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Evaluation of engineering, physiochemical and nutritional properties of three different varieties of pomelo fruit

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ABSTRACT

Purpose: The aim of this study was to identify the engineering, physiochemical, and nutritional properties of selected varieties of pomelo fruit. **Research method:** The study was carried out using a one-way analysis of variance with three replications on selected varieties of pomelo fruit. The experiment consisted of three cultivars, namely red, pink, and white pomelo to analyze the engineering, physiochemical, and nutritional properties. **Findings:** The results revealed that the geometrical and gravimetric analysis showed variation among different parameters of varieties of pomelo fruit. Textural property, such as the puncture resistance test was highest for the pink variety at 20.19 N. The color analysis in the optical parameter showed the highest values for the white variety of pomelo. The identification of functional compounds done by Fourier transform infrared spectroscopy provides advancement for the production of different functional products. The assessment of physicochemical and nutritional properties provides knowledge of nutrients, essential minerals (boron, magnesium, aluminum, silicon, phosphorous, potassium, iron, copper, zinc), and quality of fruit, making it an expert functional food ingredient and can be utilized for various applications in food industries. The physicochemical and nutritional properties indicated significant variation ($p<0.05$) among different parts of selected varieties of pomelo fruit. **Research limitations:** There was no limitation. **Originality/Value:** Pomelo is an underutilized fruit with a rich source of bioactive compounds, has a favorable nutritional profile, and has health-improving effects. With its great nutritive value, utilization of this fruit is still very limited because of a lack of information regarding its physicochemical, nutritional, and processing technologies. This research work on different food properties provides a broad area of knowledge regarding designing, processing, storage, transportation, product development and is useful to encourage commercialization.

INTRODUCTION

Pomelo, known as *Citrus maxima*, is one of the largest and most exotic fruits of the citrus family. It is a significant citrus fruit grown in India and accounts for approximately 30% of the total area used for citrus cultivation. Pomelo fruit is blessed with a large number of vitamins, minerals, pectins, dietary fibers, and also polyphenols (flavonoids and phenolics) (Li et al., 2022). The presence of these active constituents in pomelo fruit is considered to exhibit health benefits such as anti-inflammatory, antitumor, anticlotting, antimicrobial, and antioxidant activities. Known for its aroma, flavor, and tangy taste, it is commonly used to extract juice but is also consumed in raw form (Li et al., 2022; Tocmo et al., 2020). Pomelo fruit and its different fruit parts such as peel, segment peel, seeds, juice, and pomace are composed of an array of physicochemical and nutritional components. The waste discarded during production and processing contains a huge number of useful active compounds and presents valuable prospects in the fields of technology and health promotion (Yin et al., 2023; Lin et al., 2021). Despite all health-encouraging and therapeutic benefits, the pomelo fruit is regarded as underutilized due to the lack of processing techniques that further because several post-harvest losses. During agricultural processing to avoid post-harvest damages, information related to engineering properties such as physical, frictional, mechanical and optical properties are valuable for effective industrial processing of pomelo fruit, benefit with designing and manufacturing of various processing equipment, for handling, cleaning, conveying, grading, transportation, and storage (Lawal et al., 2023; Ihrahim & Hamed, 2018; Sirisomboon & Lapchareonsuk, 2012). It is necessary to know about how the external and internal properties of pomelo vary ultimately affecting the transportation and storage.

Information regarding the engineering properties of pomelo fruits is sparse, so there is a need to evaluate the properties that can benefit with designing and manufacturing of various processing equipment (Shravan & Shere, 2018). For the identification of functional groups fourier transform infrared spectroscopy (FTIR) is a rapid method for the estimation of different absorption bands and further provides a vision for the advancement of several functional foods. The physicochemical properties of fruits are important to determine the final quality of the product as well as evaluate the inner and outer structure of the fruit (Sirisomboon & Theamprateep, 2012). Furthermore, the assessment of these characteristics is crucial to design and ensure the quality of the food during its processing. The nutritional value and health benefits of pomelo fruit cause popularity among consumers because of the development of emerging food products from the waste of pomelo fruit (Gupta et al., 2021; Motie et al., 2014). Mineral elements are vital for the growth and development of living organisms, primarily binding to proteins to create metalloproteins, particularly enzymes. Mineral elements typically play crucial roles in maintaining human health, and a lack of these elements can result in unfavorable clinical disorders. However, these conditions can be prevented or reversed with appropriate supplementation. The majority of mineral elements found in the human body are derived from daily food consumption, with fruits being a particularly significant source (Zhang & Rui, 2012). Figure 1 depicts the overview of the engineering, physiochemical, and nutritional properties of pomelo fruit. From the literature, the engineering properties were mainly studied on orange, mandarin, tangerine, kinnow, and murcott varieties of citrus. No specific paper was available on pomelo varieties regarding all the engineering properties, and only the textural properties of pomelo were available. Also, less data availability related to the physicochemical, nutritional, and mineral properties of different varieties of pomelo fruit. Hence, the present study was undertaken to evaluate the engineering, physiochemical, and nutritional properties of different varieties of pomelo fruit to build essential information for food researchers, processors, and scientists regarding industrial processing and applications in food industries.

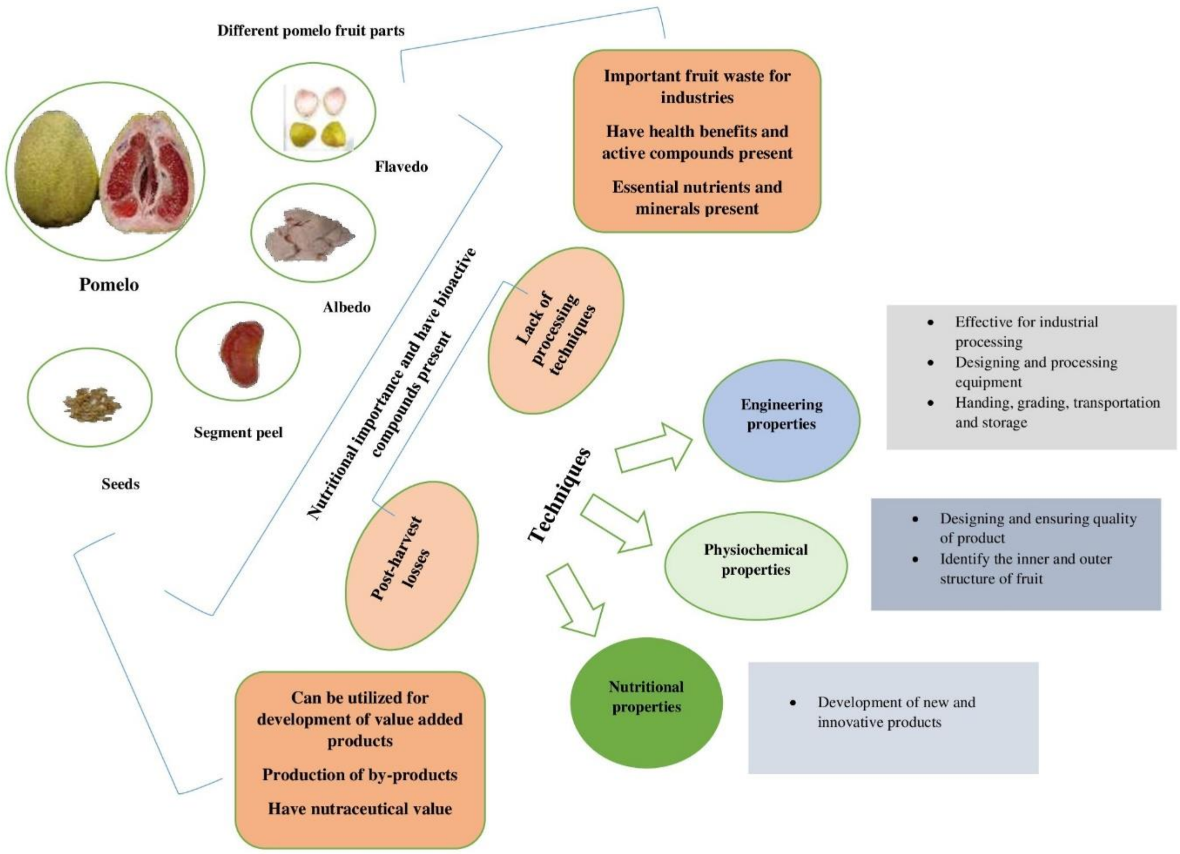

Fig. 1. Overview of engineering, physiochemical and nutritional properties of pomelo fruit.

