Physico-chemical and Nutraceutical Characterization of Selected Indigenous Guava (Psidium guajava L.) Cultivars

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Abstract
In order to ascertain physicochemical and nutraceutical attributes, indigenous guava (Psidium guajava L.) cultivars were comprehensively characterized. Eight cultivars namely Gola, Chota Gola, Surahi, Choti Surahi, Sufaida, Sdabahar, Lal Badshah and Karela were selected due to their climatic adaptability and commercial suitability. All the cultivars showed significant variations in terms of their studied quality attributes. Amongst physical characteristics, Gola exhibited highest (79.9 mm) GMD with lowest (50.3 mm) was estimated in Choti Surahi. Insignificant varietal differences were observed in most of the proximate parameters as well as in mineral contents. Nutraceutical estimations showed significant variation in ascorbic acid (222.26-289.43 mg/100 g), total phenolic contents (94.06-190.64 mg GAE/100 g), total flavonoid contents (81.30-154.19 mg QE/100 g) and radical scavenging activity (27.70-78.15%) in the selected cultivars. A highly significant correlation (R² = 0.9970 p < 0.05) was observed between ascorbic acid and radical scavenging activity. In sensory evaluation, Gola received over all maximum score (8.8) amongst its counterparts. Processed data were then analyzed using Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA). The combination of PCA and HCA yielded in a sufficient discrimination of the examined guava cultivars. In PCA analysis, first two PCA components explained 65.98% of the total variation. Dendrogram successfully classified the tested cultivars into three major groups featuring dissimilarities amongst the cultivars. Research outcome will provide baseline for the farmers, researchers, exporters and other stalk holders to realize the ultimate potential of indigenous guava cultivars for their appropriate commercial utilization.

Keywords: guava cultivars; nutraceutical characterization; principal component analysis.

Practical Application: Varietal characterization along with possible value addition

1 Introduction

Guava (Psidium guajava L.) a member of Myrtaceae family is an important commercial fruit crop of tropics. Archeological studies revealed South American countries as its origin and from there it migrated to Asia (Rodriguez et al., 2010). It is estimated that the World annual production of guava is about 6.8 million tons (Food and Agricultural Organization of the United Nations, 2017); with India and Pakistan shared around 50 percent of the total world production (Yahia, 2018). Brazil, Mexico, Venezuela, Egypt, Sudan, Indonesia, Bangladesh and Vietnam are the other major guava producing countries (Mehmood et al., 2014). Amongst fruit crops of Pakistan, guava occupies 3rd position after citrus and mango with the annual production of 0.586 million tones and carries biannual bearing (Government of Pakistan, 2018).

As “poor man’s apple of tropics” guava truly happens to be the fruit for masses in terms of its commercial availability (Hassan et al., 2012). Nutritionists often characterize it under “super-fruits” owing to its diversified bioactive compounds and remarkable antioxidant activity (Joseph & Priya, 2011). In addition, it can offer four times more vitamin-C than an orange (Hassimotto et al., 2005). Pharmacological studies proved its anti diarrheal, antidiabetic, antimicrobial, hepatoprotective, anti-allergic, anti-plasmodia, anti-spasmodic, anti-inflammatory activities and found equally effective in cardiovascular disorders (Gupta et al., 2018; Upadhyay et al., 2019). An average guava fruit carries 83% water contents, 15% carbohydrates, 2.58% protein, 2.8-5.5% crude fiber, 0.6% fat and 0.7% ash. The fruit is also a significant source of micronutrients like; calcium (23 mg/100 g), phosphorous (42 mg/100 g), Iron (0.09 mg/100 g), Vit. C (250-300 mg/100 g) and Vit. A (200-400 IU/100 g) (Kadam et al., 2012; Flores et al., 2015). Guava is generally consumed as a fresh fruit; however, multiple value added products; as jelly, jam, juices, guava leather, wine, freeze-dried and dehydrated slices are also being prepared on industrial scale.

Being a climacteric commodity, guava fruit carries active metabolism, high respiration rate and limited storage stability at ambient temperature. Physiological processes are regulated by a natural growth hormone known as ethylene which is produced from L-methionine via 1-aminocyclopropane-1-carboxylic

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acid (ACC) synthase in a complex signal transduction pathway (Rueda, 2005). Resultantly, guava fruit attains its climacteric perishability between four to five post-harvest days depending on the variety, harvest time and storage conditions. Reduced postharvest storage life limits options for the commercialization of this important fruit in local and export market.

