

Physical and chemical characterization of guava (*Psidium guajava* L.) genotypes grown in subtropical condition

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Abstract

Guava is a high-value tropical fruit that is widely grown in tropical and subtropical regions around the world. In the adaptation studies carried out in Turkey, guava was determined as the most prominent species with its cold resistance feature. The use of seedlings in cultivation created a genetic variation and differences were observed between the resulting genotypes, especially in terms of fruit size, shape and colour. Based on this observation, this study aimed to characterize 13 different guava fruit genotypes based on physical, chemical, bioactive and aroma properties. In the adaptation studies carried out in Turkey, guava was determined as the most prominent species with its cold resistance feature. There is only one commercial variety namely 'Ruby Supreme' grown in Turkey. Presently, the interest of the guava cultivation has been increased and farmers were used seedling material instead of vegetative to establish orchard. Due to the cross pollination, it has been observed great variation in the population. Therefore, it is important to select promising genotypes according to fruit size, shape and colour. The present study was evaluated 13 different guava genotypes according to physical, chemical, bioactive and aroma properties. Significant differences were observed among the genotypes. One genotype was found superior over all the genotypes, in terms of fruit weight (131.44 g) and length (82.00 mm). Although three genotypes were having lower values than the other samples in results of total soluble solids, they had higher results in terms of antioxidant capacity and total phenolic content. Two genotypes formed a separate group from all other genotypes in terms of (Z)-3-Hexen-1-yl acetate (sweet, pear, melon), 3-Hexenal (melon, tropical) and Ethyl alcohol (fruit and sweet) components. The flavor components are distinctive for the guava samples, as are the physical properties. It was also determined that the white guava genotypes had very different chemical and aromatic properties from other genotypes. The promising genotypes can be utilized in the future breeding programme to improve new guava varieties.

Keywords: aroma profile; antioxidant activity; genotype; guava; physical properties

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Introduction

Guava (*Psidium guajava* L.) belongs to the *Psidium* genus and comprises 150 species. “Apple guava”, “yellow-fruited cherry guava”, “strawberry guava”, and “red apple guava” are some of the important species (Devi *et al.*, 2012; Parvez *et al.*, 2018). Guava is a tropical and aromatic fruit that is widely cultivated in tropical and subtropical regions and is becoming increasingly popular worldwide. Guava trees can grow up to 7-10 meters in height and have a shallow root system. Although they are in shrub form, they have a sturdy stem and branch structure. The leaves on the plant are opposite and have an oval shape. The fruits range from 3 to 10 cm in diameter and can be rounded (globose), egg-shaped (ovoid), or pear-shaped (pyriform) and have pink, white, and yellow flesh skin color. The fruit’s skin color, which is green in the immature stage, turns yellow as the fruit matures and it has a strong characteristic aroma (Nayik and Gull, 2020).

The chemical composition of guava fruits changes with factors such as variety, maturity, and environmental conditions (Musaa *et al.*, 2015). Previous studies (Thaipong *et al.*, 2005; Lim *et al.*, 2006; Murmu and Mishra, 2015) reported that guava fruit contains 74-87% moisture, 0.5-1% ash, 0.4-0.7% fat, 0.8-1.5% protein, 0.5-1.8% pectin, also vitamins (vitamin C, vitamin A, and vitamin B) and minerals (calcium, iron, potassium, and sodium). The vitamin C content in guava fruit can be 3-6 times higher than that in oranges, and the level of lycopene content is twice as high as in tomatoes (Silva *et al.*, 2018). Guava fruit also contains high amounts of bioactive compounds that help to increase healthy benefits. In addition, guava has a high level (approximately 50% of guava fruits) of dietary fiber thus making it valuable for health benefits. Previous studies showed that different cultivars affect the phytochemical contents of fruits (Bashir and Abu-Goukh, 2003; Suwanwong and Boonpangrak, 2021) reported that white-flesh cultivars have higher amounts of phenolic and ascorbic acid than pink-flesh cultivars. Also, seeded cultivars have higher amounts of phenolic compounds and ascorbic acid than seedless cultivars (Lim *et al.*, 2006).

Guava fruits have a pleasant aroma with a sour-sweet taste (Steinhaus *et al.*, 2008) and their aroma impression is often described as “quince banana” (Quijano and Pino, 2007). Numerous studies focusing on guava fruit aroma profile have identified approximately 400 volatile compounds in different varieties (Steinhaus *et al.*, 2008) and different countries such as Colombia (Quijano and Pino, 2007), Taiwan (Chen *et al.*, 2006), India (Borah *et al.*, 2019). However, both the chemical contents and aroma profile of fruits grown under different conditions in different climatic regions differ. The studies indicate that hexanal, (E)-2-hexenal, (Z)-3-hexen-1-yl acetate, 3-phenylpropyl acetate, and cinnamyl acetate are the most important aroma volatiles in guava fruits (Quijano and Pino, 2007). The characteristic aroma profile combines fruity, sweet, green, and note attributes, and a distinct apple, and pineapple fruit-like aroma contributes to the characteristic tropical fruit character. Additionally, the limited studies focusing on aroma active compounds in guava fruits have also emphasized that the aroma compounds of different varieties may differ.

In addition, previous studies focused on either only the chemical content of the guava fruit or only the volatile compounds. Also, there are no studies that correlate the physical properties of the guava fruit with these properties. The cluster and descriptive analyses are useful methods for various identification and characterization and are frequently used on different materials to determine relationships and correlations between varieties.

Guava production in Turkey is a relatively recent development. In the adaptation studies carried out in Turkey, guava was determined as the most prominent species with its cold resistance feature. Its resistance to cold has allowed the cultivation of this species to become widespread in Turkey. The use of seed propagated seedlings in cultivation has created a genetic population. Differences were observed between the resulting genotypes, especially in terms of fruit size, shape, and color. It is very important to determine the physicochemical and aroma content, especially to determine the genotypes that will continue to produce guava. The objective of this study was to characterize of physical properties and chemical composition of guava fruits,

identify volatile compounds by SPME-GC/MS, and also to determine the correlation between these properties in different guava varieties.

