04 <sup>nm</sup>	2.37±0.04 <sup>q</sup>	TR	TR	0.12±0.00 <sup>g</sup>	12.22
Spartan	54.82±0.27 <sup>c</sup>	3.90±0.04 <sup>ih</sup>	26.79±0.13 <sup>i</sup>	0.20±0.00 <sup>i</sup>	TR	TR	85.71
Vance Delicious	22.84±0.54 <sup>g</sup>	5.14±0.05 <sup>e</sup>	29.38±0.35 <sup>h</sup>	0.10±0.00 <sup>j</sup>	TR	TR	57.46
Silver Spur	23.30±0.28 <sup>g</sup>	5.53±0.06 <sup>d</sup>	67.40±0.73 <sup>a</sup>	0.65±0.00 <sup>a</sup>	TR	TR	96.87
Red Delicious	26.68±0.24 <sup>f</sup>	4.79±0.04 <sup>ef</sup>	30.54±0.40 <sup>g</sup>	TR	TR	0.36±0.00 <sup>d</sup>	62.37
Average	28.42±0.26	4.37±0.03	26.71±0.17	0.16±0.00	4.01±0.10	0.13±0.00	

Results as mean ± SE of triplicate measurements. Means with same superscript in the same column are not significantly different

### Profiling of phenolic compounds

Besides playing a major role in enzymatic browning in apple, the phenolic compounds act as a source of dietary antioxidants that may reduce the risk of many chronic disorders, including cancer (Alberti et al. 2017). A higher absorption of phenols has been reported to lead to a reduction in heart disease and lower cholesterol levels (Craig and Beck 1999). Therefore, there has been a growing interest for using apples in functional food products, such as functional beverages and healthy snack products. In this study, chlorogenic acid was found to be the predominant phenolic compound with an average concentration of 28.42 mg L<sup>-1</sup> (Table 5). The highest concentration of chlorogenic acid was found in non-red cultivar ‘Winter Banana’ (163.97 mg L<sup>-1</sup>) and lowest in cultivar ‘Granny Smith’ (3.69 mg L<sup>-1</sup>). Phloridzin dihydrate, the second highest phenolic compound in the apple cultivars averaged to 26.71 mg L<sup>-1</sup>, with the highest concentration being in ‘Silver Spur’ (67.40 mg L<sup>-1</sup>). In addition, traces of rutin, catechin and 3-hydroxy cinnamic

acid were also found in some cultivars (Table 5). In a study, Łata et al. (2009) determined the total phenolic yield of 19 apple varieties, and reported that the concentration of the main phenolics (chlorogenic acid, catechin, epicatechin, phloridzin and rutin) varied significantly among the different apple cultivars. Carbone et al. (2011) have also reported chlorogenic acid to be the major phenolic compound in apple that ranged from 2.94 to 7.52 mg 100 g<sup>-1</sup> in different genotypes Apples with low phenolic content with a correspondingly high SSC, as observed for the Gala cultivars in the present study, make them suitable for the production of light coloured juices as suggested by Wu et al. (2007).

### Conclusion

Overall, study demonstrated that cultivars grown under Indian conditions varied widely for physical and biochemical attributes. The studied twenty two cultivars also showed differences in values than those grown in other

countries of the world. This variability may be attributed to the genetic factors and geographical locations.