In Pakistan, different commercial guava cultivars like; Gola, Chota Gola, Surakhi, Choti Surakhi, Sufaiida, Karela, Baidana, Ramzani, Surkha, Lal Badshah, Sdahbar, Selection 313, Hafsi etc. are available in the market (Mehmood et al., 2014). Nevertheless, detailed information regarding their physico-chemical and nutraceutical characterization is scanty. Characterizations of fruit cultivars based on physicochemical, biochemical and nutraceutical attributes have marketable significance in defining their intended commercial utilization (Ulhaq et al., 2013; Kyriacou et al., 2020). Furthermore, physico-chemical assessments are also imperative for packaging, consumer acceptability and transportation. Keeping in view nutritional and health-promoting properties, it can also be utilized for the development of different nutraceutical products (Ho et al., 2012). The growing mandate for fresh fruit consumption and export potentials can only be achieved through comprehensive varietal characterization and reduced post-harvest losses. Different plant breeding programs with a focus of developing nutrient-rich cultivars are also being designed to fulfill specific technological purposes. Therefore, the aim of this study was to explore physical, biochemical and nutraceutical properties of indigenous guava cultivars, so as to offer baseline data for the farmers, researchers, marketing and processing entrepreneurs.

2 Materials and methods

The presented scientific investigations were carried out at the Institute of Food & Nutritional Sciences (IF & NS), PMAS-Arid Agriculture University, Rawalpindi-Pakistan.

2.1 Collection of Guava cultivars

Different indigenous Guava cultivars namely Gola, Chota Gola, Surahi, Choti Surahi, Karela, Lal Badshah, Sdahbar and Sufaiida were collected from the Horticulture Research Institute, Ayub Agriculture Research Institute, Faisalabad (Pakistan). The fruits were sorted, graded and subsequently precooled to remove the field heat. The representative fruit samples were carefully transported to IF & NS under controlled conditions (85% relative humidity and 24°C) for further analysis.

2.2 Physico-chemical attributes

Physical characteristics of Guava cultivars were measured according to the standard scientific protocols. Digital Vernier caliper was used to measure the size (mm) of the fruits in terms of linear dimensions. Geometric Mean Diameter (Dg) was calculated by using the following Equation (1) as described by Abbasi et al. (2016).

\[
D_g = (LWT)^{0.333}
\]  

Where, L is the length; W is the width and T is thickness of the fruit.

Surface area (S) in mm² was determined according to the following formula (2) as described by Baryeh (2001).

\[
S = \pi D_g^2
\]  

Sphericity of fruit samples was determined by the following formula (3) as described by Ahmadi et al. (2008).

\[
\phi = \frac{(D_g / L) \times 100}{-}\]

The specific gravity of different guava cultivars were determined by taking the weight of the fruit in air and water according to the following equation (4) as per AOAC (Association of Official Analytical Chemists, 2005) method no. 936.13.

\[
\text{Specific Gravity} = \frac{\text{Weight in air}}{\left(\text{Weight in air} - \text{Weight in water}\right)}
\]

Total soluble solids (TSS) expressed as “Brix were determined in the pulp of each fruit sample using a digital refractometer PAL-3 (ATAGO, Japan) as described by Sinha & Sinha (2017). The pH values were measured by using digital pH meter (HI 2211 HANNA-USA) calibrated with standard buffers as elaborated by Shetgar et al. (2017). Titratable acidity was determined by titrating 5ml of juice with 0.1N NaOH and results were expressed as percentage of Malic acid on fresh weight basis (Association of Official Analytical Chemists, 2005; method no. 942.15). Similarly, total sugars were determined by Lane and Eynon method using Fehling’s solution as reported in AOAC (Association of Official Analytical Chemists, 2005) method no. 968.28.

2.3 Proximate composition

Moisture percentage was determined by oven drying method until constant weight (Association of Official Analytical Chemists, 2005; method no. 930.15), while crude fat estimation was carried out by using ST 243 Soxtec solvent extraction system (FOSS, Denmark) according to AOAC (Association of Official Analytical Chemists, 2005) method no. 930.09. Crude protein was measured by following AOAC (Association of Official Analytical Chemists, 2005) method no. 976.02 through FOSS Kjeltec 8400 Analyzer Unit, Denmark. Similarly, crude fiber and ash content were also analyzed according to AOAC (2005) method nos. 978.10 and 930.05 respectively.

2.4 Nutraceutical attributes

Extraction was carried out by taking a homogenous chopped fruit sample (20 g) with 80% methanol (80:20 methanol-water v/v, 200 ml) in 500 ml conical flasks and then shaked for 24 hrs at room temperature in an orbital shaker. All extracts were separated from the residues by filtering through Whatman No.1 filter paper and concentrated by using rotary evaporator under reduced pressure (40-50 torr) at temperature of 45°C.
(Gull et al., 2012). The concentrated extracts were weighed and stored at −4 °C until used for nutraceutical analysis.