MATERIALS AND METHODS

Raw material selection

Pomelo fruits were procured from the Department of Fruit Science, Punjab Agricultural University, Ludhiana, India for the year 2024. To provide an accurate representation of the gathered produce, random sampling was used. Only healthy fruits were evaluated for the study; all damaged and diseased fruits were thrown away. The selected fruits were washed, cleaned, and used for different analysis. For FTIR and mineral analysis lyophilized samples of pomelo fruit were used (Pomelo fruits lyophilized at -50°C, as dried samples are required for test). The evaluation of engineering, physiochemical, and nutritional properties were assessed using fresh commodity.

Chemicals

All the chemicals used in the analysis were of high purity AR grade obtained from Sigma Aldrich, USA.

Determination of the physical properties of pomelo fruit

Physical properties play a significant role in the production of processing technology and the quality of final products. The quality aspect of any fruit can be indicated by the physical parameter. The physical properties include geometric and gravimetric properties:

Geometric properties

The length and width of the pomelo fruit were measured using a digital Vernier caliper 0.01 mm. The diameter of the fruit was evaluated at three different points, i.e., the major, middle, and minor positions from the top, middle, and bottom of the fruit. Fruit weight was evaluated using 5 pomelo fruits chosen at random, and their weights were recorded on an electronic scale with a precision of 0.01 g (Shravan & Shere, 2018). The fruit parts' weight including the rind, flavedo, albedo, segment peel, seeds, pulp, and pomace were determined by using an electronic weighing balance with a precision of 0.01 g as described by Shravan & Sere, (2018).

The arithmetic, geometrical mean diameter, and sphericity of pomelo fruit were measured by standard formulas (1 to 3) Yadav et al. (2019); Selvan et al. (2021).

$$\mathrm{AMD} = \frac{\mathrm{L}+\mathrm{W}+\mathrm{H}}{3} \qquad (1)$$

Where L= Length, W= Width, H= Height (mm)

$$\mathrm{GMD} = (\mathrm{L} \times \mathrm{W} \times \mathrm{H})^{1/3} \qquad (2)$$

Where L= length, W= width, H = height (mm)

$$\mathrm{Sphericity} = \mathrm{D}/\mathrm{H} \qquad (3)$$

Where D = diameter of fruit (mm), and H = height (mm)

The shape can be predicted by evaluating the nature of the fruit and using its sphericity value. The rind thickness of citrus fruit was measured using a digital Vernier caliper with a precision of 0.01 mm (Mukhim et al., 2015). Number of seeds was measured for three fruits by manually separating and counting, after which the average was determined and expressed as a number (Shravan & Shere, 2018). The length and width of the pomelo fruit seeds were measured using an electronic Vernier caliper with a 0.01 mm accuracy. One seed and the hundred seed weight were measured by using an electronic weighing balance with a precision of 0.01 (Deivasigamani & Swaminathan, 2018).

Gravimetric properties

The surface area and volume of the sample were determined using formulas (4 to 5) Selvan et al. (2021):

$$\mathrm{S} = \pi \times (\mathrm{GMD})^2 \qquad (4)$$

$$\text{Volume of sample (V)(ml)} = \text{Final toluene level} - \text{Initial toluene level (ml)} \qquad (5)$$

The bulk density was calculated using a cylindrical container and balance. Fruits were placed into a jar to the top of its upper border. Fruits that protruded half of their part above the container's top border were removed. The mass of the fruits packed in the container was measured using an electronic balance, and bulk density was calculated as explained by Rafiee et al. (2007).

$$\text{Bulk density } (\rho b) = \frac{m_b}{V} \tag{6}$$

Where ρ_b = Bulk density (kg/m^3), m_b = Mass of fruits (kg), V = Volume of cylindrical container (m^3)

True density is defined as the samples mass divided by its actual volume. Using the toluene displacement technique, the true density was determined. A single pomelo fruit was carefully placed into a 1000 ml measuring cylinder that was half-filled with toluene and its mass was measured using an electronic balance with a resolution of 0.0001 g (Selvan et al., 2021). The fruit's displacement of toluene was measured, and the real density was determined as follows:

$$\text{True density } (\rho t) = \frac{m}{V_{td}} \tag{7}$$

Where ρ_t = True density (kg/m^3); m = Mass of individual fruit (kg); V_{td} = Volume of toluene displaced (m^3)

Porosity (ε) was computed according to Singh et al. (2019) using the following relationship from the average values of bulk and actual densities.

$$\text{Porosity } (\varepsilon) = \frac{\rho_t - \rho_b}{\rho_t} \times 100\% \tag{8}$$

The projected area was used to estimate the fruit-projected areas perpendicular to dimensions (PA1, PA2, and PA3) using the equation given by Mahawar et al. (2019).

$$\text{CPA} = \frac{\text{PA}_1 + \text{PA}_2 + \text{PA}_3}{3} \tag{9}$$

Where PA_1 = Projected area perpendicular to the length (mm^2), PA_2 = Projected area perpendicular to the width (mm^2), PA_3 = Projected area perpendicular to the thickness (mm^2)
The L-D and L-M ratio was calculated by standard equations (10 to 11) Mahawar et al. (2019).

$$\text{L} - \text{D ratio} = \text{L/D} \tag{10}$$

Where L = length; D = diameter

$$\text{L} - \text{M ratio} = \text{L/M} \tag{11}$$

Where L = length; M = mass

The flesh/seed ratio was measured by the method outlined by Ercisli et al. (2015). The mass and seeds are separated from the fruits after cutting them. To calculate the flesh-to-seed ratio, the two portions were first individually weighed and divided into their component parts to determine the flesh/seed ratio.

Frictional properties

The frictional properties are related to friction and are important in the design of handling and conveying equipment of produce. The frictional properties involve the angle of repose of seeds and the coefficient of static friction.

Angle of repose of seeds

The method used by Fathollahi et al. (2021) involved filling a hollow cylinder with seeds and gently removing the cylinder upward to allow the seeds to run down the closed container and form a conical shape, which was used to determine the angle of repose. The apex height was measured, and the repose angle was calculated using the trigonometry rule as given:

$$\theta = \tan^{-1}(h/r) \qquad (12)$$

Coefficient of static friction

This is the ratio of the force required to begin sliding the sample across a surface and the sample's weight. The method described was used to determine the coefficient of static friction on four distinct structural surfaces, including steel sheet, iron sheet, glass, and plywood (Dhineshkumar & Siddharth, 2015). Each fruit was set on the floor and lifted gradually with a screw until it started to slide. When sliding starts, the inclined surface's angle with the horizontal is measured. The following expression was used to compute the coefficient of static friction (s).

$$\text{Coefficient of static friction } (\mu s) = \tan\theta \qquad (13)$$

Where θ = Angle that the incline makes with the horizontal when sliding begins

Textural/mechanical property

The texture analyzer was equipped with a 5 mm cylindrical probe to the probe carrier to assess the puncture resistance test. The stem calyx axis of the pomelo was aligned with the flat plate before it was set on top of it. The test was run with the probe moving at a speed of 5 mm/s. Average values are presented for the three fruits (replications) used to measure the puncture resistance as determined by Singh et al. (2019).

