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Sensory Attributes and Antioxidant Potential of Value-added Products of Grapefruit (*Citrus paradisi)*

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ABSTRACT

Background: Grapefruits are one of the nutritious and most commonly consumed fruits in United States, next to oranges. Conversely, limited consumption has been reported in India due to its sour taste and bitter flavour. So, the present investigation was undertaken to produce value-added products (chiller, squash, spread and peel candy) from different varieties (Red blush, Ruby Red, marsh Seedless) with an objective to enhance its sensory acceptability.

Methods: The four cultivars of grapefruits were procured from citrus farm of PAU, Ludhiana. Half of the fresh fruits were washed thoroughly in distilled water, peeled, sectioned into small pieces and dried in hot air oven at ±55°C. The dried fruit was then ground into fine powder and stored in the air-tight containers (27°C) for nutritional analysis whereas the other half was processed manually to formulate the value-added products in the Food Lab of the same for its sensorial evaluation.

Result: Out of four varieties; Red blush became most acceptable for chiller and spread, whereas Ruby Red and Marsh Seedless for squash and peel candy. Prior to product formulation, nutritional parameters of varieties were analysed. They reported high amount of potassium and crude fibre *i.e.*111-117mg and 1.27-1.40 g/100 g. Among formulated products, ascorbic acid and antioxidant potential was highest in chiller *i.e.* 28.89 mg/100 g and 75.82%. Quercetin Equivalent was 77.33 (highest) in peel candy.

Keywords: Antioxidant potential, Ascorbic acid, Chiller, Grapefruit, Quercetin equivalent, Sensory evaluation, Spread, Squash, Peel candy.

INTRODUCTION

Grapefruit is a hybrid of pomelo (*Citrus maxima*) and sweet orange (*Citrus sinensis*) developed in the eighteenth century. In India, grapefruit remained an underutilized fruit despite being the rich source of antioxidant, vitamins and minerals and is used for the production of ethno-medicines (Barua *et al.,* 2019). It is especially high in pectin (a soluble fibre) that helps in lowering blood cholesterol levels (Younus *et al.,* 2008). The potassium found in grapefruit helps in maintaining bone strength as when we consume citrate it gets converted into bicarbonate, which further supports acid-base balance to lessen the potential losses of calcium from the bones. Besides fibre and micronutrients, it contains phytochemicals such as flavonoid, carotenoids, glucarates, coumarins, terpenes, limonoids and furanocoumarins. These phytochemicals, particularly the furanocoumarins have anti-inflammatory and anti-oxidative effects (Codoñer-Franch and Valls-Bellés, 2010). They also inhibit cancer cells proliferation and repair damaged DNA that would otherwise lead to the development of tumours.

Grapefruit peel being rich source of pectin is widely used for its extraction and utilizing it in the formulation of best quality food products including jams. Khan *et al.,* 2014 using Duncan variety, extracted maximum amount of pectin (22.55%) at 120°C at an acidity levels of 1.5 pH whereas 0.41% of pectin was extracted at 2 pH, keeping the temperature same. Essential oils can also be extracted from its peel. Red Blush variety of grapefruit constituted 67 compounds; amounting 97.9% of oils (Nijoroge *et al.,* 2005). These extracted oils can be further used as flavouring agents, anti-ageing skin care products, insects repellent/attractant, *etc*. Apart from this, its dried waste products can be used as cattle feed that will not only act as an effective waste manager but also diminishes the burden on environment. It can also be used for the production of bioethanol and as biosorbents for heavy metals in treatment of waste water (Khalil *et al.,* 2022). Chaudhary *et al* (2017) investigated that kinnow waste on using it as a cattle feed saves the cost upto 12 percent as compared to conventional sources without altering its nutrient digestibility. Fruit and vegetable pomace can be enriched in bakery products to increase their fermentability, hydration capacity and phytochemicals, *etc*. (Sahni and Shere 2018). Keeping in view the various nutritional and health benefits of the fruit, efforts were made in the present study to formulate its value-added products having good sensory and nutritional attributes.

