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Original Article

Comparative Study for the physicochemical characteristics of Local and Imported Apple Fruits in Yemen

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ABSTRACT
This work aimed to estimate the physical and chemical properties of local apple cultivar (Anna variety) and three varieties of imported apple fruits include (Granny Smith, Red Delicious and Honeycrisp apples) to compare the quality parameters of local apple with imported apple fruits. The samples were collected from local markets in Dhamar city, Yemen. The results showed that the physical properties of apple fruits were, the whole fruit weight (122.04, 113.5, 117.68 and 102.94) g, the pulp weight (109.16, 98.59, 102.77 and 89.7) g, the peel weight (11.76, 11.62, 10.92 and 8.84)g and the seeds weight was (0.0, 0.31, 0.14 and 0.41) g, the fruit extract volume was (47.83, 52.50, 57.83 and 41.70) ml in local, Granny Smith, Red Delicious and Honeycrisp apple varieties respectively. The chemical properties of apples juice were as following ,the moisture (83.43, 82.93, 84.40 and 86.27) %, total solids (16.57, 17.07, 15.77 and 13.73) %, total soluble solids, TSS (13.82, 10.85, 12.15 and 11.68) ˚Brix, reducing sugars (8.32, 6.59, 8.69 and 8.84) %, pH (3.61, 3.69, 4.10 and 4.2), titratable acidity (TA) (0.53, 0.51, 0.22 and 0.22) %, while vitamin (C) content was (16.01, 15.72, 17.46 and 17.61 mg/100 ml) in local, Granny Smith, Red Delicious and Honeycrisp apple varieties respectively. The Maturity indexes were the TSS/TA ratio (26.92, 24.88, 55.39 and 54.58), starch-iodine index (7.67, 10, 10 and 10) and Thiault index (TI) (198.28, 164.32, 149.67 and 143.92) in local, Granny Smith, Red Delicious and Honeycrisp apple varieties respectively. The results of this research revealed that the local apple fruits have good quality indicators, in terms of its physical properties and high TSS content, but the high acidity and starch content may be the reasons of its low sweetness and negatively effects on their quality characteristics.

INTRODCTION

Apple is the pomaceous fruit of the apple tree which belong to the rose family. The genetic variability found in the apple has allowed adapted types to be selected for different environments and regions (Abdualrahman, 2015). Apple fruits quality is an important factor in minimally processed or fresh-cut slices. The physicochemical properties of fruits are important for nutritional, economic, food quality after processing and storage stability considerations.

Fresh apples juices a source of various bioactive compounds include antioxidants as ascorbic acid, which give them a value addition in food commercialization. It's highly appreciated and consumed because of its flavor and nutritional properties (Kanchan *et al.*, 2020). Apple fruits represent an important source of some antioxidant nutrients in western countries because the apples are the most consumed fruits in these countries. The antioxidants and ascorbic acid contents in apple fruits have been widely studied (Haytowitz *et al*., 2009) and (Bodner-Montville *et al*., 2006). Bongers *et al*., (1994) studied the physicochemical properties of apple fruits and found significant differences in some quality parameters between apples from different origins. They also reported that the apples produced in United States, especially delicious had some superior quality parameters compared to the apple fruits from other origins.

The ecological conditions, cultural practices and genetic features are the most factors that affected on the phenology, morphology and biochemical contents of apple fruits (Geçer *et al*., 2020). The pre-harvest treatments of apple trees effects on their fruit's physicochemical properties. El-Sabagh *et al*., (2012) reported that the sprayed with Hydrogen Cyanamide (Dormex) increased significantly the average of fruit weight, fruit size, length, diameter, Total Soluble Solids (TSS) and TSS/acid ratio in compare to the control; however, they caused a significantly decreased in both fruit firmness and acidity).

Storage of apple fruits cultivars resulted in significant increase in weight loss, while starch score, juice content, acidity, TSS, total sugar, pH, ascorbic acid and TSS: TA ratio decreased with prolong storage period (Banoo *et al*., 2018). Aly *et al*., (2019) reported that the total sugar and TSS content was significantly increased with increasing storage periods of Anna apples, while ascorbic acid and acidity was significantly decreased during cold storage.

The firmness and starch iodine in apple fruits are decreased over the storage time since harvest, but the TSS content is increased. Climate changes effects on the texture and taste of apples due to it early flowering and high temperatures during the growing phase (Daniela and Vanessa, 2020).During the maturity progress of apple fruits, the physicochemical properties are change. For determination the maturity degree some tests are used. The starch pattern index (SPI) test is one of the tests that widely used to assess apple fruits maturity. It measures the changes in starch concentration in the fruits during maturation and ripening.