Materials and Methods

Plant material and chemicals

Guava samples were collected at the optimal harvesting time (eating stage) from the provinces of Mersin and Antalya, where tropical fruit cultivation is common in Turkey. Fruits were randomly collected from 10 trees per genotype and 6 fruits per tree. A general view of fruit samples is given in Figure 1. All chemicals and reagents were purchased from Sigma-Aldrich (St. Louis, MO, USA).





Figure 1. General view of guava genotypes

*Physical properties of the fruits*Fruit size and weight

The fruit size (fruit diameter and fruit length) and fruit weight were measured on 10 fruit samples. Fruit diameter and length were measured in millimetre (mm) with a digital calliper, while fruit weight was measured in gram (g) with a precision scale.

Color

The color of the guava (three measurements of each guava) was measured on 10 samples from each UV-exposure replicate using a chromameter (CR 200, Minolta, Ramsey, NJ, USA). L*, a* and b* values of guava samples were recorded. Hue angle and chroma values were calculated using the following equations (Eq 1 and 2)

$$h^{\circ} = \frac{180}{\pi} \tan^{-1} \frac{b^*}{a^*} \quad (1)$$

$$C = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

where h° is the hue angle (degree), C is the chroma value, a is the degree of redness to greenness and b is the degree of yellowness to blueness of the sample.

Moisture and total soluble solid content

The moisture content was determined by evaluating the difference in weight between the fresh sample and the dried samples at 105 °C until constant weight. Total soluble solid content (TSS) was determined using a digital refractometer (ISOLAB, Eschau, Germany) at 25 °C and given as °Brix.

Total phenolic content and antioxidant capacity

The total phenolic content (TPC) analyses were performed in triplicate, according to the adapted methodology of (Nunes *et al.*, 2016). Five guava samples were blended by using a Waring Blender. For extraction of TPC, 5 g samples were extracted with 100 mL of EtOH:H₂O 80:20 v/v for 30 min at 80 °C and centrifuged (2500 g, 5 min, 10 °C, Sigma 3-18KS Germany). Then 0.5 mL of the supernatant was treated with 2.5 mL of 0.1 N Folin-Ciocalteu phenol reagent and 2 mL of Na₂CO₃ (75 g/L) (Balci and Ozdemir, 2016). The samples were incubated in a water bath for 5 min at 50 °C and then immediately cooled to room temperature. The absorbance was then read at 760 nm with a spectrophotometer (Shimadzu UV - Vis 160A, Japan). The results were expressed as gallic acid equivalents (GAE) (g gallic acid/L).

For the analysis of antioxidant capacity, TPC extracts were used. The antioxidant activity was determined by using DPPH radical- scavenging activity (Fernández-León *et al.*, 2013). The supernatant was diluted with EtOH:H₂O 80:20 v/v in a centrifuge tube. 50 µL of the diluted supernatant was added into 950 µL of diphenylpicrylhydrazyl (DPPH, 6 × 10⁻⁵ M in MeOH) solution, mixed with vortex, and incubated for 30 min at room temperature in the dark. The absorbance of the solution was recorded at 516 nm using pure methanol as a blank. The total antioxidant activity of the sample was calculated as g Trolox equivalent antioxidant activity (TEAA)/g dm.

Ascorbic acid content

The ascorbic acid was identified (Asami *et al.*, 2003) with some minor modifications. For this purpose, five fresh guava samples were homogenized with a metaphosphoric acid solution (4.5%) in a Waring blender. The puree was centrifuged at 1640 g for 15 min at 20 °C, then the supernatant was filtered (Whatman no.1) and diluted to 25 mL with metaphosphoric acid solution (4.5%). Analysis was performed with HPLC (20AD, Shimadzu, Japan) and peaks were detected by an SPD-M20A Diode Array Detector (Shimadzu, Japan) and in a Nucleosil C18 (250 mm × 4 mm, 5 µm) column. All samples were filtered with a 0.45 µm Nylon filters. The mobile phase was acidified MilliQ water (pH 2.2) at 0.8 mL/min flow rate. Chromatograms were recorded at

245 nm for 15 min. Ascorbic acid was identified and quantified using external standard solutions of ascorbic acid and expressed as mg/100 g dm. All analyses were run in triplicate.

Volatile compounds-SPME-GC/MS

The volatile composition of the guava samples was analysed using a GC/MS (QP2010-Ultra, Shimadzu, Kyoto, Japan) and AOC-5000Auto Sampler-Plus (Shimadzu, Kyoto, Japan). Separations of volatile compounds were achieved by using a TRB5-MS (30 m × 0.25 mm i.d. × 0.25 μm film thickness). The analysis of the volatiles was identified according to (Balci-Torun and Ozdemir, 2021) with some minor modifications. Five guava samples were homogenized with a Waring blender and 1 g pureed samples were immediately weighed into a 20 mL vial. The volatiles were extracted by SPME (Solid Phase Microextraction) with a fiber, coated with a 100 μm PDMS. The adsorption fiber temperature was 40 °C for 15 min the agitation rate was 250 rpm and the desorbed fiber temperature at 200 °C for 10 min. For GC/MS the column temperature was programmed as follows: 3 min at 40 °C, rise to 100 °C at 4 °C/min, held for 3 min, finally increased to 200 °C at 10 °C/min and held for 3 min. The column with helium at 1.78 mL/min is a carrier. Ion source, injection, and detector temperatures were 200, 200, and 275 °C. MS conditions were electron impact (EI) of 70 eV, scan area of 30–500 (m/z), and scan rate of 769 s/scan. Volatiles were identified by comparing the mass spectral data of Wiley 10, the NIST library, and the retention index.

Hierarchical cluster (HCA) and principal component analysis (PCA)

The fruits were collected and grown in triplicate and measurements were performed in duplicate. The results are given with the mean and standard deviation. Data obtained from the fruits were subjected to cluster and descriptive analyses using XLStat-Base software (NY, USA). HCA and PCA analyses were performed separately for both physicochemical analyses and aroma compounds.

