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POSTHARVEST QUALITY POTENTIAL COMPARISON OF APPLE CULTIVARS AT AMBIENT TEMPERATURE

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Abstract

The postharvest performance of Apple (Malus domestica) cultivars was evaluated under ambient conditions. Fruits were harvested at commercial maturity, and data were recorded at 0, 10, 20, 30, and 40 days for evaluation of organoleptic, physical, and biochemical attributes. Data were analyzed using a factorial Completely Randomized Design (CRD) with ANOVA, and LSD test at P ≤ 0.05. Organoleptic attributes declined by day 40, Amari recorded the highest color score (4.33), while Royal Gala recorded the lowest (1.67). Red Delicious recorded the highest taste score (5.0), while Jeromine recorded the lowest (1.0). Red Delicious and Amari recorded the highest flavor score (3.67), while Royal Gala recorded the lowest (2.3). Amari recorded the highest aroma score (4.3), while Jeromine recorded the lowest (1.0). Amari recorded the highest overall acceptance (5.0), while Royal Gala recorded the lowest (1.67) score. Physical Quality Traits at day 40, Amari showed the highest weight loss (12.64%), Red Delicious the lowest (10.10%). Red Delecious lost the least fruit size (4.6) while Jeromine lost the most (3.8 cm). Royal Gala recorded the highest specific gravity (1.06), and the lowest was in Red Delicious (0.99). Disease incidence was maximum in Jeromine (4.30) and minimum in Red Delicious (2.00). Decay percentage was minimum in Red Delicious (2.00), followed by Amari (3.56), and maximum in Jeromine and Royal Gala (4.00). Red Delicious and Amari (190.37g, 152.2g) showed less decrease in fruit weight as compared to Jeromine and Royal Gala (208.63g, 208.86g). Firmness declined in all cultivars over 40 days, Red Delicious retained the highest mean (7.6 N). Red Delicious had the highest marketability index (0.73%), and Jeromine the lowest (0.46%). Red Delicious scored highest in visual quality (5.0), while Jeromine scored lowest (1.6). Biochemical characteristics at day 40, Red Delicious and Royal Gala showed the highest pH (4.26), followed by Jeromine and Amari (4.23). Amari showed the minimum TSS increase from day 0 to day 40 (14.02 °Brix to 12.47 °Brix). The lowest TA (0.04%) was found in Jeromine, Royal Gala, and Amari, followed by Red Delicious (0.05%). At day 40, Jeromine recorded the lowest TSS/TA ratio (1.28), while Royal Gala recorded the highest (1.76). The highest EC was recorded in Amari (33.33) at day 0, while at day 40, Red Delicious showed the highest (41.11) and Jeromine had the lowest (30.95). These results indicated that Red Delicious and Amari exhibited superior postharvest quality under ambient conditions, with potential for extended shelf life and better consumer acceptance.

Keywords: *Ambient conditions, Apple cultivars (cvs), Fruit shelf life, Postharvest quality, Storage period days*

INTRODUCTION

The apple (*Malus domestica*) is a fruit tree native to various regions of Europe and Asia that thrives in temperate climates. With China being the world top apple growing nation, accounting for over 41% of global apple production, the United States comes in second. (1). Though there are over 7500 apple varieties identified, very few have significant commercial value. Certain cultivars, like as Granny Smith Golden Delicious, Granny Smith, Rome Beauty, McIntosh, and Red Delicious, are widely grown all over the world. Just a small portion

of apples are eaten right once when they are harvested; instead, most of them are kept in storage for a long time to be used later. (2). Apples (86 million tons) are ranked second after bananas (120 million tons), but before grapes (78 million tons) and oranges (75.5 million tons). In 2020, China accounted for 40.5 million tons, or 47%, of the global apple production (3).

In 2020 the apple yield was 83,116 hg per ha in Pakistan. The two provinces that produce the most apples are Balochistan and Khyber Pakhtunkhwa. The 88,807 hectares of apple crop land in Balochistan produced 482,819 tons of apples annually in 2018–2019 (4). Pakistan cultivates several apple cultivars, including Amari, Mashadi, Kala Kulu, Golden Delicious and Red Delicious (5).

In the framework of the fruit farms in the Crimea, the apple tree holds the top position. Its percentage of the region between 60 and 65 in the future. As per the Russian Federations Ministry of Health, an individual should consume 50 kg of apples per day, or 137 g, annually as the physiological standard. The apple is a tasty, aromatic, and incredibly nourishing fruit. It has high levels of vitamins B, A, and C. Important minerals, it has a significant amount of sugar. It is quite refreshing, appealing in terms of color, & satisfying. It can be applied in a variety of ways. Its canned, cooked turned into jellies and preserves, candied, made into cider or vinegar, and prepared as fresh apple juice. Water and dry materials make up the chemical composition of fruits. Vitamins, polyphenols, acids, sugars, pectin, cellulose, and minerals are all present in the dry matter. A crucial contextual and personal element is present in the highly complicated attribute of quality. Moreover, the quality is no longer universally accepted ultimately, and most likely, what matters most in judging produce quality is what the buyer wants. The study goal is to identify the locally grown apple types with the best nutritional value. Consumption of more than one apple each day, according to the study decreased the incidence of colorectal cancer by about 50%. Many types of research have looked at the anticancer effects of apple extracts in vitro and in vivo, as well as the effects of phytochemical substances found in these extracts (6).

Apples are a well-liked fruit that are rich in vitamins, dietary fiber, minerals and other antioxidants. They may aid in the prevention of several illnesses because of their diverse nutrient content. Apples offer a spectrum of nutrients that can improve many various elements of a person health and come in a variety of forms, colors, and flavors. For instance, they might lessen the chance of developing diabetes, heart disease, cancer, obesity, and several other illnesses (7). Apples are a popular food that are high in phytochemicals. Because apples have considerable antioxidant activity, epidemiological investigations have linked apple intake to lower risk of diabetes, asthma cardiovascular disease & various cancer type (8)

Apples are useful and contain vitamins, sugar, acid, pectin, and tannin. The life of fruits after harvest is significantly influenced by various factors, one of which is the storage temperature. Fruits were kept in three different temperatures (0, 5 & 12°C) for a month to examine the impact of temperature on the shelf-life of Red Delicious apples. Following a month, measurements were made of length, diameter, firmness, volume, weight, (TSS) total soluble solids, (TTA) total titratable acids, potassium and sodium elements, marketable quality, and color surface. Overall findings suggested that keeping products at 0°C could preserve their superior quality (9).