Optical properties

The Hunter lab colorimeter was utilized to access the color parameters of the fruit samples by measuring L*, a* and b* values using the CIE system (Lab Scan XE spectro-colorimeter), which were assessed in terms of CIE L (lightness), a (redness and greenness), and b (brightness) (yellowness and blueness). A white tile and a black tile were used to normalize the sensor's color measurement. Each fruit was placed over the colorimeter's sample measurement port's 8 mm aperture to measure its color. At each place, measurements were taken three times, and then they were averaged Hongwiangjan et al. (2015).

Identification of functional groups

FTIR

The different functional groups present in different parts of selected varieties of pomelo fruit were evaluated using FTIR (PerkinElmer, USA). The absorption spectra of the samples were analyzed in the range of 450–4000 cm^{-1} with 4 cm^{-1} resolutions (Deng et al., 2021).

Physiochemical properties

Different physiochemical properties such as pH, TSS, titratable acidity, ascorbic acid, and reducing, non-reducing, and total sugars of pomelo varieties are studied. pH was measured using method 981.12 (AOAC, 2005). The total soluble solid of the fruit was determined with a refractometer (LABOLAN, SL, Mod 301, Navarra, Spain) using method 932.12 (AOAC, 2005). Titratable acidity was measured according to method 942.15 (AOAC, 2005). Ascorbic acid (AA) was determined based on the quantitative discoloration of 2,6-dichlorophenol indophenol titrimetric method as described in method 967.21 (AOAC, 2005). The reducing, non-reducing, and total sugars were estimated using Lane and Eynon method (Khan et al., 2021). All observations were taken in triplicates.

Nutritional properties

Each part of selected varieties of pomelo fruit is utilized for the determination of nutritional properties such as moisture content, total ash, crude fat, crude fiber, crude protein, and carbohydrate content. Moisture content was determined according to method 930.04 AOAC (2005). Total ash assessed the quality of food products for the presence of inorganic substances in it by using method 930.05 (AOAC, 2005). Crude fat was determined in accordance with the Soxhlet extract method using petroleum ether as the extracting agent (60-80 °C) according to method 930.09 (AOAC, 2005). Crude fiber was determined according to the method of Ani & Abel (2018). Crude protein content (N × 6.25) was determined following the Kjeldahl method (method 978.04) (AOAC, 2005). The carbohydrate content was determined by a difference method (Khan et al., 2021). The sum of the percentage moisture, ash, protein, fat, and crude fiber was subtracted from 100.

$$\text{Percentage (\%) carbohydrate} = 100 - (\text{\%moisture} + \text{\%ash} + \text{\%protein} + \text{\%fat} + \text{crude fiber}) \quad (14)$$

Mineral elements were identified using Inductive Coupled Plasma mass spectrometry (ICP-MS, 7900, Agilent), and pomelo samples were prepared by microwave digestion with similar conditions and operating requirements as described by (Zhang & Rui, 2012).

Statistical analysis

The means and standard deviations were computed for the different properties of pomelo fruit. All experiments were performed in triplicate, and final values were reported as the mean ± standard deviation (SD). The data were analyzed using one-way analysis of variance (ANOVA) using IBM SPSS Statistics version 22 software (Armonk, NY: IBM Corp.). To assess the significant values ($p \leq 0.05$), the Tukey range HSD test was performed.

RESULTS AND DISCUSSION

Physical properties of pomelo fruit

The physical properties include both geometric and gravimetric properties. Obtained results for the tested geometric properties are presented in Table 1. Geometric properties indicate dimensional characteristics and are vital for designing mechanisms for the storage and transportation of harvested produce. Length is a geometric property used in safeguarding solids by separating non-native particles and defining thermal and mass transfer (Khan et al., 2021; Shravan & Shere, 2018). The variation in fruit length and width varies with varieties of pomelo fruit. The red pomelo attained the highest length and width of 143.63 and 128.19 mm as compared to pink and white pomelo, respectively. The fruit diameter of pomelo fruits was measured from the top, middle, and bottom portions. The red pomelo had the highest diameters from the middle and bottom portions at 116.38 and 122.22 mm, with a low mean value at the top portion of 89.15 mm. The white pomelo had an eminent diameter of 97.93 mm at the top portion, whereas low average values of 115.66 mm and 104.71 mm were attained from the middle and bottom areas, respectively. The pink pomelo had a small diameter of fruit at all three top, middle, and bottom portions. The highest fruit weight was observed in pink pomelos at 1238.17 g followed by red and white pomelos. Primary dimensions such as length, width, and thickness are critical in the design of processing equipment such as graders, sorters, and cleaners. The weights of different parts, including the rind, flavedo, albedo, segment peel, seeds, pulp, and pomace of pomelo, were measured. The pink pomelo had the highest rind weight, flavedo, albedo, segment peel, seeds, pulp, and pomace at 326.17, 156.87, 235.57, 110.47, 23.20, 674.20, and 174.50 g, respectively. The arithmetic and geometric mean diameters were highest in red pomelo at 129.43 and 128.94 mm, respectively. Sphericity values are used to size equipment and design separators, and the aspect ratio shows how oblong the fruit is. The sphericity was higher in red pomelo at 1.12%, whereas pink and white pomelo had values of 1.02 and 1.08%, respectively. It showed that the red variety of pomelo fruit can be considered a spherically shaped fruit. The shape of the red pomelo was obovate, the pink pomelo was round and the white pomelo was oblate in shape due to the variation in diameter and values of sphericity of all three varieties from the top, middle, and bottom portions, respectively. The rind thickness protects the fruit from external environmental stresses. The rind thickness was highest in the pink pomelo at 14.48 mm. Red pomelo showed the highest average seeds per fruit, i.e. 67.67, whereas pink and white indicated fewer seeds per fruit at 62.67 and 25.33. The seed length was highest in the red pomelo at 27.74 mm and seed breadth was large in the white pomelo at 18.91 mm. One seed weight indicated the highest in red pomelo at 0.41 g, whereas the 100 seed weight was highest in pink pomelo at 44.93 g. The mean values for the geometric properties of the three varieties of pomelo showed significant ($P<0.05$) differences for all the studied properties. The results of the geometric properties of pomelo cultivars are close to the values determined by Mahawar et al. (2019) in Kinnow mandarin and Rehal et al. (2017) in Murcott mandarin.

Gravimetric properties are imperative for the design of packaging material and transportation systems. The data related to gravimetric properties are indicated in Table 2. The surface area of the red pomelo had the highest mean value of 52317.80 mm^2. The volume of fruit was determined with the displacement method. The volume of the white pomelo fruit was the highest at 578.67 ml. These volumes help in the estimation of density and heat transfer rates during fruit drying and cooling. The values of surface area and volume of fruit were higher than the values evaluated by Shahbazi and Rahmati (2013) in grapefruit. The bulk and true densities were higher for pink pomelo fruit at 565.97 and 1318.33 kg/m^3. The results of the bulk and true densities of pomelo fruit were higher than the values depicted by Rehal et al. (2017) in Murcott mandarin. The porosity was higher in white pomelo at 69.73%, and red and pink pomelo had porosities of 54.11 and 57.06%, respectively. The bulk density, true density, and porosity are useful factors for constructing the hopper and managing the flow rate in fruit processing, grading, transporting, and packaging equipment (Ani & Abel, 2018; Shahbazi & Rahmati, 2013). The projected area serves as an accurate model for heat and mass transfer analysis during drying and cooling unit operations and serves as a suitable indicator of mass and specified information regarding projected areas that generate the design of grading units (Rehal et al., 2017). Red pomelo had the highest projected area of 41677.46 mm^2. The results related to porosity and projected area of pomelo fruit were higher in relation to the results of Miraei Ashtiani et al. (2014) in lime and Singh et al. (2019) in sweet orange and sweet lemon. The L-D ratio was higher in the red pomelo at 1.24, whereas the L-M ratio was higher in the white pomelo at 0.19. The flesh/seed ratio was highest at 64.85 in red pomelo. The mean values for all the gravimetric properties of pomelo varieties defined significant ($P<0.05$) differences for the studied properties. The results derived for L-D, L-M, and flesh/seed ratio of pomelo cultivars were higher compared to results evaluated by Mahawar et al. (2019) in Kinnow mandarin and Rehal et al. (2017) in Murcott mandarin.