Results and Discussion

Physical properties of the fruits

The physical properties of 13 different guava genotypes are given in Table 1. Physical fruit characteristics of guava fruits varied significantly among different genotypes. The weight, width, and length of the guava fruits ranged between 42.00-131.44 g, 41.77-60.87 mm, and 40.20-82.00 mm, respectively. Genotype 8 was found superior over all other genotypes, in terms of fruit weight (131.44 g) and length (82.00 mm). The highest fruit width (60.87 mm) was observed for Genotype 7. The obtained values in this study were relatively similar to the report of (Kumari *et al.*, 2020) as 74.88-353.75 g for weight, 32.73-73.03 mm for length, and 41.25-86.35 for width. The authors reported that variation in fruit weight, length, and width might be attributed to agro-climatic conditions, as well as phenotypic and genotypic interactions.

Table 1 Physical properties of guava fruits depending on different genotypes

Genotype number	Mesocarp color	Fruit shape	Fruit weight (g)	Width (mm)	Length (mm)
1	Pinkish	Roundish	42.67 ^d ±0.67	42.77 ^d ±0.31	40.20 ^h ±0.64
2	Pinkish	Roundish	63.69 ^c ±1.54	50.27 ^c ±4.00	47.70 ^g ±1.47
3	Pinkish	Ovate	115.50 ^a ±3.44	57.87 ^{ba} ±0.83	60.87 ^{cd} ±1.49
4	Pinkish	Roundish	88.11 ^b ±8.25	52.83 ^{bc} ±1.84	52.03 ^{ef} ±1.71
5	Reddish pink	Roundish	115.83 ^a ±13.02	59.43 ^{ba} ±3.67	54.67 ^f ±1.68
6	Pinkish	Roundish	42.00 ^d ±1.17	41.77 ^d ±0.62	42.27 ^h ±0.95
7	Pinkish	Roundish	124.83 ^a ±4.37	60.87 ^a ±0.80	55.90 ^{ef} ±0.12

8	Creamy white	Pear shaped	131.44 ^a ±3.75	58.10 ^{ba} ±0.68	82.00 ^a ±2.40
9	Creamy white	Ovate	120.94 ^a ±3.68	57.12 ^{bac} ±2.26	67.40 ^c ±1.54
10	Reddish pink	Sub-globose	94.70 ^b ±2.14	55.20 ^{bac} ±0.38	60.65 ^{cd} ±0.47
11	Pinkish	Pear shaped	95.80 ^b ±7.17	53.83 ^{bac} ±1.39	74.65 ^b ±1.44
12	Pinkish	Roundish	76.32 ^{cb} ±2.72	53.69 ^{bc} ±0.46	51.66 ^{ef} ±0.47
13	Reddish pink	Sub-globose	86.49 ^b ±1.77	53.71 ^{bc} ±1.35	61.91 ^d ±2.50

Moisture and total soluble solids (TSS) are important quality parameters of acceptability for fruit and vegetables because parameters affect the taste and texture (Kurubas *et al.*, 2019). Remarkable differences were observed among the moisture and TSS values (Table 2). Moisture and TSS values ranged between 79.30%-87.58%; and 7.10-14.55 °B, respectively. These results align with existing literature. In a study investigating Malaysian guava genotypes, the moisture content varied between 79.2% to 85.9% and TSS values were less than 9% (Yusof, 1989), while in another study investigating Mexican genotypes, TSS values of guava fruits were observed to be between 8.9-17.5 °B (Hernández-Delgado *et al.*, 2007).

Table 2. Chemical properties of guava fruits depending on different genotype

Genotype No	Moisture (%)	TSS (°Bx)	Total phenolic content (mg GAE/g dm)	Antioxidant capacity (mg/g dm)	Ascorbic acid (mg/g dm)	L values	Hue Angle	Chrome
1	79.78 ^f ±0.42	14.55 ^a ±0.05	5.63 ^a ±0.40	25.10 ^e ±0.09	9.17 ^b ±0.03	54.37 ^b ±2.50	52.40 ^b ±2.16	34.25 ^b ±0.99
2	83.42 ^d ±0.09	12.45 ^c ±0.15	5.00 ^a ±0.36	23.53 ^b ±0.00	10.89 ^a ±0.02	50.72 ^c ±0.72	48.81 ^{cb} ±0.83	32.01 ^{dc} ±0.46
3	79.30 ^f ±0.35	9.45 ^e ±0.15	2.89 ^b ±0.32	17.46 ^d ±0.15	6.56 ^f ±0.05	51.03 ^c ±1.48	40.62 ^c ±0.34	28.43 ^f ±0.80
4	85.16 ^c ±0.47	10.45 ^d ±0.05	3.45 ^k ±0.24	19.17 ^d ±0.00	7.72 ^d ±0.77	50.95 ^c ±0.16	50.67 ^{cb} ±0.36	30.63 ^{de} ±0.25
5	80.66 ^e ±0.18	9.05 ^b ±0.35	2.72 ^m ±0.19	10.65 ^k ±0.00	5.41 ⁱ ±0.04	51.27 ^c ±2.79	49.59 ^{cb} ±1.53	36.70 ^a ±1.09
6	80.49 ^e ±0.45	12.90 ^b ±0.10	5.39 ^b ±0.38	18.64 ^d ±0.05	7.54 ^c ±0.07	50.32 ^c ±0.31	46.94 ^{cd} ±0.31	32.19 ^c ±0.22
7	83.29 ^d ±0.25	10.85 ^d ±0.05	7.30 ^a ±0.53	32.63 ^a ±0.21	6.28 ^h ±0.05	45.42 ^d ±0.14	40.32 ^c ±0.70	31.47 ^{dec} ±0.24
8	85.80 ^c ±0.11	6.85 ^f ±0.25	6.59 ^f ±0.47	30.98 ^b ±0.00	6.46 ^e ±0.01	60.93 ^a ±0.15	84.95 ^a ±0.38	12.13 ^b ±0.16
9	85.60 ^c ±0.18	9.95 ^f ±0.25	4.64 ^d ±0.33	24.18 ^b ±0.02	7.76 ^c ±0.06	62.21 ^a ±0.12	86.02 ^a ±0.19	11.31 ^b ±0.11
10	85.45 ^c ±0.30	10.95 ^d ±0.25	7.62 ^d ±0.83	43.92 ^d ±0.06	4.92 ^j ±0.07	43.81 ^{cd} ±0.08	44.56 ^d ±2.71	27.65 ^f ±0.22
11	86.92 ^b ±0.18	7.75 ^e ±0.05	10.08 ^c ±1.09	53.85 ^b ±0.19	4.72 ^k ±0.04	41.57 ^c ±0.98	29.59 ^e ±3.38	31.21 ^{dec} ±0.53
12	87.58 ^a ±0.06	7.70 ^e ±0.10	12.38 ^a ±1.34	64.65 ^a ±0.30	4.15 ^l ±0.03	41.72 ^c ±0.16	28.77 ^e ±0.16	30.66 ^e ±0.44
13	86.51 ^b ±0.03	7.10 ^e ±0.10	10.15 ^b ±1.10	51.58 ^c ±0.35	3.74 ^m ±0.02	45.42 ^d ±0.53	33.51 ^f ±1.97	25.37 ^g ±0.27