The standard of apples fruits was examined in relation to the storage temperature. Overall soluble solid, pH, acidity, fruit weight, peel, pulp, and seeds were all measured for every fruit. Two different storage temperatures (10±2 and 15±2^{0}C) were applied to the two different fruit varieties in a split plot randomized design 2×2, with replications throughout the duration of the experiment. Appealingly, the ideal temperature for star apple fruit storage was 10± 2^{0}C. But fruits with purple skin turned out to be more perishable than those with green rinds (10). Variations in the physical and chemical characteristics and biochemical makeup of apples kept in a controlled environment. Before the apple samples were placed in the chambers with regulated atmospheres and eight months later, we examined their biochemical composition (sugars, soluble solids, (TA) titratable acidity & ascorbic acid) as well as their physicochemical characteristics (Peel, flesh firmness, and colour correlates) (11).

Physical characteristics such as color, overall look, and weight loss were analyzed to determine the impact of regular room temperature storage on five apple cultivars Golden Delicious, Mashadi, King Amari,

Kala kulu, & Amari over the course of two weeks in September. The color did not alter during the first two weeks of storage before gradually changing. In all apple varieties, the fruits skin became loose and shriveled over the final four weeks of storage, although it was tight, firm, soft, and appealing during the first two weeks of storage. Weight losses were significantly impacted by storage (12). Investigations were carried out to measure the actual physical shift in apple texture measurements in response to temperature changes in the fruit. Royal Gala, Granny Smith, & Pacific Rose TM apple fruit kinds were stored at 0°C, while Coxs Orange Pippin was kept at 3°C. Before measures of flesh firmness and cortical tensile strength were made, the fruit was maintained at room temperature, at 20°C for 24 hours, or at the storage temperature for 24 hours (13).

A review is conducted on the effects of preharvest direct sunshine exposure of fruit and vegetables, together with the resulting high tissue temperatures, on postharvest reactions. In both hot and temperate settings, direct sunshine has been observed to record fruit and vegetable flesh temperatures much beyond 40°C in a variety of crops. When it comes to long-term exposure and daily variations, these high temperatures can cause variations in mineral content as well as internal quality attributes including sugar concentrations, tissue hardness, and oil levels. Fruit that has seen varied temperatures in the past can likewise respond differently to lows and heat treatments used to rid the fruit of insects after harvest. For instance, avocado fruit from exposed tree locations has less chilling damage, whereas exposed citrus and persimmon tissues exhibit greater chilling damage. The impact of elevated temperatures on postharvest reactions is examined, encompassing the function of heat shock proteins, impairment of membranes, & skin properties. Due to variations in fruit exposure on the tree, there is often a significant amount of variation in fruit concerning at-harvest quality, ripening, and postharvest behavior (14).

The main elements influencing an apples postharvest quality are its storage circumstances. Despite various challenges associated to production and marketing, the growers manage to generate an incredible profit, which in turn motivated them to expand their fruit output (15). Fruit gradually loses weight while being stored, and when this happens, other characteristics of the fruits nutritional content are also impacted (16).

MATERIALS AND METHODS

A study was conducted to evaluate the postharvest quality potential of apple cultivars under ambient temperature at the Horticulture Departmental Laboratory, Balochistan Agriculture College, Quetta during the year 2022. Four different apple cultivars (Red Delicious, Jeromine, Royal Gala, and Amari) were hand-harvested using local collection bags from Ziarat. Each cultivar was separately packed in cotton boxes and transported to the laboratory for further analysis. Upon arrival, samples were cleaned with tap water followed by distilled water to remove dust and allowed to dry at room temperature for thirty minutes. The experimental area and equipment were sanitized using a solution of ethanol and distilled water to maintain hygiene. The apples were then stored at room temperature (24 °C) for forty (40) days, ensuring uniformity in shape, size, and color and avoiding any external damage.

The experimental design was a completely randomized design (CRD) with two factors. Factor: 1 comprised four distinct cultivars: Red Delicious, Jeromine, Royal Gala, and Amari. Factor: 2 corresponded to the sampling time, with data recorded at five specific intervals: 0, 10, 20, 30, and 40 days. Each cultivar was replicated three times. The parameters measured during the storage period included (Organoleptic evaluation, Physical fruit quality trait and Biochemical characteristics). Measurements were taken from randomly selected apples at each sampling interval to ensure the collection of reliable and consistent data.

ORGANOLEPTIC EVALUATION

To determine organoleptic properties such as color, taste, flavor, Aroma and overall acceptance, the fruit were assessed using a scale of 1-9 (17). The examination Performa after organoleptic properties of fruit was filled by a jury of five judges. For each treatment, the total score was considered. Organoleptic properties have been tested based on a scale of 1-9, i.e.1= bad (found, 3 = average (usability limit), 5 = decent (marketability limit), 7 = really good, 9 = excellent and fresh. The average score was recorded for each producer, organoleptic assessment of the score table.

PHYSICAL FRUIT QUALITY TRAITS

FRUIT WEIGHT LOSS (%)

The experiments beginning and each storage intervals (days) conclusion saw the weight of the fruit samples. Overall weight loss over that storage period was defined as the difference between the starting and final fruit weight. The following formula was used to calculate percentages based on fresh weight.

$$\text{Fruit weight loss (\%)} = \frac{\text{Initial weight (g)} - \text{final weight (g)}}{\text{Final weight (g)}} \text{x } 100$$

FRUIT SIZE (CM)

The dimensions of apple length and width were precisely measured using a digital caliper (D-K, 15190-01-00, Germany). in cm and average was calculated.

SPECIFIC GRAVITY

Specific Gravity Volume of each Apple cvs was measured using water displacement method based on the Archimedes principle. Each sample was submerged in a 500 cm^3 eureka container and the volume of water displaced was measured using graduated cylinder. Water temperature during measurements was kept at 25°C. After measuring the volume, the specific gravity of each fruit was calculated using the equation (46)

$$\text{Sg} = \frac{\text{Mass in air}}{\text{Volume in air}}$$

DISEASE INCIDENCE (SCORE)

Every fruit from all the experimental unit was visual tested for any signs of disease. The fruit was treated as a diseased fruit with some signs of disease such as spots, pathogen formation, etc. The frequency of the disease was represented in a score of 1-5 (1 = zero, 2 = 5 percent, 3 = 5- 10 percent, 4 = 10-25 percent and 5 = 25 percent of fruit coated with disease symptoms) (20).

FRUIT DECAY (SCORE)

Fruit decay symptoms, all the fruits, from each replication were visually tested. Decayed fruit was known to display some fruit that displayed rotting symptoms. The percentage of fruit decay was expressed using score 1-5 scale viz, 1 = non, 2 = slight, 3 = moderate, 4 = moderately sever (21).

FRUIT WEIGHT (G)

Fruit weight determined by method given by (17). Fruit was weighed individually of each treatment by using the digital weighing balance (Model-ATOAG, Japan) then average was calculated.