Total phenolic contents (TPC) were quantified through Folin-Ciocalteu reagent as per method explained by Gull et al. (2012). The concentrated extract (0.5 ml) was taken in 25 ml volumetric flask to which 5 ml Folin-Ciocalteu reagent (2N) and 4 ml freshly prepared 7.5% sodium carbonate solution were added and the total volume was made up with 80% methanol. The absorbance at 765 nm using a CE-2021, Spectrophotometer (CECIL Instruments Cambridge, England) was noted after one hour. Standard gallic acid solutions with varying concentrations (50-450 ppm) in methanol were prepared to draw calibration curve. Quantification of total phenolic contents was carried out as milligrams of gallic acid equivalents (GAE) per 100 g on dry weight basis.

Total flavonoid compounds (TFC) were measured by the method reported by Gull et al. (2012). One ml of the aqueous extract was placed in a 10 ml volumetric flask, along with distilled water (5 ml) followed by 5% NaNO₂ (0.3 ml). After 5 min, 10% AlCl₃ (0.6 ml) was added to the mixture. After another 5 min, 1 M NaOH (2 ml) was added and the total volume was made up with distilled water. Standard Quercetin solutions with varying concentrations (50-450 ppm) were prepared for calibration curve and absorbance was recorded at 510 nm using UV-visible spectrophotometer. TFC were expressed as milligrams of Quercetin equivalents (QE) per 100 g of sample on dry weight basis.

The stable radical 2, 2-diphenyl-1-picrylhydrazyl (DPPH) was used for determination of radical scavenger activity (RSA) expressed as antioxidant activity of the extracts by following the method of Verma et al. (2018). According to the method, 3.9 ml of 0.1 mM DPPH was added in 0.1 ml of fruit extract. After 30 min at room temperature, the absorbance was recorded at 517 nm. The percentage of scavenging activity was calculated as the ratio of the absorbance of the sample reactive to the control (0.1 mM DPPH solutions without the extract). Radical scavenging activity was measured by using the following formula 5.

\[
\text{Radical scavenging activity (\%) } = 100 \times \left( \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \right) / A_{\text{control}} \tag{5}
\]

Where \( A_{\text{control}} \) and \( A_{\text{sample}} \) are absorbance of control and sample, respectively.

Vitamin C content (Ascorbic Acid) was determined by titrimetric method using 2, 6-dichlorophenol indophenol (Redox dye) as described by AOAC (Association of Official Analytical Chemists, 2005) method No. 967.21.

2.5 Mineral composition

The mineral contents of guava cultivars were determined according to AOAC (Association of Official Analytical Chemists, 2005) method no. 2015.06. The oven dried fruit samples (1.0 g) were first digested using wet digestion method. Calcium (Ca), Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu), Nickel (Ni) and Magnesium (Mg) were determined in an Atomic Absorption Spectrophotometer (GBC-932 Australia) whereas Sodium (Na) and Potassium (K) by Flame Photometer (Model PFP 7 Jenway, England) and Phosphorus (P) by using a Spectrophotometer (CE-2021, 2000 series CECIL Instruments Cambridge, England).

2.6 Sensory evaluation

Sensory evaluation of different guava cultivars was conducted by using 9-point hedonic scale as described by Amerine et al. (2013). A panel of trained judges was selected to record their observations in terms of scores for color, aroma, taste and texture attributes.

2.7 Statistical analysis

Data obtained after characterization of guava cultivars involving multiple traits was analyzed by different statistical tools. Statistical difference in mean values was compared by Tukey's HSD test using STATISTIX 8.1 (USA) data analyzing software and interpreted according to Steel et al. (1997). Principal component analysis (PCA) was performed by using Addinsoft XLSTAT Pearson Edition version 2015.5.01 software. Pearson correlations were also used to correlate the biochemical characters. The cumulative data from the quantitative and qualitative attributes was used for dendrogram (HCA) construction by following Ward's method.

3 Results and discussion

3.1 Physico-chemical analysis

The results pertaining to physicochemical characterization of eight indigenous guava cultivars are shown in Table 1 which shows significant variability amongst the tested attributes. However, fractional significant difference was found regarding pH values among different guava varieties at \( p < 0.05 \) (Table 1). Physico-chemical estimations are quite important for consumer acceptability and also found to be suitable for cultivar identification (Padilla-Ramirez et al., 2012). Physical dimensions of fruits also help to calculate the number of fruits to be engaged during possible value additions (Demir & Hakki Kalyoncu, 2003). Indigenous Pakistani guava cultivars have historically been named by the growers according to their physical dimensions for example Gola and Surahi having round to pear shape fruit, respectively (Mehmood et al., 2014).

Some of the present results are found in close agreement with Mehmood et al. (2014), who studied different genotypes of guava collected from multiple locations of Pakistan. All the tested indigenous guava cultivars contain appreciable amounts of sugars (Table 1); however, Gola found to be the sweetest amongst other counterparts.