SPI values increased and starch concentration decreased with maturity progress of fruits. The binding capacity of iodine to starch depends on starch composition and by the amylose concentration. Amylose concentration in total starch decreases during maturity progress and reached to low levels at the later stages of fruits. The Starch index (SI) is less reliable in representing total starch during later stages of Fuji apple maturation (Doerflinger *et al*., 2015 and Fan *et al*., 1995). Thammawong and Arakawa, (2009) found that, the starch degradation in apples are varied depends on apples cultivars, and they suggested that, iodine staining is recommended more for determining the maturation of late-maturing cultivars rather than the early-maturing.

In Yemen, the apples fruits are cultivation in some areas like Sa'adah, Emran and Dhamar governorates. The local apple varieties are belonging to the (Anna and Ein shemer) apple varieties. The imported apples had more consumers' acceptability than local apples in Yemen. Therefore, we conducted this research to study and compare the physiochemical properties of local and imported apples and define the reasons for the more acceptability of imported apples than local apples fruit.

MATERIALS AND METHODS

Sampling:

Apple fruits were collected randomly from local markets of Dhamar city during the period between August and November, 2022. The local apple variety was Anna variety while; an imported apple was Granny Smith, Honeycrisp and Red Delicious (Fig. 1). The fruits were placed in plastic bags and brought to the laboratory of Biotechnology and Food Technology Department, Faculty of Agriculture and Veterinary Medicine; Thamar University for analysis the physical and chemical properties of apple fruits and their extracted juice.

Physical properties of fruits

The total weight of fruit was measured using an analytical balance. The peel was removed from the fruits by knife carefully. Then, the fruits were cutting and the seeds were removed manually. After then, the fruits flesh, seeds and peel weight were measured. For juice extraction, the fruits pulp was crushed by electrical blender, the mixed, filtered through sieving, weight and volume measured.

Chemical analysis of apples juice

Apples` juice was obtained from fruits pulp. Fruits pulp was blended and sieved to remove the seeds. The extracted juice was used for chemical analysis including the following parameters: Moisture and total solids content, acidity, total soluble solids (TSS), reducing sugars, vitamin (C) and the pH value.

Determination of moisture and total solids content

Moisture content was estimated by drying method using microwave oven as described by (Suhaime *et al*., 2018). 10 g of apple juice were weighted in Petri dish and dried until the weight stable. The yield was cooled, weighted. The moisture content and total solids were calculated, five replicates were analysis and the average was calculated.

Determination of total soluble solids (TSS)

The total soluble solids (TSS) of apples pulp were determined using a hand refractometer, Atago Company, Japan.

Estimation of reducing sugars

Reducing sugars contents were estimated by Lane-Eynon method (AOAC, 1990). Juice sample (20 ml) was transfer to 500 ml volumetric flask. 100 ml water were added, and then the juice mixture/solution was neutralized with NaOH solution to phenolphthalein end point. 10 ml of neutral lead acetate solution was added to the flask contents. The flask contents was shaken and let stand for 10 min. Potassium oxalate solution in small amounts was added to the mixture in the flask until there is no further precipitation. The volume was completed with distilled water and mixed well. After that the sample mixture was filtered through Whatman No. 1 filter paper. 50 ml of filtrate was transferred to the burette. 5 ml each of Fehling A and B solutions was transferred to 250 ml conical flask. Fehling solution was titrated with sample solution from the burette with continuous heating to boiling and 3 drops of methylene blue indicator was added and continuation the titration until the indicator is decolorized and the brick red color was appeared. The consumed sample solution volume in titration was recorded. Duplicated titration was carried and the average of sample solution was calculated. The direct reducing sugar was calculated by the equation. The Fehling factor was primary found by using a known glucose solution concentration.

$$\text{Reducing sugar (\%)} = \frac{(\text{Fehling factor}) \times \text{Vol.made up} \times 100}{\text{Wt.of sample} \times 1000}$$