Colour serves as an indicator of the maturity of fruits and vegetables, with a wide range of hues observed in the epicarps, spanning from white to green and from yellow to red. In this study, colour measurement was carried out depending on the variety of guava samples. Generally, the flesh colour of guava includes a wide range of white, yellow, orange, and pink. Colour of the guava samples were presented as L* value (Lightness), Hue angle (0°=red–purple, 90°=yellow) and chroma (color-intensity). The hue angle represents true color, which is important for color appearance. According to the result, the lightness (L* value) of epicarp ranged from 41.57 to 62.21. Hue angle and chroma value varied from 28.77 to 86.02 and 11.31 to 36.70, respectively. The most basic difference between the samples in terms of colour is due to the variety. Genotypes 10 and 11 were white guava, others were pink guava, and colour measurements indicated this colour view. The pink guava fruit's epicarp colour is near orange-red colour except for white guava samples which were near to yellow. Studies have generally focused on determining the relationship between the colour of the skin of the guava fruit and maturity

(Gonzalez *et al.*, 2011; Sinuco *et al.*, 2010) or change with some thermal degradation (Ali *et al.*, 2016). However, the colour analyses performed on fresh fruits in these studies showed similar results with this study.

Total phenolic content and antioxidant capacity

Total phenolic content of guava samples was observed at 2.72 and 12.38 mg GAE/g dm and total antioxidant capacity ranged between 10.65 and 64.65 mg TE/g dm, respectively. Genotype 12 guava samples had the highest total phenolic content and antioxidant capacity (Table 2). Total phenolic content increases as a response to the plant's secondary metabolism and the phenolic content of fruits could change with plant location, amount of sunlight, variety of fruits, and other stress conditions. It has been reported that the skins of guava fruit have a high phenolic content, and this affects the total phenolic composition of the fruit. In a study performed by (Musaa *et al.*, 2015) the total phenolic content of smaller guava fruits was higher. The phenolic composition, which changes with stress and other conditions, is directly proportional to the amount of antioxidant activity of the fruit. It has been mentioned that antioxidant capacity exhibited strong positive correlations with total phenolic content (Chen and Yen, 2007). Also, our results show a significant ($p < 0.05$) linear correlation (0.987) between antioxidant capacity and the total phenolic content of guava varieties. Guava has many compounds that show high antioxidant effects. Therefore, producing guava varieties having higher levels of antioxidant compounds may cause the increase in dietary antioxidant intake. Obtained results showed that guava fruits have potent free radical scavengers and could be used as a good source of natural antioxidants for food, medical, pharmaceutical and commercial uses.

Ascorbic acid

Guava is very tasty and is the second fruit with the highest vitamin C content (Patil *et al.*, 2014). Therefore, there is an increasing worldwide demand for guava as a healthy and nutritious fruit. The ascorbic acid content was found between 3.74-10.89 mg/g dm in guava fruits. The vitamin C content of the guava genotypes was found to be quite high. In addition, different genotypes showed different vitamin C content. Especially, genotypes 1 (9.17 mg/g dm) and 2 (10.89 mg/g dm) were determined as guava fruits with the highest vitamin C content. Luximon-Ramma *et al.* (2003) reported that ascorbic acid content ranged between 7.22-14.26 (mg/g fresh weight) in guava fruits and white guava had higher ascorbic acid content than pink guava. It has been mentioned that guava fruits are rich in vitamin C (0.50-3 mg/ g fresh weight) and are higher than an orange by 3-6 times (Mehmood *et al.*, 2014; Silva *et al.*, 2018). However, 100 g of guava fruits are sufficient to cover the recommended daily allowance of 60–90 mg of ascorbic acid per person (Levine *et al.*, 2001).

Volatile compounds

The descriptions of aroma components provided in the literature are presented in Table 3, while the aroma components identified in guava fruits are shown in Table 4. The samples were extracted with SPME and a total of 83 volatile compounds were identified by HS-SPME-GS/MS. Table 3 shows the peak area of the aroma components identified in the guava fruits and the aroma definitions of the aroma components. Ethyl alcohol (fruit and sweet), ethyl acetate (fruit and sweet), 3-hexenal (melon and tropical), hexanal (fruity), (E)-2-hexenal (green), (Z)-3-hexenal (green), ethyl caproate (sweet), (Z)-3-hexen-1-yl acetate (sweet, pear, melon), isopropyl acetate (sweet, banana), cinnamyl acetate (sweet) are considered the most abundant volatile compounds in the guava fruits. Volatile metabolites are commonly detected in many genotypes of fruits and these volatile components vary with fruit development or due to genetic differences. Although eight of the identified volatile components were detected in each sample, it was determined that the variety in the guava samples was effective on the volatile components. In parallel with the results reported in similar studies, this study also showed that C₆ aldehydes, alcohols, and esters are important volatile compounds in guava fruits (Jordán *et al.*, 2001).