FRUIT FIRMNESS (N)

Using a digital penetrometer (QA supplies, fruit pressure tester FT-327), the firmness of fruit samples was measured. The pressure required to push a plunger of a given size into the fruit pulp was expressed, and the average reading was computed. This pressure is expressed in N.

MARKETABILITY INDEX (%)

The fruit was found marketable to be of high quality and free from rot, disease and physical injury. During all the days of data processing, the marketability of each replication was checked (19). Marketability was calculated and expressed in a percentage using the subsequent formula:

$$\text{Marketabality index (\%)} = \frac{\text{Number of healthy fruits}}{\text{Total fruits}} \text{x } 100$$

FRUIT VISUAL QUALITY (SCORE 1-9 SCALE)

For the assessment of fruit visual appearance, each replication was randomly put in front of the expert panel. The findings were expressed in a score ranging from 1- 9 (where 1= bad & unusuable,3 =decent quality with usability limit, 5= reasonable marketable quality, 7= very good quality & 9= excellent quality and fresh appearance) (18). The average was taken from the panel and expressed in the score.

BIOCHEMICAL CHARACTERISTICS

pH OF APPLE JUICE

About 20 millilitres of juice were measured for pH in a beaker using a digital pH meter (ST10 pH, Pen Meter water proof, OHAUS, Instrumemts China).

TOTAL SOLUBLE SOLIDS (TSS) (⁰BRIX)

To measure total soluble solids (TSS), juice from each replication was used. Two readings were obtained from each experimental unit using a digital refractometer (DR, 201-95, Germany). The recorded TSS values for each replication were then averaged and expressed in degrees °Brix.

TITRATABLE ACIDITY (%)

Titratable Acidity (TA) was assessed with the method of Hortwitz (22) with minor modifications. For this purpose, 10ml juice of apple was taken in a beaker and mixed with 20ml distilled water. After that, 2-3 drops of phenolphthalein indicator were mixed in beaker. Finally, the prepared solution of (apple juice + distilled water + phenolphthalein) was titrated opposed 0.1 N (normal) solution of NaOH till light pink color appeared. The ml of NaOH were noticed and finally TA was measured and expressed in percentage by using the following formula:

$$\text{TA}(\%) = \frac{\text{ml of NaOH x } 0.00678}{\text{ml of juice used}} \text{ x } 100$$

TSS: TA (RATIO)

In each sample, the TSS/TA ratio was calculated by dividing the total soluble solids (TSS) by the corresponding titratable acidity (TA) values (22).

ELECTROLYTE LEAKAGE (%)

Electrolyte leakage in apples was measured using the method described by Huan, with some modifications. (23). For this reason, with the help of a cork borer, five equivalent small discs like piece of apple fruit were removed, these pieces were dipped in 50 ml distill water in a glass beaker. The first reading of electrical conductivity (EC) was measured at room temperature after 30 mints with the help of a digital EC meter (SKU: HI2003, HANNAN instruments Thailand). Then the solution was boiled in microwave oven. After cooling down, again second reading of electrical conductivity (EC-2) was taken. Finally, the ion leakage was measured with the help of following formula and expressed in percentage:

$$\text{Electrolyte lekage} = \frac{\text{EC } 1}{\text{EC } 2} \text{x } 100$$

STATISTICAL ANALYSIS

All the information collected were tested by (CRD) Completely Randomized Design with Analysis of Variance (ANOVA) by two-factor factorial through statistics 8.1 for Microsoft windows. The LSD was employed at $P \leq 0.05$ for all means of treatments (24).

RESULTS AND DISCUSSION

ORGANOLEPTIC EVALUATION

An arbitrary scale from 1-9 was used to test the sensory evaluation likewise aroma, flavor, color, taste and over all acceptance. The technique of Peryam and Pilgrim was used (17).

COLOR

The color of the apples stored at different temperatures assessed by a panel of judges using 10 points hedonic scale varied for storage duration as well as by storage temperatures. Three semi trained judges used the hedonic scale to grade the fruit samples under various treatments based on their color organoleptic qualities. (25).

The statistical analysis of color in different apple cultivars revealed highly significant effects of shelf life, cultivar type, and their interaction. Color quality decrease with the time, the maximum color of apple was

recorded in Amari Which was (score 4.33) as compared to others, the average observed in Red Delicious was (score 3.67), and average observed in Jeromine was (score 3.00) at 40 days of shelf period. While minimum average was recorded in Royal Gala at 40 days of shelf period which was (score 1.6667).

During the storage period, colour is another crucial quality trait that has a direct effect on appearance and consumer acceptability. Positive and significant changes were seen in the colour parameters L (lightness), a (redness), and b (yellowness), which were found on the range (26).

TASTE

The data concerning fruit taste of the apple cultivars Red Delicious, Royal Gala, Jeromine, and Amari were presented in the graph. Statistical analysis at the 5% level of significance showed highly significant effects of shelf period and apple cultivar, while their interaction showed a significant effect.

The highest mean taste score for apple fruit was recorded as (9) on day 0 of the shelf life period, while the lowest mean score (1) was observed after 40 days of shelf life. Likewise, the highest taste score was recorded in the cultivar Red Delicious (5), followed by Amari (4.3), and Royal Gala (3.0). The lowest taste score was recorded in Jeromine, which had a score of (1) after 40 days of shelf life at ambient temperature. Sugars and organic acid both influence the sourness and sweetness of fruits, so the change in Taste is due to a decrease in acidity (27).

FLAVOR

Apple cultivars display significant observations among shelf life and cultivars. However, non-significant observations were recorded for interactions between days and cultivars. Graphical results of flavour are demonstrated in graph. The maximum mean for flavour score was recoded in Red Delicious followed by Royal Gala, Jeromine and Amari at 40 day of shelf period. The average flavour in Red Delicious (3.67 score), and Amari was (3.67 score) followed by Jeromine exhibit average (3 score) after 40 days of shelf life period. Royal Gala exhibited lowest fruit flavour which was (2.3 score) as compared to other cultivars.

AROMA

Results showed a highly significant difference between shelf period, cultivar and the interactions between shelf period and cvs in aroma value for Apple cvs at ambient temperature.

The highest mean fruit aroma (9 score) was observed at 0 day of the study and minimum mean (1 score) was observed at 40 days of the shelf period. Likewise, the higher fruits mean aroma was recorded in Amari (4.3 score) as compared to Red Delicious (3.6 score) and Royal Gala (1.6 score) after 40 days of shelf period. While the lowest in Jeromine which was (1 score) at day 40.