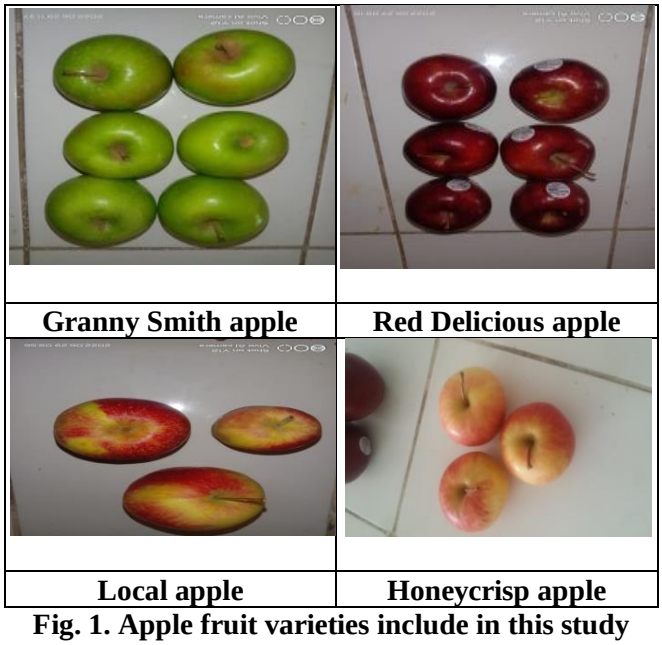

Fig. 1. Apple fruit varieties include in this study

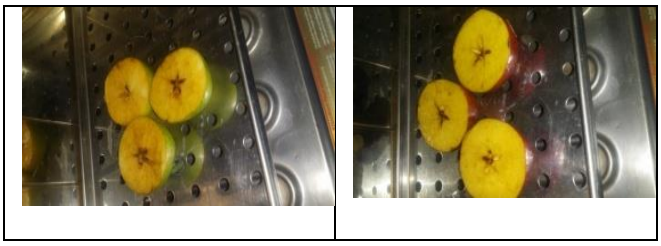

Figure 2: Starch-iodine index of apples fruits.

Estimation of pH:

The pH was estimated using a pH meter from HANNA Company. During the measuring process, the electrode was immersed directly in the juice extract and reading was recorded.

Determination of titratable acidity (TA)

The titration method with sodium hydroxide NaOH (0.1) N and phenolphthalein indicator was used for acidity measuring. The amount of alkali consumed in titration was recorded and the titratable acidity was calculated and expressed as malic acid (Kanchan *et al.*, 2020).

Determination of vitamin (C) content

Vitamin (C) was estimated by iodine titration method according to technique described by Ciancaglinia *et al.* (2001). In brief, 20 ml of the apples fruit juice was transferred to 250 ml Erlenmeyer flask. 25 ml of distilled water were added. From the diluted sample, 10 ml were transferred to 250 ml beaker and 1 ml of cooled, filtered, starch added. Slow titration by potassium iodide with stirring was carried out to reach the end point and dark blue color appeared. The volume of potassium iodide used in titration was determined and the vitamin C content was calculated as follows:

$$\text{Vitamin C (mol/L)} = \frac{ml\ of\ potassium\ iodide \times iodide\ molarity}{sample\ volume\ (ml)}$$

The amount of vitamin C in (mg/100 ml) was calculated using the following equation:

Vitamin C (mg/100 ml) = Vitamin C (mol/l) x (M.W) of Ascorbic acid x 100.

Maturity indexes of apples

Estimation of starch index

Starch index was determined by the iodine test as following, iodine solution was prepared by dissolving (40 g KI and 10 g I_2) in one liter of distilled water. Fruits were cut with the greatest diameter and dipped into solution for 3 min, after then removed from the iodine solution, access solution was drained and staining percentage estimated. The starch-iodine rating was conducted using the generic starch-iodine index chart for comparison. This method uses a 1 to 10 scale, where (0) represents the max starch content and (10) the complete degradation of the starch content (Szalay *et al*., 2013)**.**

Calculation of Thiault Index (TI)

The Thiault index (TI) was calculated from the measurements of TSS as a total sugar (TS) and titratable acidity (TA) expressed as malic acid (g/l), using the equation below (Icka and Damo, 2014).

TI = TS + (TA ×10), TS (Total sugar) = (TSS×10.6) – 20.6

Statistical analysis

Descriptive statistics analysis was performed to find the mean values and standard division (SD) of parameters. Duncan test was used as a multiple comparison test to express the differences between the average values at ($P \leq 0.05$). The statistical analysis was performed with the SPSS program version 16.

RESULTS AND DISCUSSION

Physical properties of apple fruits:

Fruit and its parts weight:

The minimum size of apple fruits shall be (60) mm, as a diameter, or (90) g, if measured by weight. Fruit of smaller sizes may be accepted if the ˚Brix value of the produce is (≥ 10.5) ˚Brix and the size is not smaller than (50) mm or (70) g (FFV-50, 2020).

In this study, the results revealed that, significant differences ($P<0.05$) were observed among the physical properties of local and imported apple fruits varieties (Table 1). These results showed that the local apple had the higher fruits weight, flesh and peel weight compared to imported apple fruits, while the Honey crisp apple fruits had the lower values. The local apple fruit weight, flesh and peel weight were (122.04 ± 23), (109.16 ±24.94) and (11.76 ±2.84) g respectively; whereas, Honeycrisp apple fruit weight, flesh and peel weight were (102.94 ± 1.156), (89.7 ±4.61) and (8.84 ±1.30) g respectively. The weight of local apple fruits varied widely from one fruit to the other. One for the reasons of this variation is that local apples fruits didn't sort or grade before its marketing. These results are in agreement with findings reported by Kassem *et al*., (2016) on Anna apple fruit weight which was (123) g. Furthermore, Macit*et al*., (2021) researched to similar results. The results of this study were lower than findings of(El-Sabagh *et al*., 2012, Zakia *et al*., 2019; Kanchan *et al*., 2020).However, it`s higher than findings reported by Anwar *et al*., (2020).In others studies, Jan and Davide, (2018) reported that the Red Delicious apple had higher fruits weight (213.64) g than Fuji and Granny Smith apples (204 and 202.08) g respectively.