Table 3. Aroma descriptions for volatile compound

Odor description	Compound
Fruity	Acetaldehyde
Pineapple, fruity	Ethyl Acetate
Tropical, fruity	1-Penten-3-ol
Pineapple, fruity	ethyl propionate
Fruity, banana, tropical	Isobutyl acetate
Melon, tropical	3-Hexenal
Fruity	Hexanal
Fruit, pineapple	ethyl butyrate
Green, melon	(Z)-3-hexenal
Fruity, banana	isoamyl acetate
Fruity, apple	(Z)-2-heptenal
Fruity, green,	2-pentyl furan
Sweet, pineapple	Ethyl caproate
Sweet, pear, melon	(Z)-3-hexen-1-yl acetate
Apple and pear	Hexyl acetate
Minty, fruity	ethyl benzoate
Fruity, sweet, banana	isopropyl acetate
Fruity, tropical	(Z)-3-hexen-1-yl hexanoate
Sweet, fruity, tropical	hexyl hexanoate
Sweet, spice	cinnamyl acetate
Fruity, pear, guava	(E)-geranyl acetone
Fruity peach	gamma-decalactone

Previous studies showed that, (Z)-3-hexen-1-yl acetate, 3-phenylpropyl acetate and (E)-cinnamyl acetate were the largest amount compounds in the guava fruits and ethyl butanoate, ethyl hexanoate, hexanal, hexyl acetate were the important compounds (Quijano and Pino, 2007).

Table 4. Volatile compounds in guava (GC-MS peak area %)

RT	RI	Compound	1	2	3	4	5	6	7	8	9	10	11	12	13
1.309	1.260	Acetaldehyde	783798	542722	540695	479974	2263271	330980	4156969	2328293	2274295	1019809	418894	1942079	1614318
1.389	1.370	Ethyl alcohol	868888	827012	472741	713851	2572723	664169	8530571	11421292	2061886	1905080	277776	1837039	851043
1.479	1.450	Isopropenyl acetate	94516	83516	n.d.	n.d.	n.d.	n.d.	n.d.	70028	n.d.	500125	757701	1213593	2047960
1.584	1.525	methyl acetate	88357	148053	288554	238823	102628	n.d.	36182	n.d.	156997	111590	n.d.	n.d.	n.d.
1.905	1.885	pentane, methyl-	32851	30490	82784	16996	n.d.	175226	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2.020	2.000	Ethyl Acetate	1348717	2586215	1343676	2244500	4847293	1943448	1796929	18943007	5612703	3107122	1838169	7938029	5727523
2.175	2.155	methyl propionate	n.d.	8066	31179	35298	n.d.	4523	n.d.	n.d.	n.d.	191970	75391	60502	353802
2.342	2.320	trans-2-Methyl-2-butenal	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1317747	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2.732	2.715	1-Penten-3-ol	79283	70031	40997	40942	n.d.	45337	n.d.	n.d.	n.d.	79406	n.d.	n.d.	n.d.
3.107	3.085	2-Butanone, 3-hydroxy-	78356	n.d.	n.d.	386551	175367	n.d.	7299458	497316	297620	467189	n.d.	n.d.	n.d.
3.217	3.195	ethyl propionate	108087	247060	207784	151555	51072	131559	44743	127574	103627	n.d.	280362	624220	1046146
3.281	3.260	propyl acetate	20384	30041	49217	43189	n.d.	n.d.	n.d.	199036	77323	51809		129160	50921
3.432	3.420	methyl butyrate	12988	34007	68302	n.d.	9925	20152	n.d.	16753	n.d.	191970	215462	250164	1101292
3.684	3.610	isoamyl acetoacetate	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	62977	34917	n.d.	n.d.	n.d.	n.d.	49130
3.763	3.750	isoamyl alcohol	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	72555	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
4.107	4.090	(E)-2-pentenal	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	72340	n.d.
4.450	4.425	amyl formate	74498	56081	32761	39688	19410	40051	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	34288
4.763	4.735	2,3-butane diol	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	176044	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
4.536	4.515	(E)-2-hexen-1-ol	39368	40484	14977	n.d.	n.d.	26171	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
4.624	4.600	Isobutyl acetate	n.d.	95597	n.d.	577672	45757	124901	n.d.	255365	132075	3183656	n.d.	39466	35930
5.200	5.150	3-Hexenal	8262736	5337140	5740857	n.d.	2852097	11342973	n.d.	15510609	n.d.	23263875	13374058	5736522	6458403
5.241	5.215	Hexanal	21062920	22037397	19718656	39240433	14225274	12251670	19352157	290503	14288441	13935264	32342742	24028957	19123628
5.343	5.320	ethyl butyrate	529334	1867332	639732	1327838	1523737	908337	633455	2833883	358034	2243	1950408	4006957	4940807
5.791	5.760	butyl acetate	n.d.	48895	n.d.	n.d.	39307	23053	34121	72845		48038	145768	189593	212442
5.865	5.835	2-Methyl-2-pentenal	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	19299	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6.720	6.665	2-Butenoic acid, ethyl ester	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	292502	237893	n.d.	n.d.	n.d.	n.d.	n.d.
6.920	6.835	(E)-2-hexenal	12924678	14519381	8753795	7277813	6858808	7759398	4491511	2604628	3293322	15691783	13889127	11725446	13273618
7.093	7.070	(Z)-3-hexenal	150964	226739	240176	164836	65900	148162	123660	151564	1208436	581308	753854	764103	826497
7.550	7.525	hexanol	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2492591	920809
7.885	7.845	isoamyl acetate	n.d.	87767	n.d.	42625	67086	51166	n.d.	160358	54215	205337	288365	261915	279405
7.979	7.945	2-methyl butyl acetate	n.d.	35053	n.d.	32943	n.d.	35373	n.d.	49222	81050	128351	78565	56557	60343
8.710	8.680	Heptanal	32866	27481	21755	32836	n.d.	16638	n.d.	n.d.	n.d.	54666	n.d.	17250	
9.007	8.980	2,4-Hexadienal	118194	n.d.	n.d.	n.d.	105697	14342	61919	n.d.	n.d.	n.d.	n.d.	n.d.	86248
9.214	9.185	4-Penten-1-ol acetate	n.d.	24843	30688	40341	39798	n.d.	n.d.	n.d.	n.d.	n.d.	263671	n.d.	n.d.
9.646	9.620	methyl hexanoate	n.d.	n.d.	16948	n.d.	61051	n.d.	n.d.	n.d.	57606	n.d.	73851	95706	947903
10.775	10.745	(Z)-2-heptenal	158804	157110	77144	139763	41120	53140	n.d.	38821	n.d.	87662	678188	96736	61741
10.915	10.835	(E)-4-Oxohex-2-enal	268247	306465	309522	256315		383163	20972	n.d.	n.d.			302734	256345
12.015	11.975	methyl heptenone	135062	125842	186993	151935	49817	49064	177255	n.d.	n.d.	328010	328780	504702	266024