OVERALL ACCEPTANCE

The data concerning to fruit overall acceptability of the Apple cultivars Amari, Red Delicious, Royal Gala and Jeromine is presented in fig. (1.5). Data analysed statistically at 5% level of significance showed non-significant results for shelf period and cultivars While interaction among them showed significant for cultivars of apple.

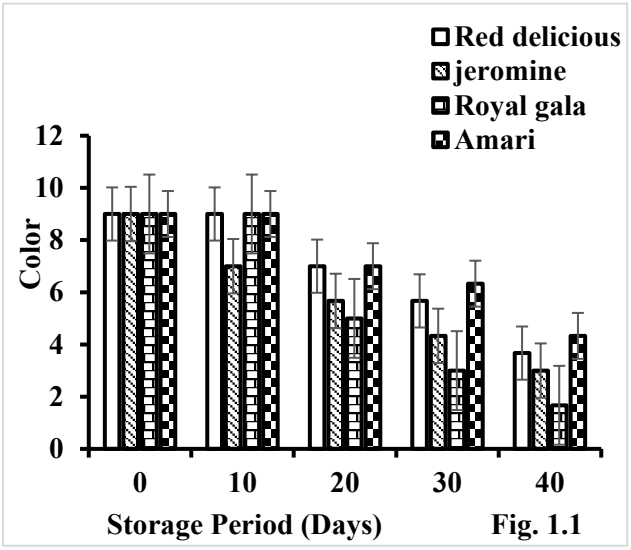
The maximum average of Apple overall acceptance was recorded in Amari (score 5.00) followed by Red Delicious (score 4.3), and average observed in Jeromine was (score 2.00) at day 40 of shelf period. While the minimum average was recorded in Royal Gala at day 40 of shelf period was (score 1.67).

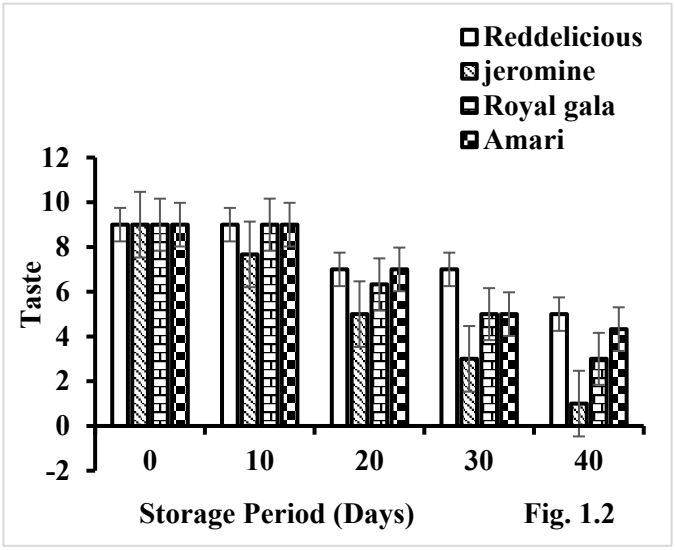
PHYSICAL FRUIT QUALITY TRAITS

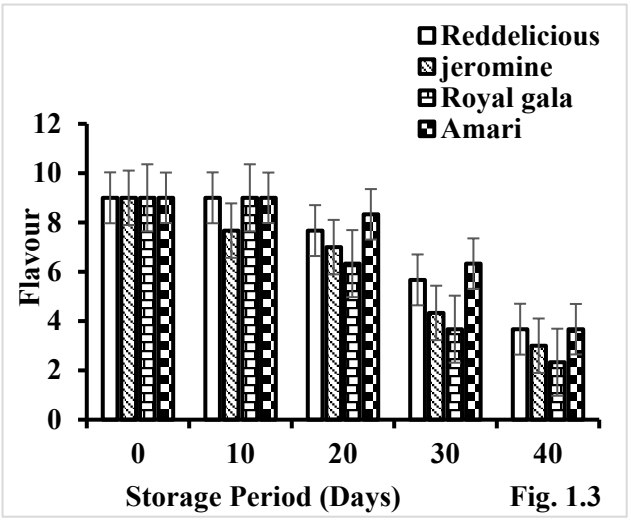
WEIGHT LOSS (%)

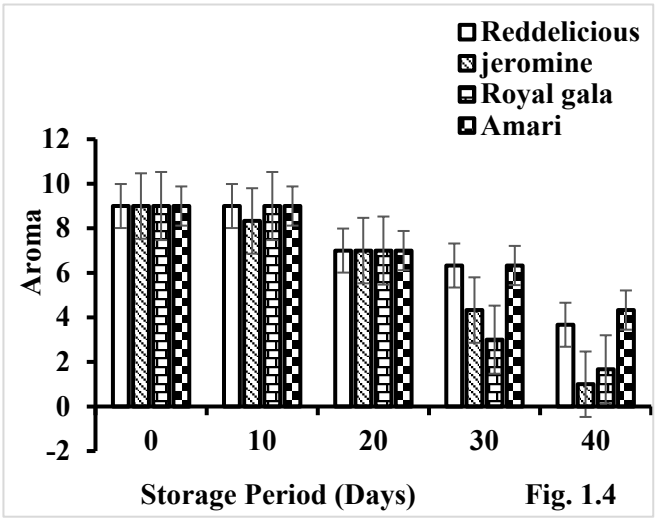
During the ambient shelf period of Apple cultivars, the analysis of variance showed non-significant results among shelf period, cultivars and interaction between cultivars and shelf period was significant. The highest weight loss (12.64 %) was seen in Amari followed by Royal Gala (11.7 %) and Jeromine (11. 10%), while lowest weight loss was recorded in cultivar Red Delicious which was (10.10%) after 40 days of shelf as compared to other cultivar. Fruit weight loss is resolved by the fruit's composition and skin structure (28, 29).

Decreased visual quality and subsequent softening are caused by the moisture loss, which also lowers turgor pressure (30).









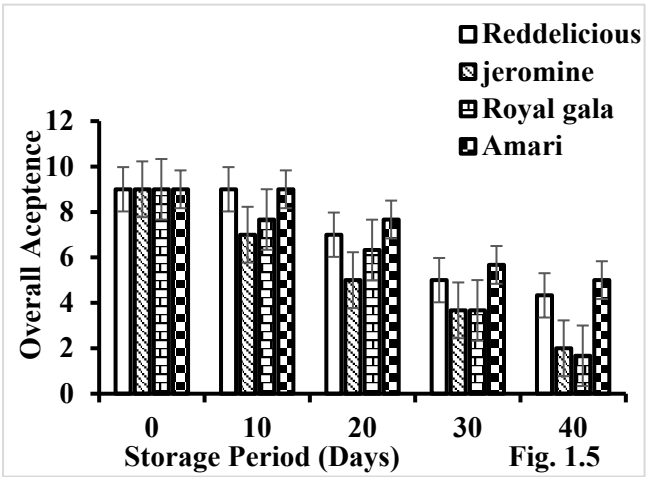


Fig. 1. Change in the Organoleptic evaluation of (A) Red Delicious, (B) Jeromine (C) Royal Gala (D) Amari apple at ambient conditions.