The results demonstrated that, seeds were not existed in local apples fruit, while; presence in Honeycrisp apples, Granny Smith and Red Delicious apples with weight as 0.41±0.07,0.31 and (0.14) g respectively (Table 1). The results obtained here indicated that the local apples fruits had two good physical properties compared to the imported apples, which were its high fruit weight and the absence of seeds. The differences between the present results and the findings of previous studies may be attributed to the growing conditions and geography of the study areas. Pre-harvest treatments such as foliar spraying of brassinoloide at (3 – 4) ppm improved some physicochemical properties of Anna apple such as the diameter, weight and color of the fruits (Attia and Adss, 2021).

The juice volume and juice yield ratio results for all apples varieties investigated showed no significant differences ($P<0.0$) were observed. Red Delicious apple had the high juice volume and juice yield ratio, while Honeycrisp apples and the local apples had the low juice volume and low juice yield ratio respectively. The juice content of apples is an important parameter for industrial production of juices from fruits. The low juice yield ratio in local apple fruits may be related to the variation in maturity degree, moisture contents and firmness of local apple fruits. Higher volume juices contents in apple fruits (58%) was reported earlier by Kanchan*et al*., (2020), while lower juice content (29.03%) by Agbaje *et al*., (2020). In other studies, Jan and Davide, (2018) found high juices contents in Fuji apple (74.38) % compared to Red Delicious and Granny Smith apples which was (57.51) and (67.28) % respectively.

Fruits diameter and length

The results of fruits dimensions are shown in Table 2. The length/diameter ratio was significantly

different (P<0.05)among apple fruits varieties. The local apple fruit had more length/diameter ratio (1.362); while, Granny Smith apple had less length/diameter ratio (0.952).Similar results are reported on Egyptian Anna apple (Anwar *et al*., 2020) and Anna apple fruits (El-Sabagh *et al*., 2012). In addition, Zakia *et al*. (2019) studied the fruit diameter and length apples and researched to similar results. Previously, Jan and Davide, (2018) reported that the fruit diameter was the more in Granny Smith apple (76.20) mm compared to Fuji and Red Delicious apples which were (74.38 and 76.14) mm respectively. Furthermore, Sotiropoulos and Syrgianidis, (2009) found that, fruit length/width ratio in Granny Smith apple was (0.81). These variations may be related to many factors including pre-harvest treatments, apples varieties and environmental conditions.

Physicochemical properties of apple fruit juice

Moisture and total solids

The moisture and total solids contents didn't differ significantly (P<0.05) between local and imported apples varieties. The higher mean of moisture content was recorded as (86.27±2.11) in Honeycrisp apple, while; the lower was (82.93 ±3.93) in Granny Smith apple variety. The low moisture content (83.43 ±2.13)of local apple fruit is an indicator for a good shelf life. These data are in agreement with results of Lee *et al*., (2017) for the moisture in Fuji apple (85%) and lower than moisture content values reported in apples (90.02%) by Agbaje *et al*., (2020). The moisture contents in apple fruits ranged between (80) and (85) % depends on cultivar type and the season of production (Guiné *et al*., 2009). In this study, the total solid content in Golden delicious apple juice was (15.21%) and these results are in line with the finding of Rouchaud *et al*.(1986).

Titratable acidity and pH value

The apples cultivars are grouped by classes according to their acid contents as: low-acidity class (< 0.4%), intermediate-acidity apples (0.4 and 1.0%), and high-acidity apples (>1.0%) malic acid (Guiné *et al*., 2009).Local and Granny Smith apples juice had the higher titratable acidity value which were(0.53 ±0.11 and (0.51 ±0.24); while, Red Delicious and Honeycrisp apples juice titratable acidity were (0.22 ±0.04) and (0.22 ±0.03) respectively (Table 3).The high value of acidity in local apples may be due to that local apples didn't reach to optimum maturity degree at harvest and its marketed fresh after harvesting without any treatments or storage periods.