Sugars are domineering food constituents that act as an immediate source of energy for the routine body accomplishments. A high sugar level along with total soluble solids often serves as maturity indices in tropical fruits. Table 1 also showed significant correlation between total sugars and total soluble solids. These attributes increase with the passage of time during ripening process, resulting degradation of carbohydrates to soluble sugars (Oms-Oliu et al., 2008). The above cited
Table 1. Physico-chemical analysis of Guava Cultivars.

| CULTIVARS | Fruit Size mm | GMD mm³ | Sphericity % | Surface Area mm² | Specific Gravity | TSS °Brix | pH | TA % | Total Sugars % |
|-----------|---------------|---------|--------------|------------------|-----------------|---------|----|------|----------------|
| GOLA      | 80.3 ± 2.40 b | 79.9 ± 2.15 a | 99.5 ± 4.01 a | 20077 ± 25.05 a | 1.071 ± 0.14 a | 8.1 ± 1.10 a | 4.47 ± 0.60 a | 0.70 ± 0.12 c | 6.74 ± 1.00 a |
| CHOTA GOLA| 60.9 ± 2.88 d | 59.8 ± 2.04 f | 98.2 ± 3.44 c | 11226 ± 13.18 f | 1.055 ± 0.11 d | 7.8 ± 1.15 b | 4.30 ± 0.50 ab | 0.68 ± 0.52 cd | 6.52 ± 0.50 b |
| SURAHI    | 94.6 ± 1.88 a | 67.0 ± 3.03 d | 70.8 ± 3.27 h | 14116 ± 14.7 d | 1.054 ± 0.12 d | 6.3 ± 1.17 d | 4.10 ± 0.70 bc | 0.66 ± 0.61 de | 6.18 ± 0.45 c |
| CHOTI SURAHI | 57.8 ± 1.13 c | 50.3 ± 2.65 h | 87.0 ± 2.26 e | 7954 ± 14.28 h | 1.062 ± 0.31 c | 6.8 ± 0.76 c | 4.20 ± 0.50 bc | 0.76 ± 0.70 ab | 6.07 ± 1.00 cd |
| SUFAIDA   | 75.7 ± 1.28 b | 65.2 ± 3.16 e | 86.1 ± 3.52 g | 13339 ± 22.81 e | 1.071 ± 0.23 a | 6.4 ± 1.00 d | 4.30 ± 0.40 ab | 0.64 ± 0.45 e | 5.99 ± 0.90 d |
| LAL BADSHAH | 55.8 ± 2.28 cd | 55.4 ± 3.02 g | 99.2 ± 4.28 b | 9627 ± 8.38 g | 1.067 ± 0.42 b | 5.8 ± 1.10 e | 4.01 ± 0.90 cd | 0.60 ± 0.50 f | 5.65 ± 0.50 e |
| SDABAHAR  | 69.7 ± 1.27 b | 67.6 ± 4.05 c | 97.1 ± 2.71 d | 14371 ± 21.91 c | 1.061 ± 0.14 c | 5.6 ± 1.30 e | 4.00 ± 1.05 cd | 0.74 ± 0.30 b | 5.22 ± 0.25 f |
| KARELA    | 86.1 ± 1.69 a | 74.7 ± 2.73 b | 86.7 ± 3.16 f | 17526 ± 13.16 b | 1.055 ± 0.55 d | 5.3 ± 1.20 f | 3.76 ± 0.70 d | 0.78 ± 0.40 a | 5.01 ± 0.80 g |

Geometric Mean Diameter (GMD), Total Soluble Solids (TSS), Titeratable Acidity (TA), Means with common letters are non-significant at P < 0.05.

Table 2. Proximate composition of Guava Cultivars.

| CULTIVARS | Moisture %  | Ash %     | Crude Fiber % | Crude Fat %  | Crude Protein % | TC %   |
|-----------|-------------|-----------|---------------|--------------|-----------------|--------|
| GOLA      | 84.3 ± 1.20 a | 0.65 ± 0.21 bc | 3.40 ± 0.45 a | 0.90 ± 0.15 ab | 2.09 ± 0.35 ab | 8.67 ± 0.90 d |
| CHOTA GOLA | 83.1 ± 1.80 c | 0.60 ± 0.10 e | 3.35 ± 0.30 a | 0.86 ± 0.09 bc | 2.03 ± 0.27 bcd | 10.1 ± 0.12 a |
| SURAHI    | 83.2 ± 1.50 c | 0.63 ± 0.31 cd | 3.46 ± 0.50 a | 0.92 ± 0.20 a | 2.11 ± 0.20 a | 9.64 ± 0.80 ab |
| CHOTI SURAHI | 84.3 ± 0.90 a | 0.61 ± 0.20 de | 3.34 ± 0.30 a | 0.85 ± 0.15 c | 2.04 ± 0.35 bcd | 8.86 ± 0.16 cd |
| SUFAIDA   | 82.9 ± 0.50 c | 0.66 ± 0.25 ab | 3.45 ± 0.28 a | 0.93 ± 0.20 a | 2.06 ± 0.29 abc | 9.94 ± 0.18 a |
| LAL BADSHAH | 84.2 ± 1.37 a | 0.59 ± 0.30 e | 2.96 ± 0.55 b | 0.87 ± 0.09 bc | 2.03 ± 0.30 cd | 9.27 ± 0.38 bc |
| SDABAHAR  | 83.1 ± 2.11 c | 0.68 ± 0.22 a | 3.32 ± 0.40 a | 0.87 ± 0.25 bc | 1.99 ± 0.25 d | 10.05 ± 0.15 a |
| KARELA    | 83.7 ± 1.10 b | 0.67 ± 0.30 ab | 3.44 ± 0.50 a | 0.85 ± 0.16 c | 2.02 ± 0.20 cd | 9.23 ± 0.13 bc |