Table 1. Geometric properties of different varieties of pomelo fruit.

Geometric parameters		Red pomelo	Pink pomelo	White pomelo
Fruit length (mm)		143.63±12.11^{a}	100.75±4.68^{b}	116.45±2.22^{b}
Fruit width (mm)		128.19±1.46^{a}	101.90±9.01^{b}	122.55±7.81^{a}
Fruit diameter (mm)	Top	89.15±2.45^{b}	86.64±8.34^{ab}	97.93±5.34^{a}
	Middle	116.38±2.43^{a}	102.84±7.59^{b}	115.66±8.78^{a}
	Bottom	122.22±3.53^{a}	97.71±7.01^{c}	104.71±12.21^{b}
Fruit weight (g)		932.50±78.76^{ba}	1238.17±165.19^{a}	621.00±71.17^{c}
Fruit parts weight (g)	Rind	325.93±0.84^{b}	362.17±0.59^{a}	216.80±31.61^{c}
	Flavedo	126.50±1.05^{b}	156.87±0.42^{a}	58.18±0.59^{c}
	Albedo	206.30±2.25^{b}	235.57±0.74^{a}	126.17±0.65^{c}
	Segment peel	82.00±0.87^{b}	110.47±0.64^{a}	37.60±0.85^{c}
	Seeds	7.28±0.06^{ba}	23.20±0.20^{a}	5.33±0.04^{cb}
	Pulp	472.13±2.10^{b}	674.20±0.20^{a}	218.10±0.56^{c}
	Pomace	157.70±1.30^{b}	174.50±0.70^{a}	65.81±0.46^{c}
Arithmetic mean diameter (mm)		129.43±0.03^{a}	101.84±0.02^{c}	118.24±0.02^{b}
Geometrical mean diameter (mm)		128.94±0.02^{a}	101.85±0.02^{c}	118.17±0.03^{b}
Sphericity (%)		1.12±0.02^{a}	1.02±0.02^{b}	1.08±0.02^{a}
Shape		Obovate	Round	Oblate
Rind thickness (mm)		9.95±2.43^{cb}	14.48±2.08^{a}	10.06±1.86^{b}
Number of seeds per fruit (Seeds/fruit)		67.67±1.53^{a}	62.67±0.58^{b}	25.33±0.58^{c}
Seed	Length (mm)	27.74±0.67^{a}	16.28±1.24^{c}	23.76±1.12^{b}
	Breadth (mm)	18.73±0.63^{a}	9.66±0.85^{b}	18.91±0.69^{a}
One seed weight (g)		0.41±0.05^{a}	0.38±0.01^{ba}	0.28±0.05^{c}
100 seed weight (g)		41.67±1.45^{b}	44.93±0.31^{a}	19.26±0.02^{c}

Values are expressed as Mean ± SD (n=3). Values having different superscripts in the same row indicated significant difference (p<0.05).

Frictional properties of pomelo fruit

The data related to frictional properties are depicted in Table 3. The angle of repose of seeds was higher in the pink pomelo at 73.55, whereas the red and white pomelo had 65.56 and 59.05. For the measurement of the coefficient of static friction, different structural surfaces, such as steel sheets, iron sheets, glass, and plywood were utilized. The steel sheet, glass, and plywood had the highest coefficient of static friction of 0.30, 0.42, and 0.41 under red pomelo. The iron sheet had the highest static friction of 0.35 under the white pomelo. The mean values for all the frictional properties of pomelo varieties defined significant (P<0.05) differences for the studied properties. The coefficient of friction and angle of repose parameters aid in determining shearing forces between fruits and surfaces for conveyor design. They can also be used to determine the natural rest position of fruit during storage

(Singh et al., 2019; Miraei Ashtiani et al., 2014). The results of the angle of repose of seeds and the coefficient of static friction parameters of frictional properties are close to the values depicted by Miraei Ashtiani et al. (2014) in lime and Singh et al. (2019) in sweet orange and sweet lemon.

Textural/Mechanical property of pomelo fruit

The textural properties indicated an important role in the quality of the produce. These properties are beneficial to design a machine that can puncture the fruit with ease. For textural properties, a puncture resistance test was examined. The data related to textural properties are indicated in Table 4. The puncture resistance test was higher in pink pomelo at 20.19 N, whereas red and white pomelo had 11.81 N and 15.27 N puncture resistance. The mean values of the textural properties of pomelo varieties defined a significant ($P<0.05$) difference for the puncture resistance test. The results determined that the pink pomelo variety had more strength and therefore, the machine required more energy to break the fruit. But, as literature revealed the energy required to break the fruit should be minimal to cut costs and enhance machine efficiency. The result of puncture resistance was close to the values reported by Sirisomboon and Theamprateep (2012) in pomelo fruit.

Table 2. Gravimetric properties of different varieties of pomelo fruit.

Gravimetric parameters	Red pomelo	Pink pomelo	White pomelo
Surface area (mm^2)	52317.80±16.90[a]	32643.00±9.79[c]	43945.15±19.69[b]
Volume of fruit (ml)	512.00±102.14[a]	299.67±14.50[b]	578.67±70.47[a]
Bulk density (kg/m^3)	487.14±0.99[b]	565.97±1.87[a]	284.28±2.02[c]
True density (kg/m^3)	1061.67±3.51[b]	1318.33±3.51[a]	941.67±60.93[c]
Porosity (%)	54.11±0.21[b]	57.06±0.05[b]	69.73±1.70[a]
Projected area (mm^2)	41677.46±3044.87[a]	24140.98±2179.89[c]	32966.62±1994.83[b]
L-D ratio	1.24±0.13[a]	0.98±0.07[b]	1.01±0.10[b]
L-M ratio	0.16±0.02[a]	0.08±0.01[b]	0.19±0.03[a]
Flesh/seed ratio	64.85±0.25[a]	29.06±0.25[c]	40.92±0.43[b]

Where; L-D ratio = Length-diameter ratio, L-M ratio = Length-mass ratio. Values are expressed as Mean ± SD (n=3). Values having different superscripts in the same row indicated significant difference ($p<0.05$).

Table 3. Frictional properties of different varieties of pomelo fruit.

Frictional parameters		Red pomelo	Pink pomelo	White pomelo
Angle of repose (°) of seeds		65.56±0.58[b]	73.55±1.15[a]	59.05±2.97[c]
Coefficient of static friction (°)	Steel sheet	0.30±0.05[a]	0.18±0.05[b]	0.29±0.06[a]
	Iron sheet	0.34±0.11[a]	0.22±0.03[b]	0.35±0.07[a]
	Glass	0.42±0.12[a]	0.24±0.03[b]	0.38±0.12[a]

Values are expressed as Mean ± SD (n=3). Values having different superscripts in the same row indicated significant difference ($p<0.05$).