The Anna apple fruits are characterized by its high acidity content. This acidity content was decreased gradually and significantly from harvest to storage and post-storage shelf life periods (Nagy, 2018; Singh *et al*., 2017). Klein and Lurie (1990) found that the acidity of Anna apple fruits at harvest was (0.66) % and it decreased after two months of storage at 0 ˚C to (0.55%). Moreover, they reported that the titratable acidity was reduced in Granny Smith and Anna apple fruits that treated with heat treatment for 4 days before storage. In other hand, the results of acidity in local apple fruits are similar to those previously reported on Egyptian Anna apples (Anwar *et al*., 2020), and Granny Smith apples (Bongers *et al*., 1994). Furthermore, higher acidity in Anna apple fruits was previously reported by(Kassem *et al*., 2016, Attia and Adss, 2021 and El-Sabagh *et al*., 2012).In addition, Lee *et al*., (2017) and Zakia *et al*., (2019) found the titratable acidity in Fuji apple and Red Delicious apple were (0.39) and (0.42) % respectively.

In current study, the results revealed that, the local apple and Granny Smith apple juice had the low pH values which were (3.61 ±0.12) and (3.69 ±0.29) respectively; while; the pH of Red Delicious and Honeycrisp apples were (4.10 ±0.05) and (4.2 ±0.35) respectively (Table 3).These results are in line with findings of Abdualrahman (2015) and with Sotiropoulos and Syrgianidis, (2009) who reported the pH value in local apple fruit juice was (3.90%),but it's lower than the pH in imported apple fruit juice (4.18%). Macit *et al*., (2021) reported that, local apple varieties from Anatolia (3.72 - 4. 18%).However, the pH value was3.24and 3.60 in Golden delicious apple juice and in apple fruits respectively as mentioned by Rouchaud *et al*. (1986) and Kanchan *et al*., (2020) .

Total soluble solids (˚Brix)

Total sugar concentration and TSS measurements represent good tools to define the maturity degree of apple fruits (Wosiacki *et al*., 2007).The results obtained in current study showed that the local apples juice had the highest total soluble solid content (83.43 ±2.13) ˚Brix, while the Granny Smith apples juice had the low TSS content (10.85 ±1.60) ˚Brix (Table 3).These results are closed to those found in Egyptian Anna apple variety (12.67 and 12.83%) and (12.53 and 12.30%) by Anwar *et al*.(2020) and Attia & Adss (2021).

These results are fallen in the range of Bongers *et al*., (1994) for apple fruits from different origins that sold in European markets which were (11.25 – 15.60) %. They reported that the TSS values were (12.40- 14.15), (11.25– 14.08), (11.41–

12.61) % in Delicious, Golden Delicious and Granny Smith apples respectively. Almeida and Gomes, (2017) reported that the TSS value in Granny Smith and Fuji apples was (10.8) and (13.9) % respectively. These results are similar to the results of TSS in local apple fruits from Sudan (13.80) % (Abdualrahman, 2015). In other studies, Kanchan *et al*., (2020) found the TSS in apple fruits was (11.50) °Brix. Low TSS contents in Anna apple fruits was reported by Kassem *et al*., (2016) as10.8 % and by El-Sabagh *et al*., (2012) as 9.96 and 10.75 % at 2008 and 2009 seasons respectively. Meanwhile, Macit *et al*., (2021) found the TSS in local apple from Anatolia was ranged between (7.07 - 8.93) %.

The mean of TSS tended to increase with the progression of either cold storage or post-storage shelf life periods (Nagy, 2018). Fruits with higher TSS content typically have more intense sweaty and juicy (Alwaseai and Al-Gaber, 2023). However, higher TSS value was found by BateljaLodeta *et al*., (2019) in traditionally grown domesticated apple varieties from Croatia, which was ranged between (14.97 – 20.27) Brix and by Zakia *et al*., (2019) for Red Delicious apple juice TSS was (14.29) %. Bongers *et al*., (1994) reported that the TSS were (11.41 – 12.61) % in Granny Smith apples, while Jan and Davide, (2018) found that, the highest TSS content was in Fuji apple compared with Red Delicious and Granny Smith apples, by (13.61, 13.39 and 13.0) ˚Brix respectively.

Vitamin C (Ascorbic acid):

The vitamin C content in Anna apple fruits was significantly decreased with advanced storage and post-storage shelf life periods to reach the least content after three months of cold storage (Nagy, 2018). The results in Table 3 showed that the ascorbic acid didn't differ significantly ($P<0.05$) among all apples varieties included in this study.

The local apples, Granny Smith, Red delicious and Honeycrisp juice ascorbic acid content were (16.01 ±3.57), (15.72 ±2.59), (17.46 ±1.82) and (17.61±3.37) mg/100 ml respectively. Previously, studies reported that, low values of vitamin C in apples varieties ranged between 1.28-22.10 mg/100 ml; Zakia *et al*., 2019; Attia and Adss, 2021;Macit *et al*., 2021).

Reducing sugars content

Sugars content in apple fruits increased gradually during fruit development. The sugars are quantitatively or qualitatively converted to other sugars. Conversion of polysaccharides into sugars during growth and development lead to increase the sugar content in fruits. This conversion has a great impact on the fruit quality (Dar *et al*., 2021).