Total Carbohydrates (TC), Means with common letters are not significant at P < 0.05.
K (3645-4167.7 ppm), Ca (222.1-274.7 ppm), P (87.33-101.0 ppm), Fe (3.67-7.66 ppm), Mg (201.33-236.33 ppm) and Zn (9.67-12.66 ppm) were the major minerals estimated in the present study. While taking in account of mineral contents, it was revealed that all the under investigation guava cultivars validated difference in their mineral contents. These variations in mineral contents of tested guava cultivars may be due to the genetic variability, soil chemistry, climate and agricultural practices (Khushk et al., 2009; Chiveu et al., 2019). Guava fruit is known for its higher mineral composition especially P, K, Ca, Mg and Zn (Tanwar et al., 2014; Dube & Singh, 2019). Every mineral has its significant role in human health like; calcium and phosphorus are needed for teeth and bone formation (White & Broadley, 2009). Whereas, Na, K and Mg are required for neural conduction and muscular contraction (Gharibzahedi & Jafari, 2017).

Similarly, iron is one of the most cited and extensively studied macronutrial with recommended daily allowance of 10-20 mg for humans (WHO, 1996). As a component of hemoglobin as well as an integral part of enzymatic systems, iron plays a significant role in oxygen transport and cellular respiration (Aberoumand & Deokule, 2009). Results pertaining to mineral composition of guava cultivars (Table 3) illustrated that Karela was found to be mineral enriched followed by Sdabahar. Amongst all cultivars, Choti Surahi turned out to be the richest source of magnesium (236.33 ppm) followed by Safaida (235.67 ppm). Substantial amounts of Zn (9.67-12.67) were also present in all the examined guava cultivars which is an integral part of enzymes kinetics and proteins synthesis in humans (Badii et al., 2012). In general, the studied fruit samples had the concentrations of the essential elements above or around the values reported for traditional tropical fruits. The results pertaining to mineral composition of guava were also in close agreement with the findings of Pereira et al. (2014) and Chiveu et al. (2019) who also found guava as a significant source of valuable micronutrients.

### Table 3. Minerals composition of Guava Cultivars

| CULTIVARS | Na (ppm) | K (ppm) | Ca (ppm) | P (ppm) | Fe (ppm) | Mg (ppm) | Zn (ppm) |
|-----------|---------|---------|---------|---------|---------|---------|---------|
| GOLA      | 317.33 ± 4.52 cd | 3854.3 ± 32.6 d | 261.7 ± 2.08 b | 91.67 ± 1.53 bc | 5.33 ± 0.27 bc | 222.67 ± 3.06 b | 11.65 ± 0.88 ab |
| CHOTA GOLA| 312.33 ± 3.21 d | 3740.0 ± 20.5 e | 268.3 ± 2.52 ab | 90.33 ± 2.58 bc | 3.67 ± 0.19 d | 214.33 ± 4.04 bc | 10.33 ± 0.51 bc |
| SURAHI    | 323.33 ± 3.06 bc | 3912.7 ± 26.1 c | 251.3 ± 3.21 c | 101.0 ± 7.94 a | 5.67 ± 0.21 b | 217.67 ± 2.54 bc | 12.66 ± 0.31 a |
| CHOTI SURAHI | 330.33 ± 4.12 ab | 3871.3 ± 36.1 cd | 265.3 ± 4.51 ab | 87.33 ± 5.08 c | 3.66 ± 0.36 d | 236.33 ± 3.06 a | 10.33 ± 0.24 bc |
| SUFaida   | 296.67 ± 2.13 e | 3645.0 ± 31.0 f | 274.7 ± 3.06 a | 90.33 ± 4.58 bc | 4.33 ± 0.24 cd | 235.67 ± 3.17 a | 10.65 ± 0.64 bc |
| LAL RADSHAH | 310.33 ± 3.18 d | 3764.3 ± 41.0 e | 233.0 ± 4.01 d | 87.33 ± 2.08 c | 5.34 ± 0.39 bc | 201.33 ± 3.51 d | 7.63 ± 0.19 d |
| SDBAHAIR | 312.33 ± 2.52 d | 4094.3 ± 55.0 b | 222.1 ± 1.15 e | 91.00 ± 3.10 bc | 6.67 ± 0.45 ab | 212.33 ± 1.53 c | 9.67 ± 0.63 c |
| KARELA    | 332.67 ± 3.51 a | 4167.7 ± 39.5 a | 244.3 ± 4.04 c | 98.00 ± 2.29 ab | 7.66 ± 0.28 a | 216.00 ± 4.18 bc | 10.66 ± 0.74 bc |