12.161	12.075	2-pentyl furan	51815	38355	n.d.	54011	23162	n.d.	38211	n.d.	n.d.	43231	94154	40384	
12.271	12.220	5,5-DIMETHYL-1-HEXEN-6-OL	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	26451	n.d.	n.d.	n.d.		184302	143829
12.267	12.230	6-Methyl-5-hepten-2-ol	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	283953	1499788	2116457
12.524	12.475	Ethyl caproate	463971	697854	420363	979595	11942131	146986	1736152	n.d.	1820644	n.d.	5840559	16752131	21834131
12.600	12.580	Octanal	41157	n.d.	n.d.	619658	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1123377	12956991	2880573
12.750	12.715	(Z)-3-hexen-1-yl acetate	1016643	3054428	13065457	4464262	9601300	2843437	n.d.	9251084	39532614	423999	n.d.	27756	n.d.
13.066	13.020	Hexyl acetate	308418	430979	1063366	1144850	1170360	326890	83412	1169427	8628214	71021	n.d.	25714	n.d.
13.549	13.490	dl-Limonene	803806	n.d.	n.d.	50175	n.d.	n.d.	n.d.	199994		140860	99220	41692	39177
13.613	13.570	3-Cyclohexen-1-ol, acetate	n.d.	n.d.	41297	n.d.	n.d.	n.d.	n.d.	n.d.	935131	n.d.	n.d.	79931	212563
13.658	13.620	2-ethyl-1-hexanol	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	46065	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14.242	14.200	ethyl 2-hexenoate	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	41665	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14.722	14.680	(E)-2-octenal	n.d.	n.d.	n.d.	121298	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	47467
14.774	14.745	Isovalerone	319050	314865	n.d.	n.d.	126678	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14.784	14.755	3-Pentanone, 2,2,4,4-tetramethyl- (CAS)	n.d.	n.d.	262576	n.d.	n.d.	366409	n.d.	n.d.	n.d.	1319737	494860	n.d.	n.d.
15.271	15.240	1-Octanol	21405	n.d.	n.d.	n.d.	11264	n.d.	n.d.	48364	342196			108397	n.d.
16.110	16.065	Methyl benzoate	n.d.	n.d.	n.d.	n.d.	137063	n.d.	n.d.	n.d.	n.d.	n.d.	196214	180988	4748365
16.117	16.085	1-Pentadecanol	43913	n.d.	74087	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	69569
16.321	16.285	(Z)-3-hexen-1-yl propionate	n.d.	72660		n.d.	n.d.	94083	n.d.	n.d.	61232	n.d.	n.d.	43198	369469
16.506	16.415	Nonanal	115398	102042	36198	105744	18924	34210	n.d.	36022	22838	214994	n.d.	57720	97210
17.555	17.515	endo-Borneol	59078		36693	78400	109927	23361	n.d.	n.d.	299779	577429		668960	93945
18.963	18.915	ethyl benzoate	110087	111473	58312	201537	4531246	79822	1491950	263622	103346	n.d.	288844	n.d.	644408
19.539	19.490	(Z)-3-hexen-1-yl isobutyrate	146306	267867	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	55184
19.595	19.570	(Z)-3-hexen-1-yl butyrate	80111	88925	n.d.	n.d.	47286	226896	n.d.	n.d.	n.d.	n.d.	n.d.	110852	21866
19.674	19.630	5-methyl-4-hexen-3-one			n.d.	n.d.	n.d.	36153	n.d.	n.d.	n.d.	197189	n.d.	n.d.	36818
19.694	19.645	Oxalic acid, cyclohexyl isobutyl ester	22942	18604	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	67079
19.800	19.730	hexyl isobutyrate	64117	46617	n.d.	n.d.	n.d.	27722	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	139016
19.985	19.925	ethyl octanoate	n.d.	n.d.	n.d.	n.d.	1758298	n.d.	n.d.	1710938	383010	n.d.	n.d.	n.d.	n.d.
19.995	19.965	ethyl palmitate	31394		42216	49750		n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
20.003	19.970	methyl 2-methyl stearate	n.d.	29724		491562	1473474	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	194459	n.d.
20.512	20.470	nonyl acetate	n.d.	87759	1455965	41553	n.d.	70480	57835	1261094	6160316	n.d.	n.d.	n.d.	n.d.
20.501	20.450	Caprylyl acetate	201403	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	445039	5943923	n.d.
21.099	21.060	3-Phenylpropanol	n.d.	n.d.	n.d.	n.d.	77400	n.d.	1050072	n.d.	n.d.	n.d.	n.d.	67709	n.d.
21.821	21.780	3-Mercaptohexyl acetate	n.d.	n.d.	49887	166697	132183	n.d.	n.d.	n.d.	65940	219431	n.d.	n.d.	n.d.
22.492	22.455	cinnamaldehyde	n.d.	12619	377061	41990	289912	n.d.	204327	n.d.	256215		118618	451711	n.d.
23.543	23.490	Theaspirane A	185660	144766	251699	467461	n.d.	75951	n.d.	n.d.	n.d.	1008860	177142	171851	n.d.
24.120	24.060	Theaspirane B	161944	109834	230848	402491	n.d.	58218	n.d.	n.d.	n.d.	1038081	2132473	n.d.	47845
25.196	25.145	ethyl hydrocinnamate	n.d.	n.d.	n.d.	n.d.	280498	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	52062
25.912	25.840	isopropyl acetate	6917399	5707525	7220766	9419407	22875107	5452298	624230	5823059	4442458	1418387	19254084	22704574	6730766
26.227	26.205	(Z)-3-hexen-1-yl hexanoate	44060	131067	n.d.	n.d.	165274	67937	n.d.	117494	84520	n.d.	n.d.	n.d.	n.d.
26.450	26.415	hexyl hexanoate	21465	51838	33920	n.d.	19247	n.d.	n.d.	n.d.	81695	n.d.	n.d.	77264	n.d.