FRUIT SIZE

Fruit size data for various apple cultivars, analyzed statistically over the ambient shelf period, demonstrated highly significant effects attributable to shelf duration, cultivar differences, and their interaction." The evaluation of fruit size across cultivars revealed notable differences during the 40-day storage period. The Jeromine cultivar exhibited the largest initial fruit size, followed by Red Delicious, Amari, and Royal Gala. On day 0, the fruit size of Jeromine was (5.9 cm), which decreased to (3.8 cm) by day 40. Red Delicious had an initial fruit size of (5.8 cm), declining to (4.6 cm) by the end of the storage period. Similarly, Amari measured (5.7 cm) on day 0 and decreased to (4.2 cm) after 40 days. Royal Gala also started at (5.7 cm) and reduced to (4.2 cm) by day 40. Among all cultivars, Red Delicious exhibited the smallest reduction in fruit size (1.2 cm), whereas Jeromine showed the greatest loss (2.1 cm). The greater shrinkage observed in 'Jeromine' may be attributed to higher initial water content or a thinner peel, both of which are known to accelerate moisture loss during storage (50). However, the extent of lenticels on fruit skin contribution to water loss may vary with lenticel size, cultivar, and harvest season (51). The comparatively lower size reduction in 'Red Delicious' indicates its potential advantage for extended storage and transportation

SPECIFIC GRAVITY

The data obtained on the effect of ambient shelf period on specific gravity were analyzed statistically. The analysis revealed significant variations associated with shelf-life duration and treatment. However, the interaction between storage days and treatment was not statistically significant for the cultivar. The corresponding means were illustrated in the graph.

The specific gravity of stored fruits varies significantly due to the different cultivar as well as storage period. The specific gravity was highest in Royal Gala (1.06), followed by Amari (1.03) and Jeromine (1.01), while the lowest value was observed in Red Delicious (0.99). The key factor which directly affect specific gravity was, weight loss, transpiration, temperature, shelf-life period and the chemical interaction which occur in apple. The specific gravity of apple cvs, decreased under room temperature. In addition, specific gravity was used as a basis for grading mangosteen and potato at the commercial level (47). The specific gravity of mango (48), dragon fruit (49).

DISEASE INCIDENCE

Analysis of variance show highly significant result for different cultivars of Apple among all variations shelf-life and its interaction respectively. At 40 days of storage, a gradually increased in disease symptoms noticed in all cultivars. The disease incidence was maximum at the end of storage duration in all cultivars.

Although maximum average disease incidence (4.30 score) was noted in Jeromine followed by Royal Gala and Amari. While little bit or minute symptom of disease incidence was recorded in Red Delicious (2.00 score) at 40 days of shelf life at ambient temperature.

DECAY PERCENTAGE

Data pertaining to decay in different apple cultivars were subjected to statistical analysis, and the results were presented in the graph. The analysis indicated that ambient conditions had a highly significant effect on the decay of apple fruit, based on shelf-life period, cultivar, and the interaction between them. The minimum decay percentage at ambient condition was recorded in Red Delicious (2.00 score) followed by Amari (3.56 score) and the maximum decay percentage was observed in Jeromine and Royal Gala was (4.00 score) at 40 day of shelf period. Skin browning and pitting are common symptoms of declining infection (31).

FRUIT WEIGHT

The analysis of variance at the 5% significance level revealed that apple cultivars exhibited highly significant differences influenced by shelf period, cultivar type, and their interaction. Conversely, the effect on sample physical weight was not statistically significant. The maximum average fruit weight was observed in Red Delicious was (211.0g) at day 0 which was decreased to (190.37g) at day 40 of shelf period. Average fruit weight of Royal Gala Apple decreased from (236.36g) to (208.86g) from 0 day to 40 days of shelf period, Jeromine

exhibited average (208.63g) weight at day 0 which decreased to (180.86g) at 40 days. Amari showed minimum average fruit weight (174.3g) at day 0 which decreased to (152.2g) at 40 days of shelf period at ambient condition. Red Delicious and Amari showed less decrease in weight as compared to Jeromine and Royal Gala cultivars of Apple showed in graph. These results are further supported by Chattopadhyay & Hallad also observed different fruit weight in different varieties (32, 33).

FIRMNESS

The firmness in different apple cultivars indicated a highly significant effect of shelf period, whereas the effects of cultivar and their interaction were not statistically significant. The highest mean firmness value was found in Red Delicious (13.4 N) followed by Amari (12.9 N), Jeromine (11.1 N) and Royal Gala (10.1 N) on day 0. By the end of the shelf period, the lowest mean value was recorded for Royal Gala (4.9 N), while the highest was observed in Red Delicious (7.6 N), followed by Amari (7.4 N) and Jeromine (5.7 N), as shown in the graph.

Custard apple firmness is a crucial factor in customer appeal and is linked to resistance to physical damage and deterioration (34). The majority of customers use their fingers to squeeze fruit in order to subjectively gauge how soft it is (35).

MARKETABILITY INDEX

The results of statistical analysis for firmness in different apple cultivars showed a highly significant effect of shelf period, while the effects of cultivar and their interaction were not statistically significant. However, the graphical results showed that Red Delicious had the highest marketability index (0.73%), followed by Royal Gala (0.6%) and Amari (0.5%) during the 40-day shelf period. Jeromine had the lowest marketability index (0.46%) at the end of the 40-day shelf period.

VISUAL QUALITY

With respect to visual quality, the statistical analysis of the cultivars Red Delicious, Royal Gala, Jeromine, and Amari revealed highly significant differences due to shelf period, cultivar, and the interaction between days and treatment showed in (ANOVA). The highest mean visual quality score (5.0) was recorded for Red Delicious, followed by Amari (4.3) and Royal Gala (2.3). In contrast, Jeromine exhibited the lowest score (1.6) among the cultivars after 40 days of shelf storage under ambient conditions.

BIOCHEMICAL CHARACTERSTICS

pH OF APPLE JUICE

The statistical analysis of pH in various apple cultivars revealed that both ambient shelf period and cultivar had a highly significant effect, whereas the interaction between storage duration and treatment was not statistically significant. Initially pH values exhibited decrease in pH while it increased during storage period of Apple cultivars. Maximum pH was recorded in Jeromine (3.2) followed by Royal Gala (3.1) and the minimum was observed in Red Delicious (2.93) at day 0 of shelf period. While the maximum pH was found in Red Delicious and Royal Gala (4.26) followed by Jeromine and Amari was (4.23) at day 40 of shelf period.