Sodium (Na), Potassium (K), Calcium (Ca), Phosphorous (P), Iron (Fe), Magnesium (Mg), Zinc (Zn); Means with common letters are non-significant at P < 0.05.
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studied guava cultivars. Likewise, ascorbic acid contents, the highest TPC were estimated in Gola variety (190.64 mg GAE/100 g) and lowest in Sdabahar (94.06 mg GAE/100 g). The total flavonoid contents (TFC) were assessed on the basis of mg/100 g of quercetin equivalents which were varied from 81.30 to 154.19 mg QE/100 g among the tested cultivars. The significant variations among all tested varieties were also in line with the earlier studies of Alothman et al. (2009) who found TPC ranges from 109 to 191 mg GAE/100 g of fresh weight while TFC from 13.9 to 40.9 mg CEQ/100 g. Similarly, radical scavenging activity (DPPH inhibition percentage) varies from 36.8 to 71% in different guava cultivars. Almost similar trend was observed in the results pertaining to antioxidant activity in terms of their DPPH radical scavenging activity (RSA %) as presented in Table 4.

Nutraecutical potential due to the presence of different bioactive compounds in fruits is much accepted profile that determines their quality in terms of their intended use (Ali et al., 2011). The fruits are purposely being selected in view of their specific health benefits beyond basic nutrition. Present study showed remarkable nutraceutical potential in the tested Guava cultivars (Table 4). In addition, the same has also been confirmed through significant correlation observed between estimated bioactive compounds and radical scavenging activity. This correlation has also been reported by different other researchers like; dos Santos et al (2017), Abbasi et al (2019) and Rehman et al. (2019). Based upon our investigations, we can say that the guava cultivars are effective free radical scavengers. Flores et al. (2015) also suggested that guava cultivars may be exploited as a potent source of natural antioxidants for food, pharmaceutical, medical and commercial uses.

3.5 Sensory evaluation

Table 5 showed data related to the sensory evaluation of tested guava cultivars. Amongst studied cultivars, Gola received the highest sensorial scores (8.8) on a 9-point hedonic scale ($p < 0.05$). In terms of their skin color, selected guava cultivars were statistically at par (Table 5). Guava fruit carries three-maturity stages viz un-ripe, semi ripe and full ripe which would be distinguished by the fruit color (Gull et al., 2012). Color is the most important sensory attribute perceived by the consumer and grower being a critical component of fruit maturity index (Bashir & Abu-Goukh, 2003). Likewise, there was no significant difference ($p < 0.05$) among the tested guava cultivars regarding the texture of the fruit. Texture is another important quality attribute of fruits. Sensorial texture of fresh fruits is a complex manifestation of perceptions by the senses of touch, vision, hearing and kinaesthesia (Waldron et al., 2003). Texture of fruits and vegetable products is primarily associated to the structural integrity and firmness that is mainly established by the network of cellulose, hemicellulose and pectin. This interwoven network plays a significant role during postharvest processing and storage stability of fruits (Cruz, 2011).

Aroma is a distinct feature of guava fruit due to the presence of different volatile and non-volatile compounds such as (E)-2-hexenal, Z-3-hexenal, Z-3-hexenyl acetate, E-3-hexenyl

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**Table 4. Nutraecutical analysis of Guava Cultivars.**

| CULTIVARS | ASCORBIC ACID (mg/100 g) | TPC (mg GAE/100 g) | TFC (mg QE/100 g) | RSA % |
|-----------|--------------------------|--------------------|--------------------|-------|
| GOLA      | 289.43 ± 0.97 a          | 190.64 ± 0.11 a    | 154.19 ± 0.21 a    | 78.15 ± 0.16 a |
| CHOTA GOLA| 234.32 ± 0.29 e          | 104.94 ± 0.22 e    | 97.37 ± 0.15 d     | 38.07 ± 0.43 e |
| SURAHI    | 244.43 ± 0.75 d          | 115.97 ± 0.18 d    | 100.56 ± 0.37 c    | 42.46 ± 0.41 d |
| CHOTI SURAHI | 246.20 ± 0.10 c       | 118.60 ± 0.21 c    | 101.31 ± 0.38 c    | 44.57 ± 0.41 c |
| SUFAIDA   | 250.82 ± 0.40 b          | 121.49 ± 0.46 b    | 103.45 ± 0.14 b    | 47.77 ± 0.67 b |
| LAL BADSHAH | 227.95 ± 0.36 g         | 100.19 ± 0.31 g    | 94.33 ± 0.96 e     | 31.14 ± 0.76 g |
| SDAHAR    | 222.26 ± 0.25 h          | 94.06 ± 0.26 h     | 81.30 ± 0.31 f     | 27.70 ± 0.40 h |
| KARELA    | 229.80 ± 0.26 f          | 102.19 ± 0.47 f    | 94.57 ± 0.32 e     | 34.37 ± 0.22 f |

