Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(2): 1332-1338
Received: 16-01-2018
Accepted: 18-02-2018

Aqleema Banoo
Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Shalimar, Jammu and Kashmir, India

Tsering Dolkar
Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Shalimar, Jammu and Kashmir, India

Mansoor Ali
Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Shalimar, Jammu and Kashmir, India

Correspondence
Mansoor Ali
Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Shalimar, Jammu and Kashmir, India

Role of physical and chemical performance during storage of apple cultivar

Aqleema Banoo, Tsering Dolkar and Mansoor Ali

Abstract
The fruit of apple (*Malus domestica*) cultivars Golden Delicious Red, Delicious, Red Gala and Honeycrisp were harvested at optimum maturity and stored at 5±2°C with 70-80 percent relative humidity. Physiochemical changes were determined in fruit at 30 days interval during storage and significant differences were observed among apple cultivars. Storage resulted in significant increased in weight loss, bitter pit incidence and soft rot, while juice content, starch score, titratable acidity, total soluble solids, total sugar, pH, TSS: Acid ratio ascorbic acid, firmness and density of fruit decreased with increasing storage duration. Harvesting at mid mature stage and calcium chloride (9%) treatment for 9 minutes resulted in enhanced storage performance.

Keywords: apple, physico-chemical, storage

Introduction

Apple (*Malus domestica*) is one of the popular fruits grown in temperate region of the world. In India it is particularly grown in Jammu and Kashmir. The apples produced in the state are known for their taste and nutritional quality. Golden Delicious, Amri, Kandhari, Kulu, Kalat Special, Banki, Red Beauty of Bath, and Sky Spur varieties are grown in temperate regions and other varieties grown in Ladakh *viz.*, Bong, Karkichoo, Khara, Mar, Mongol, Phamer, Sanker, Shinz, Squirmo, Tha and Yangm. The apple is a rich source of nutrients and contains, water 84.7 percent, sodium 0.3 mg/100g, 13.9 g carbohydrates, potassium 145 mg/100g, 0.4 g proteins, 0.3 g lipid, 0.3 g ash, 0.8 g fibre, vitamin C 8 mg/100gm, iron 480 µg/100g, calcium 7 mg/100g, magnesium 6 mg/100gm, Phosphorus 12 mg and Iodine 2 µg (Hussain, 2001) [21]. Besides fresh consumption of apple fruit, it is used in many products like, jams, jellies, marmalades, snacks, sandwich, filling, muraba, salads, in many dishes, puddings, sweet meats, pickles and other preserves include pie filling, slices and sauces. In foreign countries fermented apple juice is used for alcoholic purposes. Sour varieties of apple are used for the preparation of fermented apple juice as cider (Hulme, 1970) [20]. Physical characteristics of agricultural products are the most important parameters to determine the proper standards of design of grading, conveying, processing and packaging systems (Tabatabaeefar and Rajabipour, 2005) [54]. Quality differences in fruits can often be detected by differences in density. When fruits are transported hydraulically, the design fluid velocities are related to both density and shape. Postharvest evaluation gives possibilities for delivering a high quality product and a basic understanding of apple texture is necessary for the development of technology for postharvest evaluations (Ioannides *et al*., 2007) [23]. Mechanical properties of the tissue determine the susceptibility to mechanical damage that can occur during harvest, transport and storage and that eventually leads to a profound reduction in commercial value (Oey *et al*., 2007) [43]. Mechanical properties such as failure stress and strain as well as modulus of elasticity can also be used to evaluate the behaviour of the fruits mechanically under the static loading. Firmness or hardness is another important attribute of fruits and it is often used for fruit quality assessment (Vursavus *et al*., 2006) [58, 59].