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MATERIALS AND METHODS

Four varieties of marketable sized (weight ranging from 200-250 g) grapefruit namely Ruby Red, Red Blush, Flame and Marsh Seedless were procured from the Department of Fruit Science, Punjab Agricultural University, Ludhiana, Punjab and were brought to Food Analysis Laboratory of Department of Food and Nutrition. Other ingredients used for the preparation of different products, such as sugar, salt, powdered black pepper, citric acid crystals, benzoic acid, lemon, calcium hydroxide and sodium benzoate were purchased from the local market of Ludhiana and were stored at room temperature (27°C). The fruits were then peeled, sectioned into small pieces and dried in hot air oven at ±55°C. The dried fruit was then ground into fine powder with the help of pestle and mortar and stored in the air-tight containers at ambient temperature (27°C) for nutritional analysis such as proximate composition, total sugars, reducing and non-reducing sugars, minerals (potassium and calcium), vitamin C, total flavonoids and antioxidant potential by DPPH radical scavenging method. All the proximate parameters were analysed using methods described in Association of Official Analytical Chemist (AOAC, 2000). Moisture content was carried out in a hot air oven at a temperature 105°C for 8 hours. The crude protein was estimated by kjeldhal method using Kjelplus (SUPRA- LX VA) in which nitrogen content was estimated and was then multiplied with the factor 6.25 for protein estimation. The crude fat was evaluated by Soxhlet extraction method using SOCS PLUS (SCS 6). The ash content was evaluated by igniting the sample in a muffle furnace at a temp. 550°C for 4 hours. Carbohydrate was calculated by difference method:

% Carbohydrate=

100%- (Moisture+Crude fat+Total ash+Crude protein)%

Crude fiber was also estimated by the method described in Association of Official Analytical Chemists (AOAC, 2000) by using FIBRA PLUS (FES 6). The calorific value of grapefruit varieties was estimated by multiplying the percentages of carbohydrate, protein and fat with their physiological fuel value *i.e.* 4, 4 and 9, respectively. Total sugars and reducing sugars were estimated by the method described in AOAC (2000). Whereas, non-reducing sugar was calculated by subtracting reducing sugars from total sugars. Minerals namely potassium and calcium were determined by method given in AOAC (2003). Vitamin C content was evaluated by using 2, 6-dichlorophenol indophenol dye which gives blue colour on reduction by ascorbic acid and it was read in spectrophotometer (ELICO SL 177) at 500 nm (AOVC, 1996). For the analysis of flavonoids and antioxidant potential, the methanolic extract was prepared. For the analysis of flavonoids, absorbency was read at 415 nm against the blank (Zhishen *et al.,* 1999). For the analysis of antioxidant potential the sample was evaluated by DPPH (2, 2-diphenyl-1-picrylhydrazyl) method. The discoloration of DPPH was read at 517 nm against blank (Tadhani *et al.,* 2007). All the samples were analysed in triplicate.

$$\%\ \text{inhibition} = \frac{\text{Abs*. of control-Abs. of sample}}{\text{Abs. of control}} \times 100$$

*absorption.

For the formulation of the products various sensory trials were conducted in the Food Laboratory of PAU, Ludhiana to standardize the recipe of all products. Standardized amounts of ingredients and methods of preparation of grapefruit products (Chiller, squash, peel candy and spread) have been mentioned in Table 1. Each product was prepared from four different grapefruit varieties and for sensory evaluation it was served to semi-trained panel (n=30) of Departments of Food and Nutrition, Food Science and Technology and Fruit Science of PAU in a well-lit laboratory of the Department of Food and Nutrition during day time and to the untrained panel (n=50) of local consumers to check the consumer acceptability. The panel was provided with the single product (30 ml each) at a time along with water in order to prevent the interference of different flavours. They were asked to report their sensory preferences in a given datasheet. The acceptance sensory test using a nine-point Hedonic rating scale was performed for several sensory attributes such as texture, appearance, flavour, taste and overall acceptability (Nicolas *et al.,* 2010). Based on the results of this evaluation, the most acceptable variety from each product was selected and it was further evaluated for their proximate composition. The detailed experimental design of this study is given in Fig 1.