Total Phenolic Compounds (TPC), Total Flavonoid Compounds (TFC), Radical Scavenging Activity (RSA); Means with common letters are non-significant at $P < 0.05$.

**Table 5. Sensory evaluation of guava cultivars.**

| CULTIVARS | Color | Aroma | Taste | Texture |
|-----------|-------|-------|-------|---------|
| GOLA      | 8.0 a | 8.0 a | 8.8 a | 8.0 a   |
| CHOTA GOLA| 6.4 ab| 6.4 abcd| 6.4 bc| 6.4 ab  |
| SURAHI    | 6.6 ab| 6.6 ab| 6.6 ab| 7.0 ab  |
| CHOTI SURAHI | 6.6 ab| 6.8 ab| 7.2 ab| 6.6 ab  |
| SUFAIDA   | 6.4 ab| 6.2 abcd| 6.4 bc| 6.0 ab  |
| LAL BADSHAH | 5.2 bc| 5.2 bcd| 5.2 bcd| 5.6 b   |
| SDAHAR    | 3.8 c | 4.6 d | 4.6 cd| 5.2 b   |
| KARELA    | 5.0 bc| 4.8 cd| 4.0 d | 5.2 b   |
Ascorbic Acid and Total Sugars (Abbasi et al., 2019). Among chemical parameters, Sphericity and TSS and pH (R² = 0.8578) significantly correlated with other functional parameters like RSA (R² = 0.9970 p < 0.05), TPC (R² = 0.9855 p < 0.05) and TFC (R² = 0.9705 p < 0.05).

Principal Component Analysis (PCA)

PCA is statistical cum mathematical tool to identify variation present in the dataset usually to characterize the samples by using a small number of factors. In this study, Principal Component Analysis put analyzed attributes into seven components that explained total variation (Table 8). The first component, which accounted for 44.28% of the total variation, predominantly incorporated crude protein, crude fat, calcium, TSS, total sugars, nutraceutical and sensory characters. The second component, which explained 21.71% of the total variation, included attributes like crude fiber, ash, potassium, phosphorus, iron, zinc, fruit size, GMD and surface area. The third component, elucidating 12.1% of the total variation, was the function of sphericity, total carbohydrates and moisture.

The fourth component, explaining for 9.42% of the total variation while fifth component of PCA revealed 6.42% of the total variation. The sixth component was mainly the function of sphericity, total carbohydrates and moisture.
Characterization of indigenous guava cultivars

The results of our investigation are in line with the findings of Flores et al. (2015) who also performed principal component analysis while studying chemical composition and antioxidant activity of seven guava cultivars.

### Hierarchical cluster analysis (HCA)

HCA is a clustering method which explore the dissimilarities among samples presented in groups and among groups illustrating a hierarchy (Granato et al., 2018). In present study, hierarchical cluster analysis (HCA) was performed by using Ward’s method for the agglomeration and Euclidean distance was used to explore dissimilarities in eight indigenous guava cultivars.

In doing so, the dendogram (Figure 2) revealed three distinct classes. The first two classes were separated with a dissimilarity result of 74x10^{-6}. Gola and Karela cultivar form the first separated class while in second class three cultivars namely Chota Gola, Choti Surahi and Lal Badshah were placed. The third group of class included Surahi, Sufaida and Sdabahar and was separated with a dissimilarity result of 42x10^{-6}. From HCA, one can observe high level of dissimilarity amongst Surahi, Sufaida and Sdabahar while on the other hand Gola and Karela were remarkably different in terms of relatively low similarity. This may leads to inconsistency in genetic material of guava cultivars. The illustrated results are also in conformity to the findings of Mehmood et al. (2014) who performed HCA to check genetic variability among guava accessions grown in different agro ecological zones of Pakistan.