28.284	28.240	cinnamyl acetate	123083	134124	2035423	1473575	3548497	220587	n.d.	325624	1131142	n.d.	3408592	8145725	6834617
28.558	28.500	(E)-geranyl acetone	37268	n.d.	84981	94382	58999	n.d.	n.d.	n.d.	n.d.	117551	726404	n.d.	n.d.
28.982	28.920	Isovaleric acid	145884	112263	n.d.	n.d.	76392	128904	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
29.001	28.950	gamma-decalactone	n.d.	n.d.	89853	97707	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
29.624	29.575	methyl vinyl ketone	80665	61880	122153	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	132880	n.d.

*n.d. not detected

Similarly, Steinhaus *et al.* (2008) reported that (Z)-3-hexenal, hexanal, 1-hexanol, 1-hexanol acetate, ethyl butanoate, cinnamyl acetate 4-hydroxy-2,5-dimethyl-3(2H)-furanone, and 4-methoxy-2,5-dimethyl-3(2H)-furanone were important volatile components for pink guava (*Psidium guajava*, L.) and ethyl butanoate, methyl and ethyl benzoate, and cinnamyl acetate might be responsible for the sweet and fruity character of the guava fruits.

It has been reported that the major volatile in the guava extract were hexanal, (Z)-3-hexenal, and (E)-2-hexenal. Also, ethyl butanoate, hexanal, (Z)-3-hexenal, 4-methoxy-2,5-dimethyl-3(2H)-furanone, methyl benzoate, ethyl benzoate, 2- and 3- methyl butanoic acid, 4-hydroxy-2,5-dimethyl-3(2H)-furanone and cinnamyl acetate were identified as aroma-active compounds in fresh guava (Osorio *et al.*, 2011). Also, it has been mentioned that (Z)-3-hexenal has the most predominant odorant which is responsible for green leaf odor and is formed by enzymatic oxidation of linoleic acid during cell breaking in the guava fruits (Egea *et al.*, 2014). Also (Z)-3-hexenal and hexanal have been previously associated with immaturity levels. In a general trend, it is reported that terpenes decrease with increasing maturity, while the esters are formed only at full maturity. This is of great importance in determining the sensory quality between ripe green and ripe yellow fruit (Moon *et al.*, 2018).

Hierarchical cluster analysis (HCA) and principal component analysis (PCA)

HCA and PCA analyses have been widely used in fruits, vegetables, and herbal studies. Because it helps to clearly express the relationship between the product, or the effect of the applied processes. It also expresses the difference in terms of the qualities, or sensory of the relationship between the samples. In the study, aroma compounds and other physical and chemical results were analyzed separately to distinguish the differences and similarities of the samples more clearly. According to the HCA dendrogram (Figure 3), the guava genotypes were collected into four main groups according to analyses. Figure 3 shows that, the white guavas (genotypes 8 and 9) are a group apart from other samples. Genotypes 1, 2, 4, and 6 are similar in results of TSS, and depending on these results, these genotypes were a separate group in results of AC and AA amounts. Although genotypes 11, 12, and 13 are lower than the other samples in results of TSS, they have higher results in terms of AC and TPC compared to the genotypes.

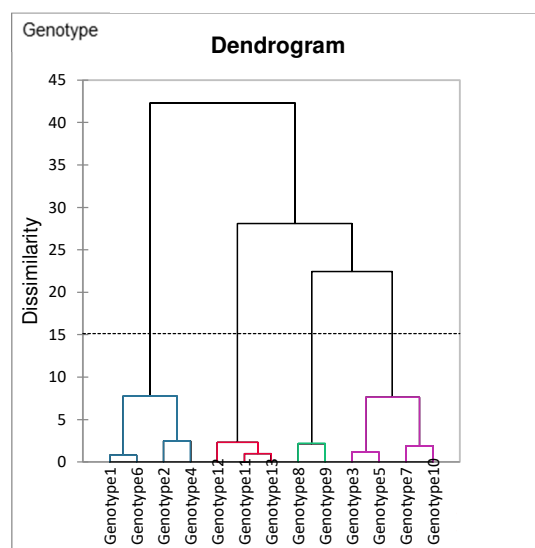


Figure 3. HCA analyses dendrogram for physical and chemical analyses (MC: moisture content. TSS: total soluble solid content. CV: antioxidant capacity. TPC: total phenolic content. AC: ascorbic acid content)

PCA is an unsupervised multivariate analysis that makes the complexity of data more understandable by converting it into several dimensions and correlations (Vidal *et al.*, 2020). In the present study, PCA was used to compare the different genotypes of guava fruits which have different physical and chemical characteristics. The PCA analysis confirms the HCA analysis results. According to the graph (Figure 4) obtained from PCA, a high correlation was determined between AC and TPC. Also, there was a high correlation between fruit weight, width, and height values of guava fruit genotypes. The physical characteristics (length, width, weight) formed one group, TPC, AC, and TSS formed a separate group, and MC and AA formed a separate group.