Statistical analysis

Mean and standard deviation for the different parameters were computed. Analysis of Variance (ANOVA) was employed following CRD and Statistical Analysis Tool Pack and SPSS 16 (statistical package for the social sciences). Least significant difference at 5% was calculated using SAS (Statistical Analysis System, version 9.3 for windows) software for the comparison among the parameters. Percentage preferences of local consumers were estimated while selecting the most acceptable variety from each product.

RESULTS AND DISCUSSION

Proximate analysis of fresh grapefruit varieties

Moisture content in different varieties of grapefruit ranged between 89.5-90.21 g/100 g. Ash is the non-gaseous, non-liquid residue left after the combustion which estimates the total mineral content of sample and in fresh edible parts of grapefruit it ranged from 0.90-1.50 g/100 g (Table 2). The carbohydrate content in grapefruit was 7 g/100 g as reported by Paul and Shaha (2004), the value being close to that reported for all the varieties of grapefruit (Table 2). The crude fibre was in the range of 1.27 (Marsh Seedless) -1.40 g/100 g (Ruby Red) and carbohydrate content was found to be in the range from 6.49 (Flame) to 7.31 g/100 g (Marsh Seedless). The calorie value of different grapefruit varieties ranged from 29.66- 32.44 kcal/100 g.

Sensory characteristics of formulated products

The formulated products were subjected to sensory evaluation and the mean overall acceptable scores of the most acceptable varieties have been depicted in web diagram (Fig 2). The chiller prepared from Red Blush variety got higher scores for taste, texture, flavor and overall acceptability by the panel of semi-trained judges and was also preferred by 69% of the untrained panel (n=50). For squash, spread and peel candy; ruby red, red blush and marsh seedless varieties got higher overall acceptability with consumer preference of 75, 73 and 78 percent, respectively.

Table 1: Formulation of value-added products of grapefruit varieties.

Name of product	Ingredients required	Amount	Method of preparation
Chiller	Grapefruit juice with pulp	300 ml	• The fresh grapefruit juice was extracted using juice extractor.
	Sugar	40 g	• Without straining the juice; sugar, lemon, black pepper, salt and water was added so that it attains the TSS of 11% and acidity 3%.
	Salt	2 g	
	Lemon juice	5 ml	
	Water	100 ml	• After the thorough mixing it was cooled in refrigerator at 5°C temp. for 30 minutes.
	Black pepper	A pinch	
Squash	Grapefruit juice	100 ml	• The grapefruit juice was extracted and sugar syrup of TSS 65°Brix was prepared.
	Sugar	165 g	
	Lemon juice	10 ml	• To the syrup; lemon juice was added and pre-strained through a sieve mesh with a pore size of 710 micrometer.
	Water	50 ml	
	Benzoic acid	600 ppm	• The syrup was air cooled at 37°C for 30 minutes. To this; pre-extracted grapefruit juice was added and strained it again through a sieve mesh with a pore size of 850 micrometer.
			• Add benzoic acid to the prepared squash and stored it in a sterilized glass bottles at a temperature of 5°C. For consumption it was diluted 5 times with water.
Peel candy	Grapefruit peel	100 g	• The peels were cut into rectangular shape and were pricked with the fork.
	Sugar	200 g	
	Calcium hydroxide*	8 g	• The slices were then dipped in a 4% calcium hydroxide solution for overnight and on other day they were washed with warm water and dipped in a sugar solution of 55°B, containing 0.3% citric acid.
	Citric acid	0.3 g	
	Sodium benzoate	A pinch	
			• Next day, degree brix of the syrup was raised by 10% by adding more sugar and then heating it.
			• It was left overnight for equilibration.
			• This process of increasing sugar by 10% was done daily till it attained 70°B of strength. Slices were kept in this syrup for a week after the addition of sodium benzoate (200 ppm)·
			• After a week, the syrup was drained and peels were dried at 55°C for 6-7 hrs. in a hot airdryer·
			• Peel candy was then stored in sterilized air tight glass containers at a room temperature (37°C).
Spread	Grapefruit pulp	50 ml	• Measured amount of grapefruit pulp and water was taken in a steel container and boiled for 10 mins. until its pulp thickened and pectin dissolved in water.·
	Sugar	55 g	
	Citric acid	0.2 g	
	Water	100 ml	
	Benzoic acid	200 ppm	• To this, sugar was added and boiled till it attained the required °Brix (36°)
			• Add citric acid and benzoic acid to it and mix it for a minute.
			• Hot pour into the sterilized air tight jars.
		·	Allow it to cool at room temperature (37°C for 30 mins.) and store it in a refrigirator at 5°C temp.