Table 4. Textural/Mechanical property of different varieties of pomelo fruit.

Textural/Mechanical parameter	Red pomelo	Pink pomelo	White pomelo
Puncture resistance test (N)	11.81±3.56^{b}	20.19±0.68^{a}	15.27±1.31^{ab}

Values are expressed as Mean ± SD (n=3). Values having different superscripts in the same row indicated significant difference (p<0.05).

Table 5. Optical properties of different varieties of pomelo fruit.

Optical parameters		Red pomelo	Pink pomelo	White pomelo
Color	L	65.82±1.20^{b}	69.02±0.63^{a}	71.24±0.60^{a}
	a	6.86±0.79^{a}	3.21±0.30^{b}	6.17±0.41^{a}
	b	32.52±1.36^{b}	31.06±0.41^{b}	36.33±0.29^{a}
	L*	71.77±1.07^{b}	74.59±0.55^{a}	76.53±0.52^{a}
	a*	7.49±0.83^{a}	3.48±0.32^{c}	6.58±0.45^{b}
	b*	54.92±3.32^{b}	48.80±1.09^{c}	61.06±1.39^{a}
	dE*	90.71±2.56^{b}	89.21±0.58^{b}	98.13±0.48^{a}

L* = Brightness, a* = Greenness, b* = Yellowness. Values are expressed as Mean ± SD (n=3). Values having different superscripts in the same row indicated significant difference (p<0.05).

Optical properties of pomelo fruit

The optical properties indicated that the L* (brightness), a* (greenness), and b* (yellowness) parameters were positively associated with the energy absorption and the deformation ratio of the whole fruit Olabinjo et al. (2017). The data related to the color parameter of optical properties are depicted in Table 5. The values for all the parameters of optical properties defined significant (P<0.05) differences. The L, L*, b, b* and dE* values were highest for the white pomelo at 71.24, 76.53, 36.33, 61.06 and 98.13, respectively. The and a* mean values were higher for red pomelo at 6.86 and 7.49. The color values of the pomelo cultivars are close to the values reported by Hongwiangjan et al. (2015) and Terdwongworakul et al. (2009) in the pomelo fruit. Color values are extremely useful in determining the maturity and browning of pomelo fruit. It is also a useful indicator of product quality.

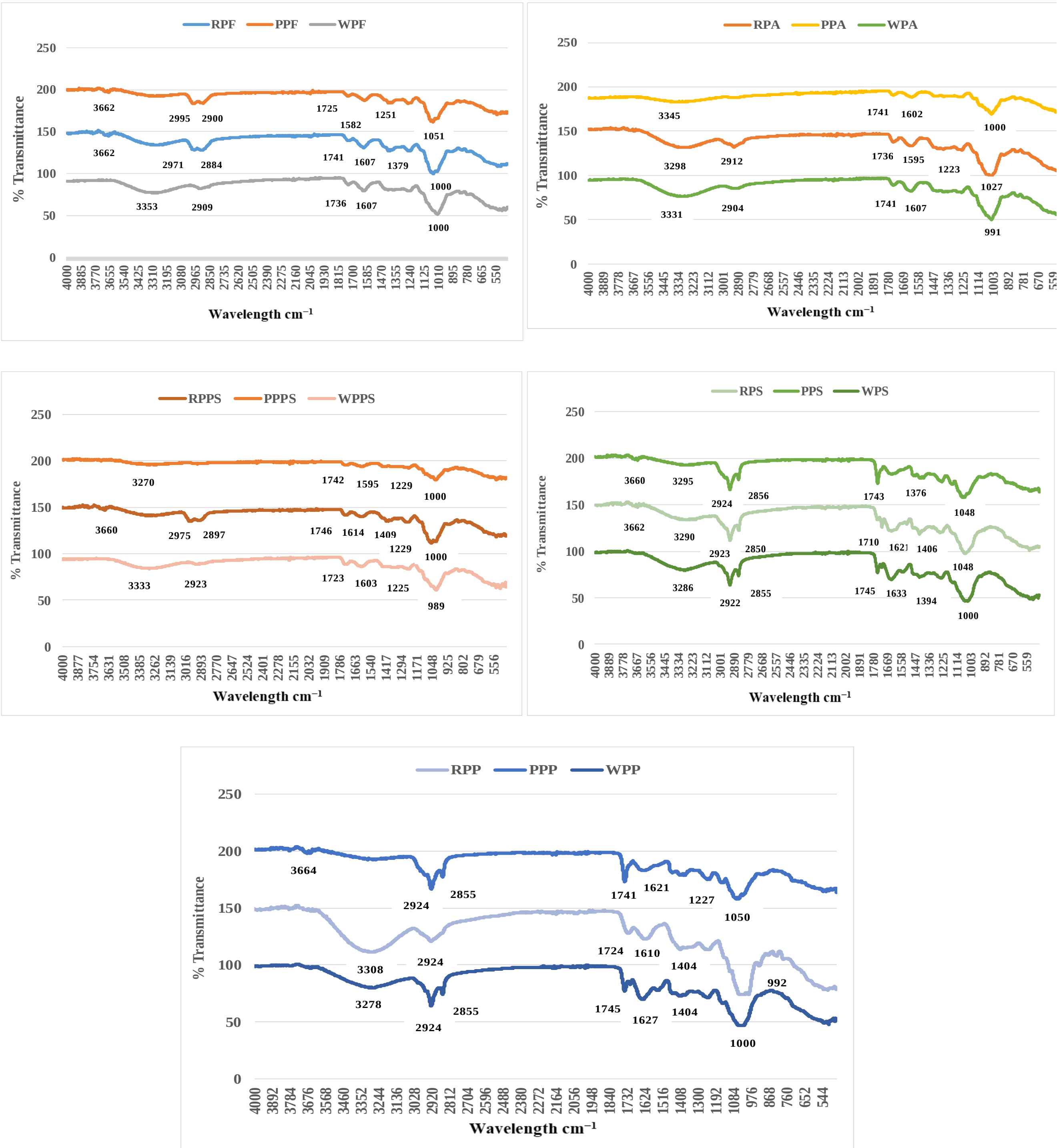

Fig. 2. FTIR spectrum of different parts of selected varieties of pomelo fruit. RPF = Red pomelo flavedo, PPF = Pink pomelo flavedo, WPF = White pomelo flavedo; RPA = Red pomelo albedo, PPA = Pink pomelo Albedo, WPA = White Pomelo Albedo; RPPS = Red pomelo peel segment, PPPS = Pink pomelo peel segment, WPPS = White pomelo peel segment; RPS = Red pomelo seeds, PPS = Pink pomelo seeds, WPS = White pomelo seeds; RPP = Red pomelo pomace, PPP = Pink pomelo pomace, WPP = White pomelo pomace.