The results of this study showed that no significant differences ($P<0.05$) were found in reducing sugar content among local, Honeycrisp and Red Delicious apple varieties, while the reducing sugar content of Granny Smith apple juice was significantly differing than other apple varieties measured in this study. The mean value of reducing sugar content was (8.32±0.96), (6.59± 0.32), (8.69±0.53) and (8.84±0.93) in local, Granny Smith, Red Delicious and Honeycrisp apples respectively (Table 3). These results are similar to findings reported by Kanchan*et al*. (2020),and Batelja Lodeta *et al*., (2019)who studied the reducing sugar content in traditionally grown domesticated apple varieties from Croatia. The contrary between the present results and previous studies findings may be attributed to the differences in the treatments that apply for apples fruits. Rouchaud *et al*., (1986) cited that treatments of apple fruits with fungicide raised the total sugars content by 22% in Golden Delicious apple.

Maturity indexes

Consumer perception of sweetness or sourness is determined not only by the concentration and type of sugars and acids, but also by the relative proportion of each. Two indices have been used in apple to describe the relationship between sugars and acids and express taste equilibrium: the simple ratio between SSC and TA and the Thiault index (Almeida and Gomes, 2017).The chemical composition of apple fruits and their acid and sugar contents depends on their maturity stage (Guiné *et al*., 2009).The results of the maturity indexes of local and imported apples fruit investigated in this study are showed in (Table 4)**.**

TSS/TA ratio

The TSS/TA ratio in apple fruits is used as indicator to determine the fruits sweetness. The fruits that have a high TSS/TA ratio are considered sweet, whereas the fruits with low ratio are perceived as sour.

The results in Table 4 showed that TSS/TA mean ratios was (26.92 ±4.20) and (24.88 ±9.90) in local and Granny Smith apples respectively, whereas; 55.39 ±9.69 and 54.58 ±9.87in the Honeycrisp and Red Delicious apples respectively. The low TSS/TA mean ratio in local apple fruits may be related to their high level of acidity, It's mean that the local apples contain high concentration of organic acids.

The organic acids contents in apple fruits are an important parameter in maintaining the quality of fruits. Some treatments for apple fruits effect on their TSS/TA ratio. The TSS/TA ratio was significantly decreased in calcium treated "Jona gold" fruits compared to the control fruits (Rabiei *et al*. 2011). The other reason of low TSS/TA ratio for local apple fruits may be due to the early harvesting before they reached to the optimum maturity. During ripening process some starch content in apples are converting to sugar which caused the increase in the TSS value, while the organic acids are consumed in plant respiration so the acidity are decreased (Cepeda *et al*., 2021).

These results were in agreement with the findings of Almeida and Gomes, (2017) who reported that the high mean ratios of TSS/TA in Starking and Fuji cultivar of apples which were (66%) and (70%), while the low values were found in Granny Smith and Reinette apples (18%) and (21%) respectively. These results also in parallel with findings of Bongers *et al*., (1994) who studied the solids/acidity ratio in Granny Smith and Fuji apples from European markets. In elsewhere studies, Icka and Damo, (2014) reported that the sugar/acidity ratio for Red Delicious at harvesting time was ranged between 33.007 and 52.473 according to harvest time and suggested that t the optimum sugar/acidity ratio for Red Delicious harvesting is 40 -50.

Starch- iodine index

The characteristic patterns of starch degradation differ between apple cultivars (Fan *et al*., 1995). The starch iodine index value is low at harvest of apple fruits. This value indicates high starch content which decreases over the course of ripening due to its hydrolysis in fructose and glucose leading to high values of the starch iodine index (Daniela and Vanessa, 2020).

Results in Table 4 displayed that the starch-iodine index for local apples had a significant difference ($P<0.05$) compared to the imported apples varieties which was (7.67 ±2.88) and (10.0 ±0.0) respectively. This means that the local apples had high starch content and the starch hydrolysis degree didn't reach to the maximum, whereas in the imported apples the starch was completely hydrolyzed. The high starch content in local apples may be due to low sweetness (Figure, 2).These results are in line with findings of Singh *et al*., (2017) who reported that the starch content was the high at harvest of Anna in comparison to Galaxy and GD apples and this content of starch are declined during storage period. In study in Egypt, the reported starch index of Anna apples was (6.78) and (6.42), during the 2016 and 2017 seasons respectively (Serry *et al*., 2019). The low value of starch index in local apple may be related to the early harvesting for local apple fruits and freshly marketed without storage periods, whereas imported apple varieties were taking suitable time from harvested, storage and marketing time. This storage period encourages degradation of starch in apples and conversion to sugars. The significant difference in starch index values between local and imported apples may relate to the variations in growing conditions such as the temperature during growth period and the variations of apples cultivar. Starch conversions to sugar are depends on temperature degree with a negative correlation between the rate of starch hydrolysis and temperature (heat units) over a period of several weeks before first acceptable harvest. Low temperature encourages the starch conversion to sugar. The test was not useful for late maturing cultivars because there was little starch loss at harvest, that is, during the normal harvesting season (Smith *et al*., 1979). Starch degradation pattern varied between apples cultivars, so separate charts for each group of apples is recommended for use in practice (Szalay *et al*., 2013).