Although the pH of different apple varieties varied non-significantly, the pH progressively decreased as storage times increased. Fruit pH is mostly determined by the organic acid that is absorbed during respiration, which causes the fruit to become less acidic and more alkaline as it is stored longer. (36-39).

TOTAL SOLUBLE SOLIDS (TSS °BRIX)

The data collected on the effect of ambient shelf duration on total soluble solids (TSS), when subjected to statistical analysis, demonstrated highly significant differences for both shelf period and cultivar. However, the interaction between these factors was not statistically significant for the apple cultivars. The corresponding means are presented in Fig. (3.2). The maximum average TSS was observed in Red Delicious (15.5 Brix) at day 0 which was increased to (17.77 Brix) at 40 days of shelf period. Average TSS of Jeromine increased from (14.37 to 16.4 Brix) from 0 day to 40 days of shelf period, Royal Gala exhibited average (11.2 Brix) TSS at day 0 which

increased to (15.3 Brix) at 40 days. Amari showed minimum average TSS (12.47 Brix) on day 0 which increased to (14.02 Brix) at 40 days of shelf period at ambient condition. Red Delicious showed a higher increase in TSS as compared to other cultivars

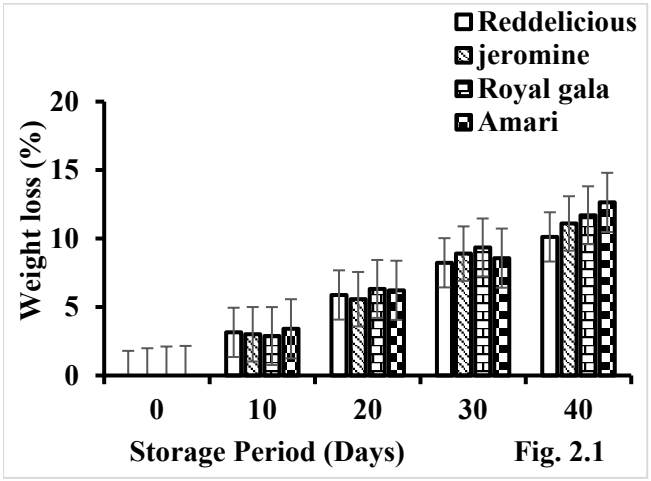


Fig. 2.1

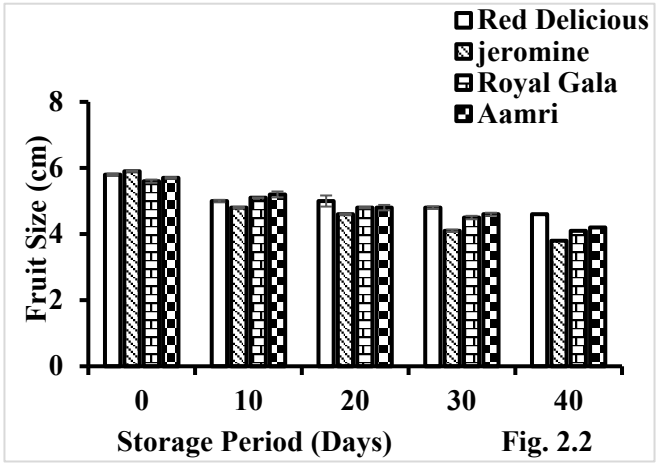


Fig. 2.2

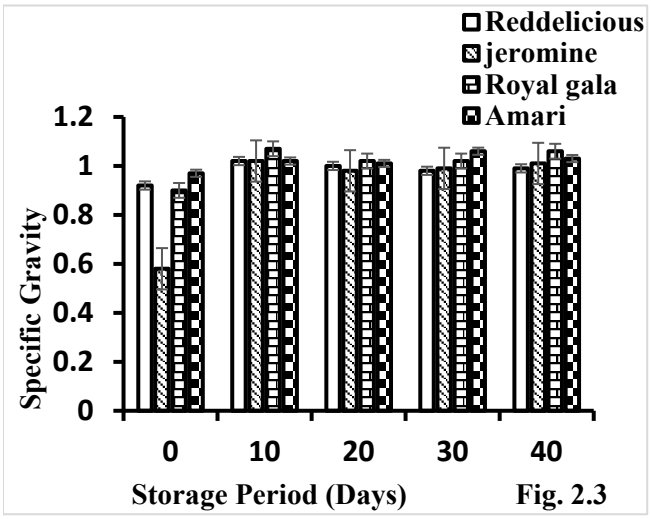
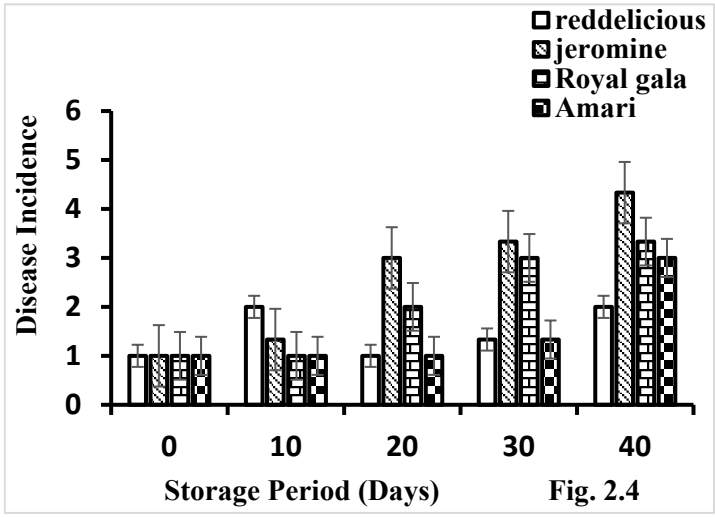


Fig. 2.3



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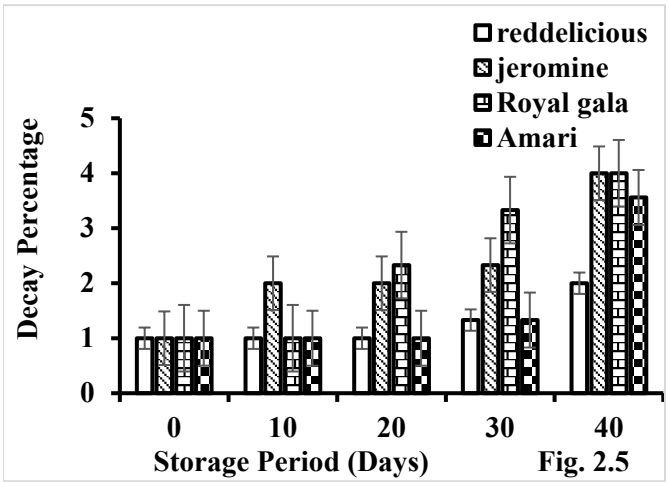