FT-IR spectroscopy

The red, pink and white pomelo varieties were utilized to identify the presence of functional groups of polyphenolic compounds based on the intensity of peak in the region of infrared radiations. FTIR spectrum for different varieties of pomelo fruit for different polyphenols is depicted in Figure 2. The graphs showed the existence of polyphenolic compounds that have been given further approval by several polyphenolic standards. In the flavedo portion, FTIR spectra of the pink variety of pomelo showed a peak at 3662 cm^{-1} which indicated the presence of O-H stretching of the alcohol group. The peak at 2995 cm^{-1} indicated the presence of C-H stretching of the alkane group. C-H stretching was observed at 2900 cm^{-1} attributed to the alkane group for the red variety of pomelo. The peak at 1725 and 1582 cm^{-1} represented the presence of C=O stretching of aliphatic ketone and N-H bending of the amine group. The peaks at 1251 and 1051 cm^{-1} depicted the presence of strong C-O stretching of alkyl aryl ether and C-O stretching of primary alcohol (Gupta et al., 2021). The flavedo portion of red and white pomelo also indicated quite similar peaks. The red variety showed a peak at 3662 cm^{-1} which represents the O-H stretching of the alcohol group. The peak at 2971 and 2884 cm^{-1} indicated the presence of C-H stretching of alkane. The peaks at 1741, 1607, 1379, and 1000 cm^{-1} indicated the presence of C=O stretching of esters, C=C stretching of alkene, O-H bending of phenols, and C-F stretching of fluoro compounds. For white pomelo 3353 cm^{-1} showed a peak of O-H stretching of alcohol. The peaks at 2909, 1736, 1607, and 1000 cm^{-1} indicated the presence of C-H stretching of alkane, C=O stretching of esters, C=C stretching of conjugated alkene, and C-F stretching of fluoro compounds. In the albedo portion, the FTIR spectra of pink variety showed a peak at 3345 cm^{-1} indicating the presence of O-H stretching of alcohol. The peaks at 1741, 1602, and 1000 cm^{-1} showed the presence of C=O stretching of esters, C=C stretching of conjugated alkene, and C-F stretching of fluoro compounds. The red and white pomelo of albedo showed similar peaks (Deng et al., 2024).

In the peel segment portion, the FTIR spectra of pink pomelo represented peaks at 3270, 1742, 1595, 1229, and 1000 cm^{-1} indicating the presence of O-H stretching of alcohol, C=O stretching of esters, N-H bending of amines, C-O stretching of alkyl aryl ether and C-F stretching of fluoro compounds. The red pomelo showed peaks at 3660, 2975-2897, 1746, 1614, 1409, 1229 and 1000 cm^{-1} depicting the presence of O-H stretching of alcohol, C-H stretching of alkane, C=O stretching of esters, C=C stretching of α,β-unsaturated ketone, O-H bending of carboxylic acid, C-O stretching of alkyl aryl ether and C-F stretching of fluoro compounds (Gupta et al., 2021). The white pomelo of the peel segment showed peaks at 3333, 2923, 1723, 1603, 1225 and 989 cm^{-1} indicating the presence of N-H stretching of aliphatic primary amine, C-H stretching of alkane, C=O stretching of aliphatic ketone, C=C stretching of α,β-unsaturated ketone, C-O stretching of vinyl ether and C=C bending of alkene 36) (Ouyang et al., 2023). In the seeds portion, the FTIR spectra of pink pomelo showed peaks at 3660 and 3295 cm^{-1} indicating the presence of O-H stretching of alcohol groups. The peaks at 2924 and 2856 cm^{-1} indicated the presence of C-H stretching of alkane. The stretching of peaks at 1743, 1376, and 1048 cm^{-1} defined the presence of C=O stretching of esters, O-H bending of phenols and CO-O-CO stretching of anhydride. The red pomelo seeds showed peaks at 3662-3290 and 2923-2850 cm^{-1} indicating the presence of O-H stretching of the alcohol group and C-H stretching of alkane. The presence of peaks at 1710, 1621, 1406, and 1048 cm^{-1} indicated the presence of C=O stretching of carboxylic acid, C=C stretching conjugated alkene, S=O stretching of sulfonyl chloride and CO-O-CO stretching of anhydride (Deng et al., 2024). The white pomelo seeds showed peaks at 3286 and 2922-2855 cm^{-1} indicating the presence of O-H stretching of alcohol group and C-H stretching of alkane. The peaks at 1745, 1633, 1394, and 1000 cm^{-1} showed the presence of C=O stretching of esters, C=C stretching conjugated alkene, O-H bending of phenols and C-F stretching of fluoro compounds. In the pomace portion, the FTIR spectra of pink pomelo showed the peaks at 3664 and 2924-2855 cm^{-1} indicating the presence of O-H stretching of alcohol group and C-H stretching of alkane. The peaks at 1741, 1621, 1227, and 1050 cm^{-1} indicated the presence of C=O stretching of esters, C=C stretching conjugated alkene, C-O stretching of alkyl aryl ether, and CO-O-CO stretching of anhydride (Zheng et al., 2022). The presence of peaks at red and white pomelo in seeds showed not much variation in peaks. Thus, concluded that pomelo is a wealthy resource of phytoconstituents and the different portions of varieties of pomelo showed peaks on specific wavelengths due to the presence of functional groups of polyphenolic compounds.

Physiochemical properties

Results for the physiochemical properties of different varieties of pomelo fruit are presented in Table 6. Physiochemical properties including pH, TSS, titratable acidity, ascorbic acid, reducing, non-reducing, and total sugars were determined in the juice portion of red, pink, and white pomelo. The pH level serves as an indicator of the acidity of the final product. White pomelo indicated highest pH (3.82) as compared to red (3.69) and pink (3.59) pomelo. Total soluble solids (TSS) refer to the amount of sugars that can be extracted from the product. TSS value showed maximum value in pink pomelo (10.10 °B) as compared to red (9.90 °B) and white pomelo (9.17 °B). The titratable acidity and ascorbic acid of white pomelo were more as compared to red and pink pomelo. The reducing, non-reducing, and total sugars were indicated more in pink pomelo than in red and white pomelo. Pink pomelo was found to have more sugar content or is sweet in flavor among other varieties of pomelo. Results showed that there was a significant difference ($P<0.05$) in the physiochemical parameters of pomelo fruit. Similar, findings were approved by Balmori et al. (2023) and Yin et al. (2023) in pomelo fruit.

Table 6. Physiochemical properties of different varieties of pomelo fruit.

Parameters	Fruit part	Physiochemical properties		
		Red pomelo	Pink pomelo	White pomelo
pH	Juice	3.69±0.01^{b}	3.59±0.01^{c}	3.82±0.02^{a}
TSS (°brix)		9.90±0.10^{b}	10.10±0.10^{a}	9.17±0.29^{c}
Titratable acidity (%)		0.69±0.04^{b}	0.56±0.02^{b}	0.85±0.10^{a}
Ascorbic acid (mg/100g)		45.31±1.97^{b}	34.93±0.58^{c}	56.74±0.02^{a}
Reducing sugars (%)		6.37±0.01^{b}	6.67±0.02^{a}	5.82±0.02^{c}
Non-reducing sugars (%)		4.13±0.01^{b}	4.24±0.02^{a}	3.14±0.02^{c}
Total sugars (%)		10.50±0.02^{b}	10.91±0.03^{a}	8.96±0.03^{c}

Values are expressed as Mean ± SD (n=3) . Values having different superscripts in the same row indicated significant difference ($p<0.05$).