*Calcium hydroxide is generally recognized as safe (GRAS) according to the Pesticide Research Institute for the USDA National Organic Program.

Table 2: Proximate composition of fresh grapefruit varieties (on DW basis) and its formulated products (g/100 g).

Grapefruit varieties	Moisture	Ash	Protein	Crude fat	Crude fiber	Carbohyd-rates
Ruby red	89.50±0.50	1.50±0.10	0.75±0.05	0.12±0.02	1.40±0.01	6.73^{a}±0.03
Red blush	89.52±0.10	1.36±0.09	0.65±0.18	0.13±0.02	1.33±0.30	7.0^{ab}±0.20
Flame	90.21±4.51	1.10±0.22	0.70±0.05	0.10±0.01	1.39±0.06	6.49^{a}±0.06
Marsh seedless	89.83±1.13	0.90±0.03	0.60±0.02	0.09±0.003	1.27±0.07	7.31^{b}±0.02
p value	0.99^{NS}	0.09^{NS}	0.73^{NS}	0.35^{NS}	0.91^{NS}	0.02*
			Most acceptable varieties of formulated products			
Chiller (Red blush)	77.60^{c}±0.92	0.82^{a}±0.02	0.60±0.15	0.09±0.02	0.68^{a}±0.09	20.20^{a}±0.02
Squash (Ruby red)	72.37^{c}±0.93	-	-	-	-	27.63^{b}±1.01
Peel candy (Marsh seedless)	15.77^{a}±1.28	4.40^{b}±0.01	0.30±0.03	-	2.0^{b}±0.30	77.53^{d}±2.64
Spread (Red blush)	37.50^{b}±0.90	0.30^{a}±0.19	-	-	0.50^{a}±0.05	61.70^{c}±1.15
p value	<0.001*	<0.001*	0.19^{NS}	-	0.02*	<0.001*

Values are Mean±SD.

Values in columns followed by different superscripts differ significantly (p≤0.05).