Some changes in apple fruit properties are occurred during the maturation progress, which the TSS content and starch pattern index increased. The change in TSS was small compared to that of the starch pattern index, so the starch pattern index could be a reliable parameter for determine harvest time and for evaluates maturity at harvest (Reid *et al*., 1982). The apple fruits sweetness quality influenced by the degree of starch degradation, sugar translocation and accumulated of sugar content (Thammawong and Arakawa, 2009).

Thiault index (TI)

Thiault index is one of the fruit quality indicators. It's used to determine the optimum ripeness of apple fruits at harvest and fruit storability. Thiault index (TI) can be used as a tool for determine the acceptability of apple juice because it produce results qualitatively similar to the sensory scores (Rouchaud *et al*., 1986).

The results in Table 4, showed a significant difference ($P<0.05$) in Thiault index (TI) between local and imported apple fruits. The Thiault index (TI) values were 183.86± 24.65, 150.91± 41.43,132.86± 19.89 and 127.24± 15.32in local apple, Granny Smith, Red Delicious and Honeycrisp apples respectively. Almeida and Gomes, (2017) reported Thiault index (TI) in Granny Smith and Fuji apple fruits as 168 and 159 respectively, while

Sotiropoulos and Syrgianidis, (2009) found Thiault index (TI) in Granny Smith apples as 182.

The high TI value for local apples indicates that local apples had high storability but didn't indicate they have more sweetness than imported apple fruits. These results revealed that the Thiault index (TI) couldn't be used as a right indicator for the fruits sweetness because the local apples had the highest TI value but their sweet taste was lower compared to Red Delicious and Honeycrisp apple fruits. The TSS/TA ratio and starch index are better than TI as an indicator for the fruit's quality in term its sweet taste.

Table 1. Whole fruits and its parts weights and the juice volume of local and imported apple

Parameter	Apple variety			
	Local	Granny Smith	Red Delicious	Honeycrisp
Fruit weight (g)	122.04 ± 23 a	113.50 ± 11 ab	117.68 ± 6.34 ab	102.94 ± 1.156 b
Flesh weight (g)	109.16 ±24.94 a	98.59 ± 9.52 ab	102.77 ±6.96 ab	89.7 ±4.61 b
Peel weight (g)	11.76 ±2.84 a	11.62 ±2.36 ab	10.92 ±1.20 ab	8.84 ±1.30 b
Seeds weight (g)	0.0 b	0.31 ± 0.25 a	0.14 ±0.10 b	0.41 ±0.07 a
Juice volume (ml).	47.83±15.24 ab	52.50 ±12.97 ab	57.83 ±9.75 a	41.70 ±10.23 b
Juice yield% (V/W).	38.66 ±6.60 a	45.89 ±8.38 a	49.03 ±7.16 a	40.44 ±9.59 a

Different letters within a row mean significant difference ($P < 0.05$).

Table 2. Length and diameter of local and imported apple fruits

Parameter	Apple variety			
	Local	Granny Smith	Red Delicious	Honeycrisp
Fruit diameter (mm)	51.3 ± 4.7 b	56.7 ± 2.4 a	54.8 ± 1.7 ab	54.2 ± 2.3 ab
Fruit length (mm)	69.7 ± 6.4 a	54.0 ± 7.7 c	62.7 ± 4.4 ab	56.3 ± 5.1 cb
Length/diameter ratio	1.362±0.12 a	0.952 ±0.10 c	1.143±0.07 b	1.042±0.09 bc

* Different letters within a row mean significant difference ($P < 0.05$).

Table 3. Physicochemical properties of apples juice

Parameter	Apple variety			
	Local	Granny Smith	Red Delicious	Honeycrisp
Moisture	83.43 ±2.13 a	82.93 ±3.93 a	84.40 ±1.69 a	86.27±2.11 a
Total solid	16.57 ±2.13 a	17.07 ±3.93 a	15.77 ±1.94 a	13.73 ±2.11 a
Total soluble solid (˚Brix)	13.82 ±1.34 a	10.85 ±1.60 b	12.15 ±1.57 ab	11.68 ±1.39 b
Acidity as (malic acid)	0.53 ±0.11 a	0.51 ±0.24 a	0.22 ±0.04 b	0.22 ±0.03 b
pH	3.61 ±0.12 b	3.69 ±0.29 b	4.10 ±0.05 a	4.2 ±0.35 a
Vitamin C (mg/100 ml)	16.01 ±3.57 a	15.72 ±2.59 a	17.46 ±1.82 a	17.61±3.37 a
Reducing sugar (g/100 g)	8.32±0.96 a	6.59± 0.32 b	8.69±0.53 a	8.84±0.93 a

Different letters within a row mean significant difference ($P < 0.05$).