Nutritional properties

Nutritional properties define the quality and health value of the commodity. Results related to nutritional properties are presented in Table 7. Moisture content, total ash, crude fat, crude protein, and carbohydrate content were studied under the nutritional properties of pomelo fruit. The juice portion of pomelo showed maximum moisture content followed by flavedo, pomace, albedo, segment peel, and seeds. The moisture content in the flavedo portion varied from 85.34, 85.31 and 83.87% in red, white, and pink pomelo respectively. The albedo portion showed moisture content of 77.65, 76.67 and 75.13% in red, white, and pink pomelo respectively. The segment peel and seeds showed more moisture content in white pomelo as 78.35 and 8.35% as compared to red and pink pomelo. The juice and pomace portions of red pomelo illustrated maximum moisture content (87.32 and 82.78%) respectively. Significant variation ($P<0.05$) was observed in moisture content among pomelo varieties. Total ash was found more in flavedo followed by seeds, pomace, segment peel, albedo, and juice. Flavedo (3.26%) and albedo (1.86 %) showed more total ash in red pomelo as compared to pink and white pomelo. Other portions of pomelo including segment peel (2.04%), seeds (3.12%), and pomace (2.24%) showed more total ash in the red variety in comparison to pink and white. Crude fat was found to be more in seeds followed by flavedo, pomace, segment peel, albedo, and juice. Seeds have more crude fat in red (38.34%) followed by pink (38.28%) and white (38.22%) pomelo. Red pomelo showed more crude fat content in flavedo (11.31%), albedo (6.34%), and segment peel (8.33%) in comparison to pink and white pomelo. Similarly, juice (0.03%) and pomace (10.32%) showed more crude fat in red pomelo. A significant difference ($P<0.05$) was observed in the total ash and crude fat of pomelo varieties. The pomelo fruit's high fiber content makes it a promising candidate for enhancing the texture, flavor, and nutritional value of bakery and other value-added products. Additionally, it offers significant health benefits by preventing gastrointestinal issues like constipation and is considered a natural anti-colon cancer agent. Red pomelo seeds (32.11%) showed the highest crude fiber in comparison to pink (32.09%) and white (32.05%) pomelo. Among flavedo and albedo, the outer portion (flavedo) had more crude fiber. Crude fiber of red pomelo (25.23%) was found to be more when compared to pink (25.14%) and white (25.19%) pomelo. Segment peel and pomace depicted no significant difference ($P<0.05$) among selected varieties of pomelo. In the juice portion, red pomelo (5.66 %) had more crude fiber compared to pink (5.62%) and white (5.56%) pomelo.

Crude protein is beneficial in food for enhancing the health potential and quality. Seeds showed more crude protein followed by flavedo, albedo, pomace, segment peel, and juice. Among red, pink, and white pomelo the red pomelo showed more crude protein in flavedo (11.24%), albedo (10.73%), and segment peels (10.61%), seeds (12.48%), juice (6.25%) and pomace (10.65%), respectively. The significant carbohydrate content found in pomelo fruit can serve as a cost-effective alternative to other expensive sources of carbohydrates, making it particularly beneficial for low-income people, especially in developing nations. Carbohydrate content was higher in seeds followed by juice, albedo, segment peel, pomace, and flavedo of pomelo. Pink pomelo was found to have more carbohydrate content in flavedo (66.89%), albedo (65.68%), segment peel (67.92%), seeds (179.05%), and pomace (66.93%) in comparison to red and white pomelo, respectively. The white pomelo showed more carbohydrate content in juice (26.67%) in comparison to red and pink pomelo. Overall, the results proclaimed that there was a significant difference ($P<0.05$) in the nutritional properties of pomelo. Similar, data was investigated by Yin et al. (2023) in pomelo and Ayona & Athira (2017) in citrus fruit.

Table 7. Nutritional properties of different varieties of pomelo fruit.

Parameters	Fruit parts	Nutritional properties		
		Red pomelo	Pink pomelo	White pomelo
Moisture (%)	Flavedo	85.34±0.02^{a}	83.87±0.56^{b}	85.31±0.03^{a}
	Albedo	77.65±0.03^{a}	75.13±0.76^{b}	76.67±0.39^{a}
	Segment peel	77.04±0.31^{b}	76.09±0.65^{b}	78.35±0.03^{a}
	Seeds	7.43±0.02^{b}	6.87±0.40^{c}	8.35±0.03^{a}
	Juice	87.32±0.09^{a}	86.97±0.45^{ab}	85.81±0.53^{b}
	Pomace	82.78±0.59^{a}	79.52±0.11^{b}	81.94±0.52^{a}
Total ash (%)	Flavedo	3.26±0.01^{a}	3.20±0.01^{b}	3.18±0.01^{b}
	Albedo	1.86±0.02^{a}	1.82±0.01^{a}	1.76±0.02^{b}
	Segment peel	2.04±0.01^{a}	2.01±0.01^{b}	1.97±0.01^{c}
	Seeds	3.12±0.01^{a}	3.12±0.01^{a}	3.09±0.02^{b}
	Juice	0.78±0.01^{a}	0.76±0.01^{b}	0.72±0.01^{c}
	Pomace	2.24±0.01^{a}	2.18±0.02^{b}	2.21±0.01^{ab}
Crude fat (%)	Flavedo	11.31±0.02^{a}	11.22±0.01^{b}	11.24±0.02^{b}
	Albedo	6.34±0.02^{a}	6.25±0.03^{b}	6.29±0.02^{ab}
	Segment peel	8.33±0.01^{a}	8.27±0.02^{b}	8.32±0.02^{a}
	Seeds	38.34±0.01^{a}	38.28±0.04^{ab}	38.22±0.04^{b}
	Juice	0.03±0.01^{a}	0.02±0.01^{b}	0.02±0.00^{b}
	Pomace	10.32±0.01^{a}	10.26±0.02^{b}	10.30±0.01^{a}
Crude fiber (%)	Flavedo	25.23±0.01^{a}	25.14±0.02^{c}	25.19±0.02^{b}
	Albedo	22.13±0.01^{a}	22.06±0.01^{b}	22.08±0.02^{b}
	Segment peel	23.23±0.01^{a}	23.17±0.01^{b}	23.21±0.01^{a}
	Seeds	32.11±0.01^{a}	32.09±0.01^{b}	32.05±0.02^{c}
	Juice	5.66±0.02^{a}	5.62±0.01^{b}	5.56±0.03^{c}
	Pomace	23.54±0.02^{a}	23.46±0.03^{b}	23.53±0.02^{a}
Crude protein (%)	Flavedo	11.24±0.01^{a}	11.19±0.02^{b}	11.16±0.01^{b}
	Albedo	10.73±0.01^{a}	10.69±0.03^{ab}	10.65±0.03^{b}
	Segment peel	10.61±0.03^{a}	10.56±0.04^{b}	10.54±0.03^{b}
	Seeds	12.48±0.01^{a}	12.42±0.03^{ab}	12.37±0.05^{b}
	Juice	6.25±0.01^{a}	6.22±0.03^{ab}	6.19±0.03^{b}
	Pomace	10.65±0.01^{a}	10.54±0.03^{b}	10.48±0.03^{c}
Carbohydrate content (%)	Flavedo	65.70±0.01^{b}	66.89±0.52^{a}	65.46±0.03^{b}
	Albedo	63.57±0.30^{c}	65.68±0.81^{a}	64.12±0.46^{b}
	Segment peel	67.17±0.29^{b}	67.92±0.61^{a}	65.70±0.08^{c}
	Seeds	178.61±0.07^{ab}	179.05±0.34^{a}	177.38±0.15^{b}
	Juice	25.40±0.07^{b}	25.64±0.10^{b}	26.67±0.48^{a}
	Pomace	63.97±0.62^{c}	66.93±0.17^{a}	64.57±0.57^{b}

Values are expressed as Mean ± SD (n=3). Values having different superscripts in the same row indicated significant difference ($p<0.05$).