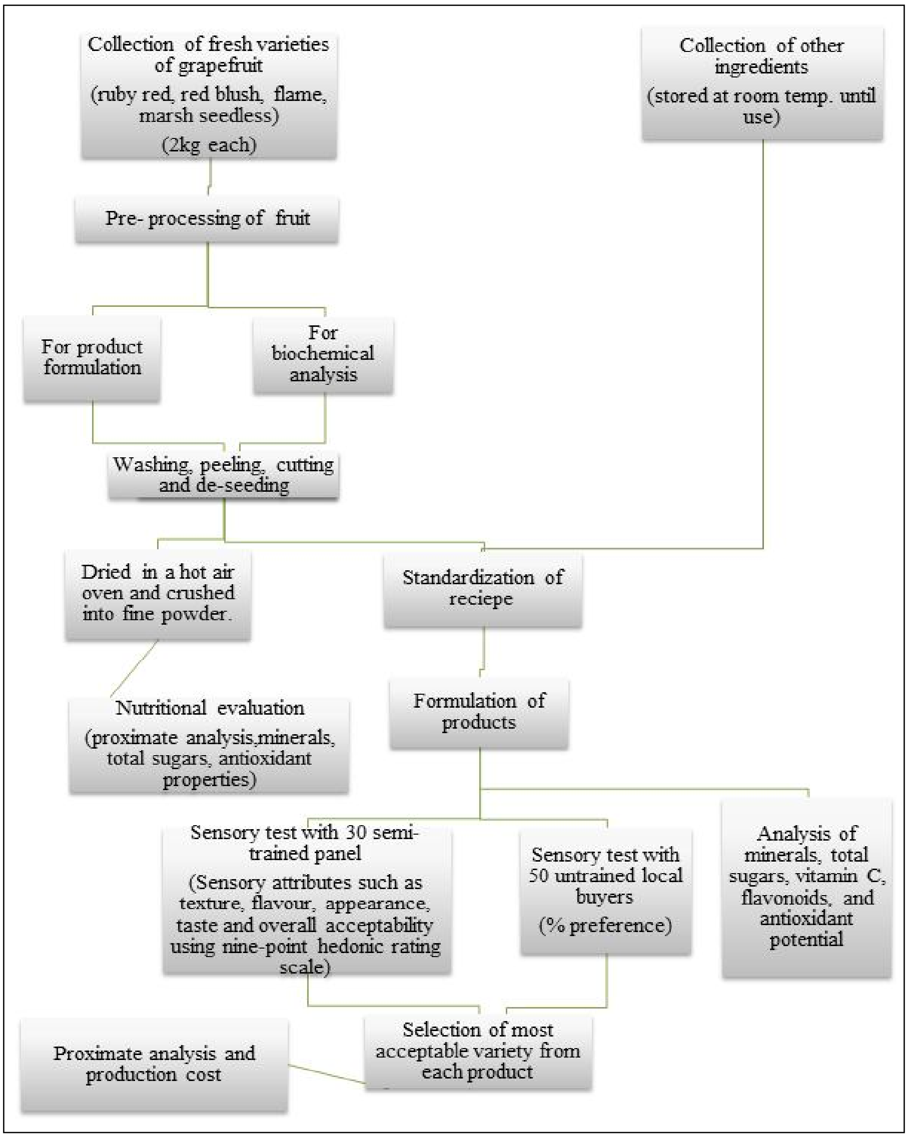

Fig 1: Experimental of formulation and nutritional evaluation of value-added grapefruit products.

Mineral content, total sugars (reducing and non-reducing) and Ascorbic acid of grapefruit varieties and its products

Potassium and calcium content of grapefruit varieties and products have been depicted in Table 4. Among products, peel candy had significantly higher amount of minerals. Reducing and non- reducing sugars ranged between 5.39-5.72 g/100 g among four varieties of grapefruit (Table 3). However, among the formulated products, peel candy had the highest amount of total sugar (56.90- 57.37 g/100 g)

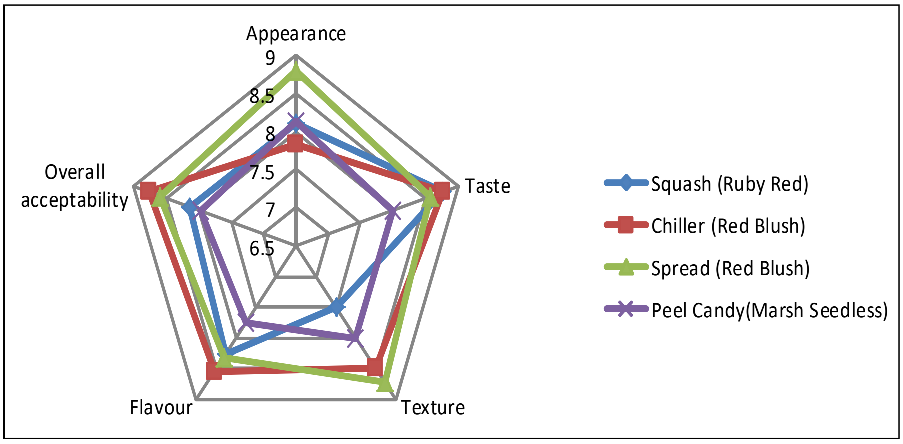

Fig 2: Overall Acceptability of most acceptable grapefruit varieties of the formulated products.

Table 3: Total sugars (reducing and non- reducing) in grapefruit varieties (g/100 g on FW basis) and its formulated products.