Table 4. Maturity indexes for apple fruits

Parameter	Apple variety			
	Local	Granny Smith	Red Delicious	Honeycrisp
TSS/TA	26.92 ±4.20 b	24.88 ±9.90 b	55.39 ±9.69 a	54.58 ±9.87 a
Starch index	7.67 ±2.88 b	10.0 ±0.0 a	10.0 ±0.0 a	10.0 ±0.0 a
TI	183.86± 24.65 a	150.91± 41.43 b	132.86± 19.89 b	127.24± 15.32 b

Different letters within a row mean significant difference ($P < 0.05$).

CONCLUSIONS:

Local apple fruits characterize by its high fruit weight and size. It's containing high TSS, total solids, titratable acidity compared to imported apples. The low TSS/TA ratio and starch iodine index in local apple indicated that local fruit harvested early. The low TSS/TA ratio and low starch index in local apple may be the reasons of its low sweet taste. The sweet taste in imported apples is related to its high TSS/TA ratio and high starch index value. Juice yield was lower in local apples compared to imported apple varieties studied in this study. Mild sugar content of local apple fruits makes them suitable for use as a healthy diet for the persons that need low energy fruits as Granny smith apple. Further studies on physicochemical properties of local apples are needed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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دراسة مقارنة الخصائص الفيزيوكيميائية لفاكهة التفاح المحلي والتفاح المستورد في اليمن

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الملخص

هدفت الدراسة إلى تقدير الخواص الفيزيائية والكيميائية للتفاح المحلي (صنف Anna) وثلاثة أصناف من ثمار التفاح المستوردة شملت اصناف (Granny Smith و Red Delicious و Honeycrisp) لمقارنة خواص جودة التفاح المحلي مع التفاح المستوردة. تم جمع العينات من الأسواق المحلية في مدينة ذمار، اليمن. أظهرت نتائج الدراسة أن الخواص الفيزيائية لثمار التفاح كانت: متوسط وزن الثمرة الكامل (122.04 و 113.5و 117.68 و 102.94) جرام و متوسط وزن اللب (109.16 و 98.59 و 102.77 و 89.7) جرام و متوسط وزن القشرة (11.76 و 11.62و 10.92 و 8.84) جرام, في حين كان متوسط وزن البذور (0.0 و 0.31 و 0.14 و0.41) جرام، بينما كان حجم مستخلص الثمرة (47.83و 52.50 و 57.83 و 41.70) مل لأصناف التفاح المحلية و Granny Smith و Red Delicious و Honeycrisp على التوالي. أما الخصائص الكيميائية لعصير التفاح فكانت النسبة المئوية للرطوبة (83.43 و 82.93 و 84.40 و86.27)% و نسبة المواد الصلبة الكلية (16.57و 17.07 و 15.77 و 13.73%) و نسبة المواد الصلبة الذائبة TSS (13.82 و 10.85 و 12.15 و 11.68) بركس ونسبة السكريات المختزلة (8.32 و 6.59 و 8.69 و 8.84)% والرقم الهيدروجيني pH (3.61 و 3.69 و 4.10 و 4.2) والنسبة المئوية للحموضة التصحيحية (TA)(0.53 و 0.51 و 0.22 و 0.22) %، بينما بلغت نسبة فيتامين (C) (16.01 و 15.72 و 17.46 و 17.61 (ملغم/100مل) في أصناف التفاح المحلية وGranny Smith و Red Delicious و Honeycrisp على التوالي. كما اظهرت النتائج لقيم مؤشرات النضج للثمار والتي شملت النسبة بين المواد الصلبة الذائبة (بركس) الى الحموضة (TSS/TA) (26.92 و24.88 و 55.39 و 54.58) و مؤشر النشأ (7.67 و10 و 10 و 10) و مؤشر Thiault index (TI) (198.28 و2164.3 و 149.67 و 143.92) في أصناف التفاح المحلية و Granny Smith و Red Delicious و Honeycrisp على التوالي. نستنتج من نتائج هذا البحث الى أن ثمار التفاح المحلي تتمتع بمؤشرات جودة جيدة، من حيث خصائصها الفيزيائية و محتواها المرتفع من المواد الصلبة الذائبة (TSS)، إلا أن النسبة العالية من الحموضة و النشأ قد تكون من أسباب انخفاض حلاوتها و يؤثران سلبياً على خصائص جودة التفاح.

الكلمات المفتاحية: التفاح الاخضر، الخواص الفيزيائية والكيميائية، التفاح اليمني، تفاح آنا، التفاح الاحمر، التفاح السكري.

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