Mineral analysis

Mineral analysis of different parts of selected varieties of pomelo fruit are presented in Table 8. Ten different mineral elements including boron, magnesium, aluminum, silicon, phosphorous, potassium, iron, copper, zinc, and strontium are identified. A significant difference ($P<0.05$) was observed in mineral elements of selected varieties of pomelo fruit. The results indicated that pomelo fruit contains significant quantities of important minerals, often surpassing the recommended dietary allowance (RDA). This suggests that consuming pomelo fruit may help to maintain the proper balance and ratios of these elements in the bodies of those in need. Boron element was observed more in pink pomelo as compared to red and white pomelo. Pink pomelo showed a boron content maximum in flavedo (1.176 ppb) followed by albedo (1.309 ppb), segment peel (1.399 ppb), seeds (1.350 ppb), and pomace (1.004 ppb), respectively. The daily recommended dose of allowance (RDF) of boron is 1-1.5

mg and results revealed a range of little more than that. Boron plays an important role in preventing calcium loss and bone demineralization by influencing the development and activity of steroid hormones (Czech et al., 2020). Magnesium element showed variation among varieties of pomelo. Red pomelo had more magnesium in albedo (69.34 ppb) and seeds (169.371). Pink pomelo had more magnesium in flavedo (130.172 ppb), juice (130.511 ppb), and pomace (87.607 ppb). However, white pomelo showed more magnesium content in the segment peel (80.820 ppb). Magnesium is an essential mineral for the activation of over 300 different enzymes in the body. It is beneficial for the absorption of certain vitamins and minerals and essential for the proper functioning and composition of the arteries, heart, kidney, bone, and neuromuscular system (Roghini & Vijayalakshmi, 2018). Aluminum is an important mineral used to combat diseases such as liver, heart, and brain. Results revealed that white pomelo was found to have more aluminum content in flavedo (10.677 ppb), albedo (7.036 ppb), and segment peel (5.435 ppb). Red pomelo in seeds (8.583 ppb) and pink pomelo in juice (6.318 ppb) and pomace had more aluminum (8.970 ppb) content. Silicon showed considerable differences among pomelo varieties. Red pomelo showed more silicon in flavedo (19.913 ppb), segment peel (50.582 ppb), and pomace (61.624 ppb). Pink showed more silicon in albedo (44.640 ppb) and juice (61.369 ppb), whereas white pomelo had more silicon in seeds (54.466 ppb). Silicon is an important mineral that has health advantages that are crucial in preventing specific ailments like atherosclerosis, tuberculosis, sleeping difficulties, and skin disorders (Silva et al., 2017). Phosphorus is essential for the body to synthesize protein, which is crucial for the growth, maintenance, and repair of cells and tissues. Red pomelo was found to have more phosphorus in seeds (430.881 ppb). Pink pomelo had more phosphorus in flavedo (180.629 ppb), juice (431.057 ppb), and pomace (282.364 ppb). White pomelo had more phosphorus in albedo (109.756 ppb) and segment peel (127.647 ppb). Potassium is a vital mineral that is necessary for the proper functioning of the entire body. It facilitates the optimal functioning of neurons, muscles, and the heart, as well as the transportation of nutrients in the body (Hong et al., 2019). The daily recommended dietary allowance (RDA) of potassium is 4300 mg. Results revealed that red pomelo had more potassium in albedo (671.928 ppb). Pink pomelo had more potassium in seeds (762.865 ppb), juice (2,204.666 ppb), and pomace (1,137.967 ppb), whereas white pomelo had more potassium in flavedo (882.49 ppb) and segment peel (574.637 ppb).

Similarly, minerals including Iron (Fe), copper (Cu), and Zinc (Zn) are also been reported as essential minerals for combating deficiency diseases. Iron is an essential component of hemoglobin, which facilitates the transportation of oxygen to the tissues of the body. Additionally, it is a constituent of various other proteins and enzymes. Copper acts as an antioxidant and maintains healthy nerve cells, the immunological system, and red blood cell production (Neshovska, 2023). Zinc being an important mineral helps to maintain the immune system, growth of cells, and heals damaged tissues. However, the strontium is a heavy element and results showed considerable differences in different parts of varieties of pomelo fruit (Hong et al., 2019). Generally, the results revealed that minerals present in pomelo fruit showed a range more than RDA (Recommended dietary allowance) and had considerable differences among varieties. It is the best fruit for someone deficient in these specific minerals. Hence, pomelo fruit is a good source of essential minerals and helps individuals to promote growth and encourage health benefits.

Table 8. Mineral analysis of different varieties of pomelo fruit.

Variety	Fruit parts	Mineral analysis									
		11B [ppb]	24Mg [ppb]	27Al [ppb]	28Si [ppb]	31P [ppb]	39K [ppb]	56Fe [ppb]	63Cu [ppb]	64Zn [ppb]	88Sr [ppb]
Red pomelo	Flavedo	1.273	97.326	5.343	19.913	104.372	637.204	23.716	0.651	2.067	3.766
	Albedo	1.284	69.34	3.102	4.041	89.028	671.928	9.028	0.557	2.734	3.815
	Segment peel	1.188	72.312	5.049	50.582	103.931	480.794	17.795	0.311	2.271	5.775
	Seeds	0.234	169.371	8.583	BDL	430.881	714.007	7.458	10.319	46.982	11.472
	Juice	BDL	60.829	3.745	55.456	193.345	781.106	11.518	0.574	2.335	0.663
	Pomace	0.513	63.516	1.451	41.624	202.314	804.828	17.600	0.703	2.694	2.096
Pink pomelo	Flavedo	1.176	130.172	3.409	2.361	180.629	796.111	7.227	0.604	2.294	3.753
	Albedo	1.309	60.390	1.837	44.640	73.891	635.343	15.317	0.652	1.872	3.666
	Segment peel	1.399	61.448	2.291	14.554	115.388	548.792	4.605	0.316	1.332	4.205
	Seeds	1.350	146.910	8.387	30.977	401.427	762.865	13.965	0.952	2.453	2.667
	Juice	BDL	130.511	6.318	61.369	431.057	2,204.666	12.738	1.475	2.512	1.334
	Pomace	1.004	87.607	8.970	9.892	282.364	1,137.967	7.826	0.494	0.979	2.234
White pomelo	Flavedo	1.460	118.968	10.677	17.449	169.31	882.49	10.809	0.381	2.462	5.437
	Albedo	0.641	68.386	7.036	4.337	109.756	586.961	8.439	0.296	1.703	4.340
	Segment peel	0.862	80.820	5.435	17.739	127.647	574.637	9.653	5.606	54.142	8.945
	Seeds	0.274	140.699	2.005	54.466	318.069	485.280	18.278	1.073	3.606	2.139
	Juice	BDL	104.030	5.550	25.427	315.807	1,355.77	5.132	0.773	1.742	0.909
	Pomace	0.262	63.503	7.504	0.043	206.908	889.122	11.188	0.473	1.767	1.650

BDL – Below Detectable Limit (Less than 1 ppb).

CONCLUSION

Pomelo fruit has very high nutraceutical and functional potential values. The difficulty in processing and lack of knowledge of its usefulness, this exotic fruit has been kept unexplored. The limited availability of this fruit is the primary factor contributing to its lack of appeal. To uncover the different benefits and to explore the pomelo fruit's different food properties including the engineering, physiochemical, and nutritional properties of selected varieties of pomelo fruit. The different food properties of pomelo fruit are studied to generate information that could be applied for the designing of various machinery and to determine the final quality of the product. The results described the significant difference ($p<0.05$) in engineering, physiochemical, and nutritional properties among the different parts of varieties of pomelo fruit. The results revealed that pomelo fruit is a good source of essential minerals including boron, magnesium, aluminum, silicon, phosphorous, potassium, iron, copper, and zinc. The variation in results was attained due to varietal differences, environmental conditions' effect on variety, soil conditions, and genotypic relation that bring changes in the varieties of pomelo providing differences in values. Overall, pomelo possesses vital chemical and nutritional properties that are considered for different applications in the food industry. These food properties are important sources of information for food processing industries to enhance the post-harvest processing of pomelo fruit and have become a perfect and long-lasting resource for the agriculture and food industry.

Contribution

Simple Sharma: Conceptualization, methodology, investigation, resources, and writing (original draft, review, and editing). Barinderjit Singh: Writing (original draft, review, and editing). Yashi Srivastava: Writing (review and editing). All authors approved the final version of the manuscript.

Conflict of interest

The authors declare no conflict of interest, financial or otherwise.

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