Grapefruit varieties	Total sugars (g/100 g)	Reducing sugars (g/100 g)	Non-reducing sugars (g/100 g)
Ruby red	5.40^{a}±0.01	3.40±0.40	2.0±0.50
Red blush	5.66^{b}±0.03	3.96±0.01	1.70±0.30
Flame	5.39^{a}±0.06	3.98±1.0	1.41±0.10
Marsh seedless	5.72^{b}±0.02	3.37±0.07	2.35±0.02
p value	0.005*	0.77^{NS}	0.28^{NS}
		Chiller	
Ruby red	11.48±0.03	4.35±0.02	6.15^{a}±0.15
Red blush	11.73±0.03	4.89±0.01	6.84^{a}±0.10
Flame	11.47±0.10	5.0±0.50	6.50^{a}±0.05
Marsh seedless	11.90±0.35	4.32±0.02	7.40^{b}±0.05
p value	0.40 ^{NS}	0.25 ^{NS}	0.003*
		Squash	
Ruby red	24.5±0.50	10.50±0.50	14.0±0.50
Red blush	24.76±0.01	11.11±0.11	14.75±0.20
Flame	24.45±0.05	11.20±0.20	14.45±0.03
Marsh seedless	24.90±0.45	10.45±0.05	15.50±0.06
p value	0.76 ^{NS}	0.25 ^{NS}	0.07 ^{NS}
		Peel Candy	
Ruby red	56.98±0.03	25.25±0.05	32.05^{b}±0.05
Red blush	57.20±0.02	25.80±0.30	31.65^{a}±0.05
Flame	56.90±0.20	26.0±1.0	31.35^{a}±0.03
Marsh seedless	57.37±0.04	25.0±0.30	32.37^{c}±0.04
p value	0.10 ^{NS}	0.60 ^{NS}	0.0004*
		Spread	
Ruby red	54.45±0.05	24.0±0.24	31.0±0.23
Red blush	54.69±0.30	23.99±0.20	30.70±0.04
Flame	54.40±0.40	24.20±0.20	30.40±0.40
Marsh seedless	54.89±0.10	23.35±0.20	31.40±0.20
p value	0.56 ^{NS}	0.15 ^{NS}	0.17 ^{NS}

Values are Mean±SD.

Values in columns followed by different superscripts differ significantly ($p \le 0.05$).

Table 4: Minerals and antioxidant properties of grapefruit varieties and its formulated products.

Grapefruit Varieties	Ruby Red	Red Blush	Flame	Marsh seedless	p value	LSD at 5%
Potassium content (mg/100 g)						
Fresh fruit	111±4	113±1	111±3	117±2.1	0.461	NS
Chiller	107±2	109±1	107±0.4	114±1.5	0.06	NS
Squash	33.3^{a}±0.3	36^{bc}±0.5	34^{ab}±0.13	40^{c}±1.3	0.008	2.81
Peel candy	118^{a}±1	120^{b}±0.3	118^{a}±0.23	124^{c}±0.64	0.007	2.45
Spread	37.3^{a}±0.1	40^{ab}±1.2	38^{a}±0.7	45^{b}±0.21	0.005	2.76
Calcium content (mg/100 g)						
Fresh fruit	20.5±0.5	21±1	20.5±0.05	21.7±0.4	0.51	NS
Chiller	19.5^{a}±0.2	20^{ab}±0.2	19.5^{a}±0.05	20.7^{b}±0.2	0.023	0.69
Squash	3±0.15	3.5±0.06	3±0.6	4.5±0.17	0.08	NS
Peel candy	21.7±0.15	22.3±0.3	21.7±0.7	23±1	0.5	NS
Spread	4.5^{a}±0.1	5^{ab}±0.3	4.5^{a}±0.11	6^{b}±0.1	0.01	0.68
Ascorbic acid (mg/100 g)						
Fresh fruit	33.03±2.13	33.39±2.19	33.29±3.39	34.73±2.33	0.72	NS
Chiller	21.75^{a}±0.61	25.15^{ab}±0.7	22.59^{ab}±1.59	28.89^{b}±0.34	0.02	3.676
Squash	1.5^{a}±0.2	2.95^{bc}±0.05	2.2^{ab}±0.2	3.72^{c}±0.23	0.004	0.722
Peel candy	21.5^{ab}±1	22^{ab}±0.5	20.07^{a}±0.64	24.10^{b}±0.1	0.05	2.536
Spread	13.39^{a}±0.39	16.25^{b}±0.5	14.28^{ab}±0.31	18.85^{c}±0.08	0.0015	1.4
Total flavonoid (mg QE/100 g)						
Fresh fruit	68.77±3.24	73.39±2.89	68.08±2.49	75.07±1.52	0.3	NS
Chiller	66.97^{a}±0.12	70.39^{b}±0.4	67.32^{a}±0.55	72.75^{b}±0.88	0.0051	2.19
Squash	48.11^{a}±0.02	51.78^{b}±0.78	49.57^{ab}±0.65	52.5^{b}±0.5	0.0164	2.23
Peel candy	73.5^{ab}±0.95	76.03^{b}±0.14	72.28^{a}±0.72	77.33^{b}±0.33	0.014	2.44
Spread	50.85^{ab}±0.98	53.3^{b}±0.3	50.66^{a}±0.06	55.91^{c}±0.3	0.0064	2.099
DPPH radical scavenging activity (% inhibition)						
Fresh fruit	75.44±1.5	76.92±1.22	75.59±0.59	78.40±3.2	0.66	NS
Chiller	70.99^{a}±0.115	73.47^{ab}±0.88	71.32^{a}±0.5	75.82^{b}±0.45	0.01	2.187
Squash	53.57^{ab}±0.07	56.77^{b}±0.77	53.22^{a}±0.3	59.3^{c}±2.3	0.065	4.764
Peel candy	65.5^{a}±0.5	68.66^{b}±0.06	65.79^{ab}±0.9	70.5^{b}±0.95	0.02	2.75
Spread	64.80^{a}±0.4	66.77^{ab}±1	65.39^{a}±0.01	69.25^{b}±0.25	0.016	2.17