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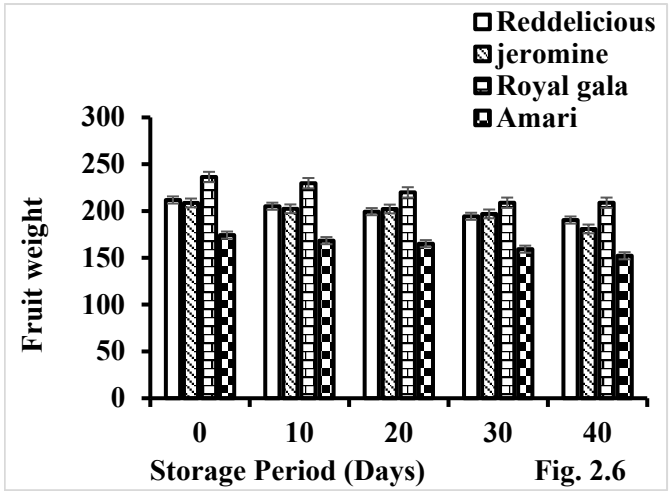
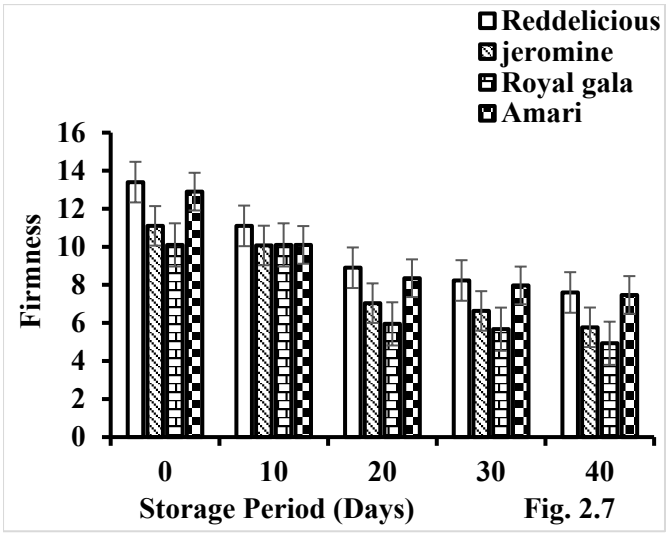
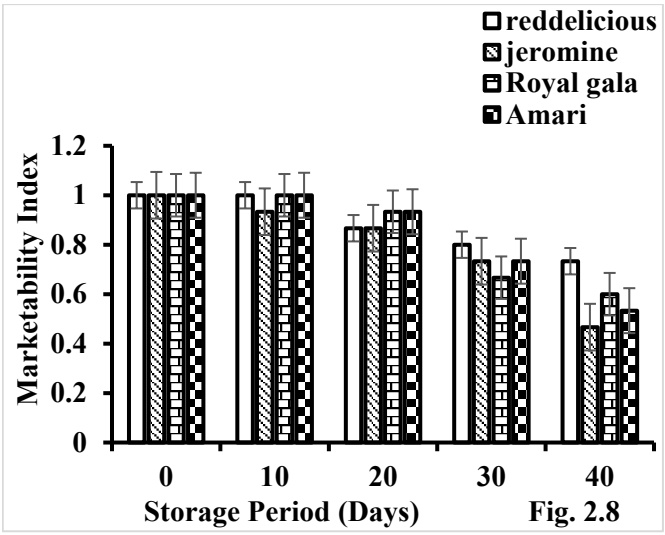


Fig. 2.6





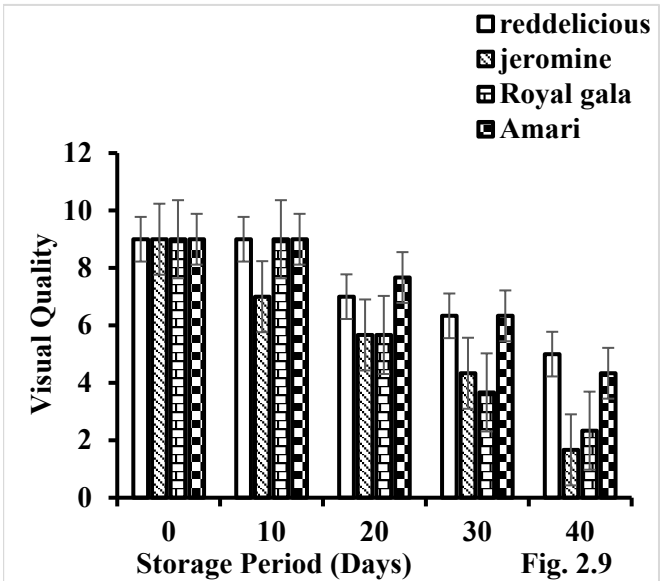


Fig. 2. Change in the physical fruit quality traits of (A) Red Delicious, (B) Jeromine (C) Royal Gala (D) Amari apple at ambient conditions.

The increase in TSS could be attributed to the breakdown of starch into sugars (40-42) reported significant variations in physico-chemical and other TSS, acidity characteristics of apples harvested from different varieties but the different cultivars under study exhibited non-significant variations in total soluble solids. The total soluble solids increased during storage (38, 43).

TITRABLE ACIDITY % (TA)

The statistical analysis of titratable acidity (TA) in various apple cultivars revealed significant effects of shelf period, cultivar, and their interaction (ANOVA). The higher mean value was found in Red Delicious, Royal Gala and Amari (0.09%) as compare to Jeromine (0.08%) at 0 day of shelf period. While, at the end of shelf period, minimum mean value was recorded for Jeromine, Royal Gala and Amari was (0.04 %) followed by Red Delicious (0.05%) showed in Fig. (3.3).

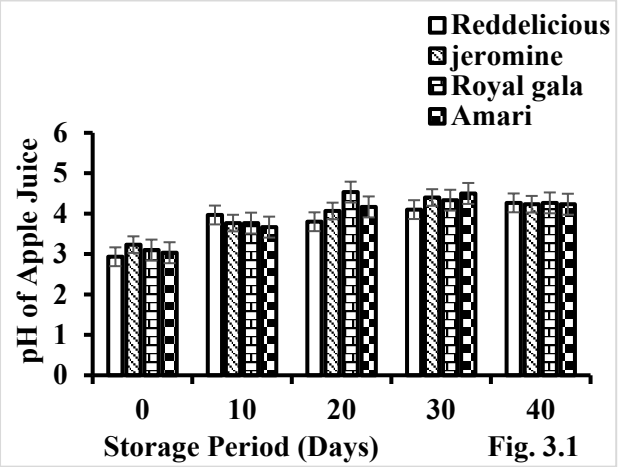
The rate of metabolism has a major impact on the change in titrable acidity. Especially respiration in particular, which reduced acidity by consuming organic acid (38, 39).