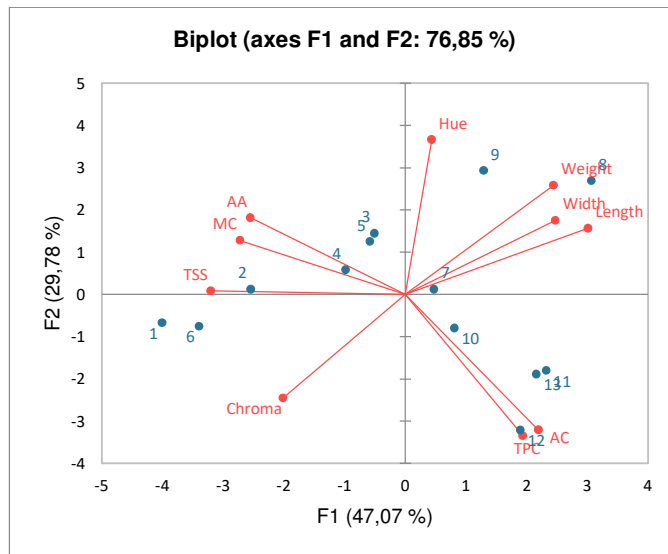


Figure 4. PCA analyses dendrogram for physical and chemical analyses (MC: moisture content. TSS: total soluble solid content. CV: antioxidant capacity. TPC: total phenolic content. AC: ascorbic acid content)

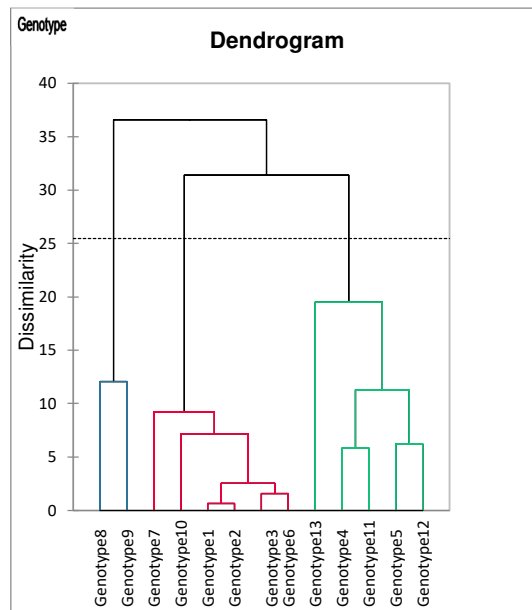


Figure 5. HCA analyses for aroma components

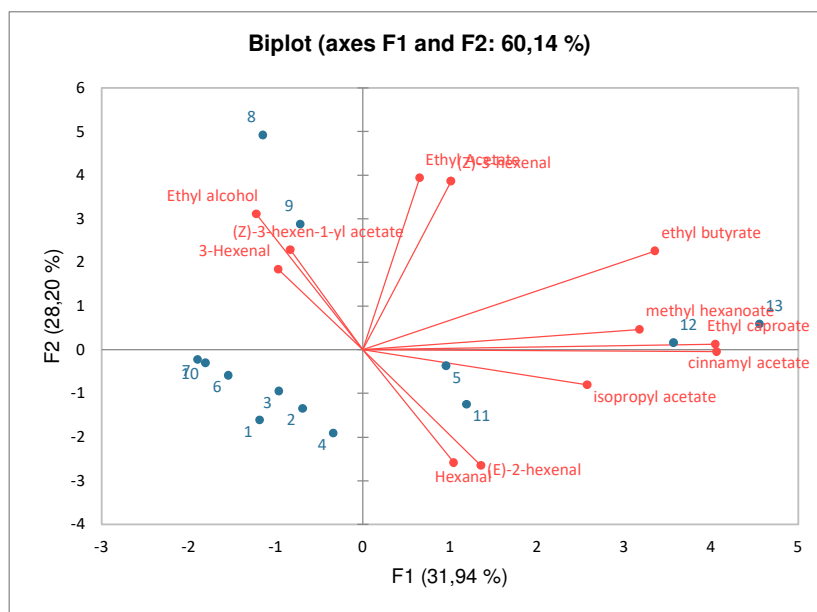


Figure 6. PCA analyses for aroma components

Likewise, aroma compounds were classified with PCA which was made more understandable. The HCA data of the aroma components show that the aroma components (Figure 5) are divided into 3 main groups. The PCA analysis results and HCA analysis were examined together, and Figure 6 showed that, genotypes 8 and 9 formed a separate group from all other genotypes in terms of (Z)-3-Hexen-1-yl acetate (sweet, pear, melon), 3-Hexenal (melon, tropical) and Ethyl alcohol (fruit and sweet) components. Genotypes 5 and 11 were similar, especially in terms of Hexenal (fruity), (E)-2-Hexenal (green). Genotypes 12 and 13 were similar, especially in terms of cinnamyl acetate (sweet) and ethyl caproate (sweet).

Conclusions

In this study, guava fruit genotypes harvested from different areas of Antalya-Mersin, Turkey were examined. The harvested fruits were compared, according to principal components, depending on possible genotypic differences. The results showed that the ascorbic content of guava fruits was quite high. In addition, the high correlation between TPC and AC values showed that the bioactive components of the guava samples were significantly higher. When the aroma composition was examined, it was determined that the guava genotypes were quite aromatic and there were differences between the genotypes. Especially, it has been determined that the white guava genotypes have very different chemical and aromatic properties from other genotypes. The obtained data will constitute material for future breeding studies.

Authors' Contributions

Conceptualization, FBT and HG; Data curation, RB, KKG and GG; formal analysis, RB, FBT, KKG and GG; funding acquisition, RB and HG; investigation, RB, FBT and HG; methodology, RB, FBT and HG; project administration, FBT and HG; resources, RB, FBT and HG; software, RB, KKG and GG; supervision, FBT and HG; validation RB and KKG; visualization, RB, FBT and KKG; writing - original draft, FBT and HG; writing - review and editing, FBT and HG. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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