Values are Mean±SD.

Values in columns followed by different superscripts differ significantly (p≤00.05).

LSD: Least significant difference at 5%.

and chiller had the lowest (11.47-11.90 g/100 g) with no significant varietal difference in the products. Amongst the varieties, flame variety had the highest amount of reducing sugar *i.e.* 3.98 g/100 g. Amongst the products, peel candy had the highest amounts (25.0-26.0 g/100 g). Total and reducing sugar was 32.84 and 8.18 percent in lemon cordial (Helali *et al.,* 2008) and 68.54 and 22.40 per cent in peel candy of sweet orange (Bisht 2017).

Citrus fruits are primarily rich in ascorbic acid and are major contributors to antioxidant activity of fruit. It scavenges the free radical by donating its own electron and breaking the chain reaction of free electrons and thus protecting the other molecules from oxidation ascorbic acid, in fresh grapefruit varieties was present between 33.03±0.3-34.73±2.33 mg/100 g with highest content in Marsh Seedless and lowest in Ruby Red variety (Table 4). Among grapefruit products, chiller reported maximum amount of it (21.75±0.61-28.89±0.34 mg/100 g).

Total flavonoids and DPPH radical scavenging activity (% Inhibition)

In grapefruit varieties flavonoids ranged from 68.08±2.49 (Flame) to 75.07±1.52 mg QE/100 g (Marsh Seedless). Among grapefruit products, peel candy had the maximum amount (72.28±0.72-77.33±0.33 mg QE/100 g). The results of antioxidant potential was in comparison with the study of Muzykiewicz *et al.,* (2019) who evaluated the highest antioxidant potential in the white grapefruit extracts by DPPH method. Antioxidant activity of fresh grapefruit varieties was found to be ranging from 75.44±1.50 to 78.40±3.20 per cent. In grapefruit products, the maximum % inhibition was observed in chiller *i.e.* from 70.99±0.11 to 75.82±0.45 (Table 4).

CONCLUSION

It can be concluded that the grapefruit can be used to make value added products with minimal processing at household level to harness the nutritional and health benefits of this fruit. The present effort can be considered a good initiative to enhance the consumption of this nutritionally rich fruit, which otherwise is not being used upto the mark due to its bitter and sour taste.

Conflict of interest: None.

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