Table 8. First 7 components from the PCA analysis of 31 traits of eight indigenous guava cultivars.

| Traits                  | F1    | F2    | F3    | F4    | F5    | F6    | F7    |
|-------------------------|-------|-------|-------|-------|-------|-------|-------|
| Moisture                | 0.234 | -0.176| -0.833| 0.260 | -0.278| 0.271 | 0.047 |
| Crude protein           | 0.809 | 0.254 | 0.234 | 0.127 | -0.450| 0.083 | 0.004 |
| Crude fiber             | 0.345 | 0.718 | 0.391 | 0.143 | 0.437 | -0.008| 0.039 |
| Crude fat               | 0.535 | 0.242 | 0.515 | -0.448| -0.351| 0.195 | -0.168|
| Ash                     | -0.154| 0.738 | -0.005| -0.462| 0.412 | 0.195 | -0.098|
| Total carbohydrates     | -0.444| -0.100| 0.750 | -0.281| 0.205 | -0.326| -0.047|
| Na                      | -0.087| 0.457 | -0.450| 0.759 | -0.054| -0.038| -0.032|
| K                       | -0.515| 0.690 | -0.412| 0.166 | 0.120 | -0.096| -0.194|
| Ca                      | 0.727 | -0.137| 0.373 | 0.244 | 0.294 | 0.123 | 0.390 |
| P                       | -0.052| 0.866 | 0.267 | 0.147 | -0.325| -0.198| 0.098 |
| Fe                      | -0.523| 0.711 | -0.341| -0.267| -0.179| -0.035| 0.025 |
| Mg                      | 0.518 | 0.106 | 0.273 | 0.234 | 0.509 | 0.576 | -0.007|
| Zn                      | 0.565 | 0.706 | 0.339 | 0.216 | 0.046 | -0.104| -0.087|
| Fruit Size              | -0.041| 0.904 | 0.243 | -0.028| -0.239| 0.251 | 0.019 |
| GMD                     | 0.243 | 0.773 | -0.204| -0.483| 0.047 | -0.219| 0.136 |
| Sphericity              | -0.031| -0.528| -0.567| -0.437| 0.312 | -0.329| 0.047 |
| Surface area            | 0.278 | 0.764 | -0.260| -0.459| 0.052 | -0.202| 0.134 |
| Specific gravity        | 0.440 | -0.342| -0.243| -0.617| 0.065 | 0.495 | -0.029|
| TSS                     | 0.857 | -0.280| -0.007| 0.074 | 0.214 | -0.369| -0.001|
| pH                      | 0.879 | -0.315| 0.161 | -0.162| 0.218 | -0.108| -0.134|
| Titratable Acidity      | -0.167| 0.493 | -0.388| 0.426 | 0.623 | -0.013| -0.096|
| Total Sugars            | 0.898 | -0.270| 0.168 | 0.089 | -0.042| -0.283| -0.061|
| Ascorbic Acid           | 0.947 | 0.168 | -0.205| -0.156| 0.019 | 0.091 | -0.012|
| TPC                     | 0.899 | 0.186 | -0.334| -0.211| 0.012 | 0.018 | -0.037|
| TFC                     | 0.894 | 0.148 | -0.367| -0.190| -0.043| -0.040| 0.070 |
| RSA                     | 0.940 | 0.174 | -0.234| -0.160| 0.054 | 0.046 | 0.018 |
| Color                   | 0.969 | -0.020| 0.041 | 0.177 | -0.084| -0.009| 0.141 |
| Aroma                   | 0.981 | -0.041| 0.007 | 0.167 | -0.009| -0.049| -0.078|
| Taste                   | 0.969 | -0.131| -0.024| 0.078 | 0.015 | -0.007| -0.194|
| Texture                 | 0.948 | 0.066 | -0.047| 0.134 | -0.143| -0.156| -0.179|
| Overall Opinion         | 0.962 | 0.103 | -0.166| 0.125 | -0.054| -0.105| 0.081 |
Figure 1. Two-dimensional PCA (2-D) plot based on the first two components (F1 & F2) for 31 different traits of indigenous guava cultivars. Fe [Iron], K [Potassium], TA [Titratable Acidity], Na [Sodium], P [Phosphorous], F_size [Fruit size], GMD [Geometric mean diameter], C_fiber [Crude fiber], Zn [Zinc], SA [Surface area], C_fat [Crude fat], CP [Crude protein], RSA [Radical scavenging activity], TPC [Total phenolic contents], TFC [Total flavonoid contents], Mg [Magnesium], T_carbs [Total carbohydrates], Ca [Calcium], Sp_grv [Specific gravity], T.Sugars [Total sugars], TSS [Total soluble solids].

Figure 2. Dendrogram for guava cultivars based on 31 different parameters.
4 Conclusion

It was concluded from the present study that the indigenous guava cultivars are remarkably rich in nutritional and antioxidant composition i.e. ascorbic acid, phenolic compounds, flavonoids and antioxidant activity. Considerable amounts of different minerals like K, P, Mg, Ca, Na, Zn and Fe were also present in guava cultivars. It is expected that the research outcome will provide baseline for the farmers, researchers, scientists, technologists, exporters and other stake holders to realize the ultimate potential of indigenous guava cultivars and their intended use. This study also provides basic technological information about guava varieties to be helpful in the development of postharvest management system and industrialized value addition of this vital fruit.

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