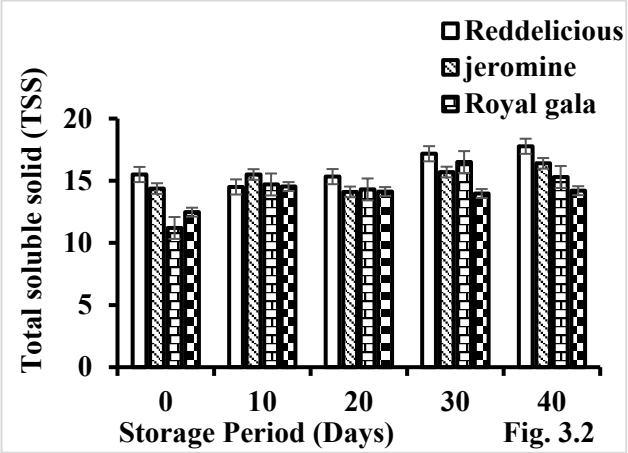
TSS/TA RATIO

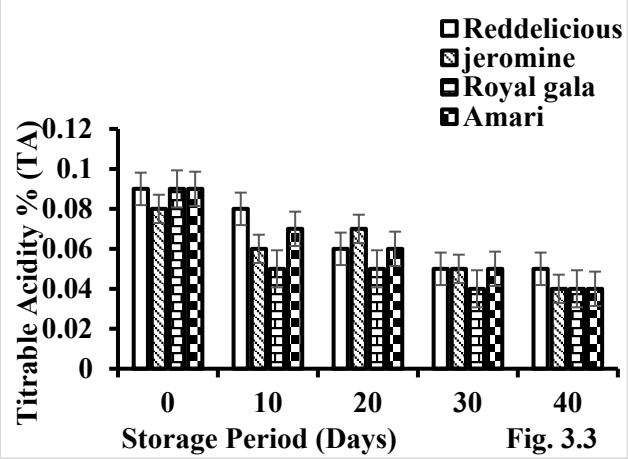
Statistical analysis of the total soluble solids to titratable acidity (TSS/TA) ratio in various apple cultivars revealed significant effects of shelf period, cultivar, and their interaction. The higher mean value was found in Jeromine (0.93%) followed by Amari (0.79%), Red Delicious (0.69%) and Royal Gala (0.63%) at 0 day. While, at

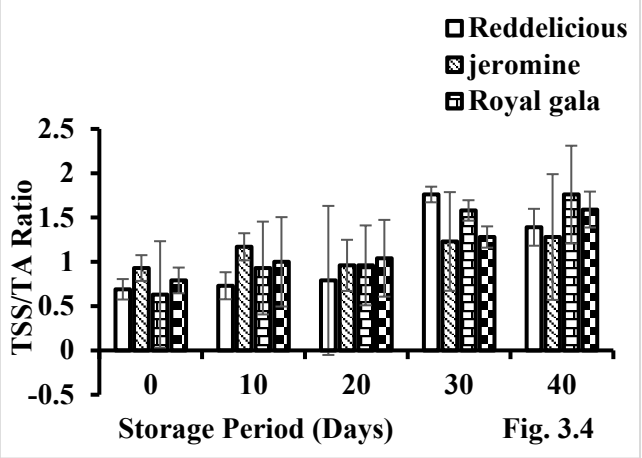
the end of shelf period, minimum mean value was recorded for Jeromine (1.28%) and maximum mean value was recorded in Royal Gala (1.76%) followed by Amari (1.59%) and Red Delicious (1.39 %).

One important quality criterion for apples and other fruits is their total soluble solids (45). As storage times extended, the TSS/Acid ratio in every cultivar. The breakdown of starch into free sugars is what causes the rise in the TSS/Acid ratio (40).









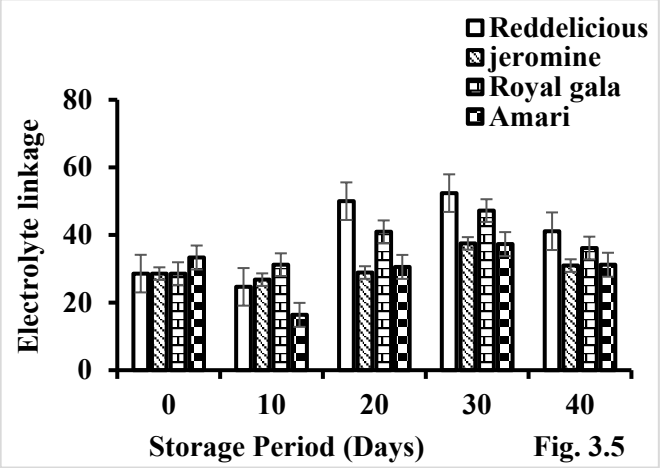


Fig. 3. Change in the Biochemical characteristics of (A) Red Delicious, (B) Jeromine (C) Royal Gala (D) Amari apple at ambient conditions.

ELECTROLYTE LINKAGE

According to the analysis of variance at the 5% significance level, apple cultivars exhibited highly significant differences with respect to shelf period. Significant effects were also observed for cultivar and the

interaction between shelf period and cultivar. The maximum mean for EC shows in Amari, (33.33) followed by Red Delicious, Jeromine and Royal Gala (28.57) at 0 day of shelf period. The maximum average EC found in Red Delicious was (41.11) followed by Royal Gala (36.14) and Amari (31.19) at 40 days of shelf period. Jeromine showed lowest EC which was (30.95) as compared to others.

It might be related to a decrease in water and ionic content. Electrical conductivity is reduced because of starch transition and cell structural changes, as well as fat content, similar results discovered in cherry.

CONCLUSION

The study revealed that Red Delicious was the most appropriate cultivar for ambient storage conditions due to its superior postharvest performance. It showed better post-harvest qualities, including taste, aroma, and overall acceptance, alongside reduced weight loss, decay, and higher firmness. Amari also performed well but with slightly higher weight loss. For consumers, both cultivars provide high quality fruit with extended shelf life, but Red Delicious is particularly well suited for fresh consumption. For supply chain stakeholders, Red Delicious is the ideal choice for ambient temperature distribution, ensuring better marketability, reduced spoilage, and longer lasting freshness during storage and transport.

Conflict of Interest:

Authors have no conflict of interest.

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