## References

- Alberti A, Zielinski AAF, Couto M, Judacewski P, Mafra LI, Nogueira A (2017) Distribution of phenolic compounds and antioxidant capacity in apples tissues during ripening. *J Food Sci Technol* 54:1511–1518
- Apak R, Guclu K, Ozyurek M, Karademir SE (2004) Novel total antioxidants capacity index for dietary polyphenol and vitamins C and E using their cupric ion reducing capability in the presence of neocuprine: CUPRAC method. *J Agric Food Chem* 52:7970–7981
- Ayaz FA, Kadioglu A (1997) Changes in phenolic acid contents of *Diospyros lotus* L. during fruit development. *J Agric Food Chem* 45:2539–2541
- Beyer M, Hahn R, Peschel S, Harz M, Knoche B (2002) Analyzing fruit shape in sweet cherry (*Prunus avium* L.). *Sci Hortic* 96:139–150
- Bondonno NP, Bondonno CP, Ward NC, Hodgson JM, Croft KD (2017) The cardiovascular health benefits of apples: whole fruit vs. isolated Compounds. *Trends Food Sci Technol* 69:243–256
- Carbone KB, Giannini Picchi V, Lo Scalzo R, Cecchini F (2011) Phenolic composition and free radical scavenging activity of different apple varieties in relation to the cultivar, tissue type and storage. *Food Chem* 127:493–500
- Cindric J, Krizman I, Zeimer M, Kampic S, Medunic G, Stinger G (2012) ICP-AES determination of minor- and major elements in apples after microwave assisted digestion. *Food Chem* 135:2675–2680
- Craig W, Beck L (1999) Phytochemicals: health protective effects. *Can J Diet Pract Res Summer* 60:78–84
- Delgado-Pelayo R, Gallardo-Guerrero L, Hornero-Méndez D (2014) Chlorophyll and carotenoid pigments in the peel and flesh of commercial apple fruit varieties. *Food Res Int* 65:272–281
- Fan X, Mattheis JP, Patterson ME, Fellman JK (1995) Changes in amylose and total starch content in ‘Fuji’ apples during maturation. *Hort Sci* 30:104–105
- Fazli FA, Fazli NA (2014) Evaluation and determination of minerals content in fruits. *Int J Pl Anim Environ Sci* 4:160–166
- Harker FR, Kupferman EM, Marin AB, Gunson FA, Triggs CM (2008) Eating quality standards for apples based on consumer preferences. *Postharvest Biol Technol* 50:70–78
- Hecke K, Herbing K, Veberic R, Trobec M, Toplak H, Stampar F, Keppel H, Grill D (2006) Sugar- acid- and phenol contents in apple cultivars from organic and integrated fruit cultivation. *Eur J Clin Nutr* 60:1136–1140
- Horsley R, Gokbel H, Ozcan MM, Harmankaya M, Simsek S (2014) Monitoring of element contents of three different apple (*Malus* Spp.) varieties in an apple tree. *J Food Nutr Res* 2:127–129
- Hudina M, Stampar F (2006) Influence of frost damage on the sugars and organic acids contents in apple and pear flowers. *Eur J Hortic Sci* 71:161–164
- Jan I, Rab A, Sajid M (2012) Storage performance of apple cultivars harvested at different stages of maturity. *J Anim Plant Sci* 22:438–447
- Joshi APK, Rupasinghe HPV, Pitts NL, Khanizadeh S (2007) Biochemical characterization of enzymatic browning in selected apple genotypes. *Can J Plant Sci* 87:1067–1074
- Lata B, Tomala K (2007) Relationship between apple peel and the whole fruit antioxidant content: year and cultivar variation. *J Agric Food Chem* 55:663–671
- Lata B, Trampczynska A, Paczesna J (2009) Cultivar variation in apple peel and whole fruit phenolic composition. *Sci Hortic* 121:176–181
- Ma T, Sun X, Zhao J, You Y, Lei Y, Gao G, Zhan J (2017) Nutrient compositions and antioxidant capacity of kiwifruit (*Actinidia*) and their relationship with flesh color and commercial value. *Food Chem* 218:294–304
- Manzoor M, Anwar F, Saari N, Ashraf M (2012) Variations of antioxidant characteristics and mineral contents in pulp and peel of different apple (*Malus domestica* Borkh.) cultivars from Pakistan. *Molecules* 17:390–407
- Mihailović NR, Mihailović VB, Kreft S, Ćirić AR, Joksović LG, Đurđević PT (2018) Analysis of phenolics in the peel and pulp of wild apples (*Malus sylvestris* (L.) Mill.). *J Food Compos Anal* 67:1–9
- Mohsenin NN (1986) Physical properties of plant and animal materials. Gordon and Breach Science, New York
- Mpaia S, du Preez R, Sultanbawac Y, Sivakumara D (2018) Phytochemicals and nutritional composition in accessions of Kei-apple (*Dovyalis caffra*): Southern African indigenous fruit. *Food Chem* 253:37–45
- Musacchi S, Serra S (2017) Apple fruit quality: overview on pre-harvest factors. *Sci Hortic*. <https://doi.org/10.1016/j.scienta.2017.12.057>
- Ornelas-Paz J, Quintana-Gallegos BM, Escalante-Minakata P, Reyes-Hernandez J, Perez-Martinez JD, Rios-Velasco C, Ruiz-Cruz S (2018) Relationship between the firmness of Golden Delicious apples and the physicochemical characteristics of the fruits and their pectin during development and ripening. *J Food Sci Technol* 55:34–41
- Péroumal A, Adenet S, Rochefort K, Fahrasmane L, Aurore G (2017) Variability of traits and bioactive compounds in the fruit and pulp of six mamey apple (*Mammea americana* L.) accessions. *Food Chem* 234:269–275
- Ranganna S (1999) Handbook of analysis and quality control for fruits and vegetable products, 3rd edn. Tata McGraw-Hill Publishing Company Ltd, Bengaluru
- Tabatabaefar A, Rajabipour A (2005) Modeling the mass of apples by geometrical attributes. *Sci Hortic* 105:373–382
- Wang X, Li C, Liang D, Zou Y, Li P, Ma F (2015) Phenolic compounds and antioxidant activity in red-fleshed apples. *J Funct Foods* 18:1086–1094
- Wu J, Gao H, Zhao L, Liao X, Chen F, Wang Z, Hu X (2007) Chemical compositional characterization of some apple cultivars. *Food Chem* 103:88–93
- Zhang Y, Pengmin L, Chen LC (2010) Development changes of carbohydrates, organic acids, amino acids, and phenolic compounds in ‘Honeycrisp’ apple flesh. *Food Chem* 123:1013–1018