Physical variations

The physical characteristics are important for storage as well as processing properties. Weibel *et al*. (2004) [60] reported significant variations in physical characteristics among apple cultivars. Surmacka-Szczesniak (2002) [52] revealed that texture is an indicator of structural and mechanical properties of food products and determines consumer's acceptability. Fruit firmness is one of the basic criteria of fruit texture estimation and in some countries a specific degree of firmness is included in primary parameters for marketing (Hoehn *et al*., 2003) [19]. According to Amarante *et al*. (2000) the fruit firmness depends on fruit density related with the quality and storage performance of apple fruit, however, the softening rate has also been reported to vary from cultivar to cultivar, depending on the presence and expression of genes which regulate the activity of hydrolytic enzymes (Konopacka and Plocharski, 2002; Johnston *et al*., 2001) [31, 24]. Chang-Hai *et al*. (2006) [6] evaluate the response of peach fruit firmness to different levels of temperature during storage. They recorded the delayed softening of peach fruit and inhibition of changes in cell wall and pectin materials at low temperature of 5 °C. They also reported that softening of fruit cell wall was due to increased activities of cell wall polysaccharide-related enzymes at higher temperature. Meisami *et al*. (2009) [39] observed the physical characteristics of apples having different diameters. Average mass and volume were 74.87 g and 104.5 cm^3 respectively while apparent density and density were 0.2401 g/cm^3 and 0.7427 respectively. Porosity of apples having different diameters was 57.24, 54.13 and 50.17 percent and their average packaging was 0.45. Kheiralipour *et al*. (2008) [29] evaluated different chemical and physical attributes of two apple cultivars. They reported that two apple cultivars were significantly different in different physical characteristics at the one percent probability level. Nislihan and Celik (2006) [42] stored the apple cultivars in controlled environment with 0ºC temperature and 85-90 percent relative humidity (RH). Then heat treatments were given for 4 days at 38 ºC to these cultivars. High weight loss was observed in cultivars with heat treatment which was found effective for firmness during storage. The heat treatment increased the ripening by accelerating the process of respiration and starch degradation. Crouch (2003) [9] treated apple cultivars with Smart Fresh and reported significant changes in fruit firmness and incidence of bitter pit. Apple cultivar Royal Gala showed highest firmness (5.7 kg/cm2) which was followed by cultivar Red Delicious (5.6 kg/cm2) while lowest firmness (4.9 kg/cm2) was recorded in Golden Delicious. Minimum bitter pit incidence was reported in cultivar Red Delicious. The physical properties of the fruit determine the diffusivity of water gases through the fruits. Thus, influences the availability of oxygen for respiration and water loss. Ho *et al*. (2010) [18] used permeation diffusion reaction model to study the gas exchange of apple fruits. They measured the gas exchange properties and respiration parameters of the apple fruit organ tissues. The measurements revealed the existence of metabolic gases in the fruit. Large potential for controlled atmosphere (CA) storage was recorded in Jonagold while Braeburn showed low diffusion properties. Kanzi had less O_2 anoxia at CA storage compared with Braeburn. Karathanos (1995) [27] used different concentrations of sucrose for determining the air drying kinetics of dehydrated and fresh apples fruits. The diffusivity significantly decreased when the samples were pre-treated with concentrated solutions of sugar of 45 percent. The low diffusivity helps in storage stability and for better utilization of fruits.

Cultivars and storage performance

According to their storage performance, considerable differences have been reported in a large number of apple cultivars. Saleh *et al*. (2009) [49] stored four apple cultivars in two seasons at 0ºC temperature with 85-90 percent relative humidity in different durations. Highest weight loss was recorded in Gala while least weight loss was observed in Star Cremson. Golden delicious showed highest fruit firmness while lowest firmness was observed in Star Cremson and Starking Delicious. Treatments and storage intervals significantly affected the physico-chemical properties of apples. Omaima *et al*. (2007) [44] treated pre-harvest apple cultivar Anna with boric acid and calcium chloride as a foliar spray to decrease the incidence of *Bortytis cinerea*, a main causal agent of fruit rot. The combined treatments of foliar spray significantly increased total soluble solids, fruit firmness, total anthocyanine and total sugar, while decreased fruit rot decay percentage, weight losses percentages and total acidity at 5°C and cold storage for 60 days. All apple cultivars were significantly affected in all parameters during cold storage. Apple cultivar Star Cremson showed highest fruit storability. Ali *et al*. (2011) [1] examined chemical changes in apple pulp during storage and reported ascorbic acid content, pH and sugar acid ratio was decreased while TSS and titratable acidity was increased in 90 days of storage.

Kvikliene *et al*. (2006) [33] evaluated the pre and post harvest chemical changes in apple cultivar Auskis. Least weight loss was observed in apple cultivar harvested at optimum maturity. Fruit firmness was decreased with late harvesting. Positive correlation was observed between firmness at harvest and post-storage acidity and negative correlation was observed in firmness at harvest and post-storage sugar/acid ratio. Post-storage sugar/acid ratio and post-storage soluble solid content were correlated to soluble solids content at harvest. They reported that optimal harvest time is in between of 114 and 121 days for apple cultivar Auskis after full bloom. Markuszewski and Kopytowski (2008) [35] grafted different apple cultivars on each other and applied soil cultivation in six manners in rows. After the harvest and storage period, fruits were contained less ascorbic acid, dry matter and organic acids and more simple sugars and total sugars. The cultivar Szampion grafted on MM.106 showed best results for all parameters. The manner of soil cultivation significantly affected the apple cultivars for most of the parameters while the best results were obtain with manure and polypropylene fabric. Eugenia *et al*. (2006) [12] compared the four apple cultivars in both traditional and refrigerating storages. Refrigerating storage showed best results as compared to traditional storage. Refrigerated storage resulted lowest dehydration in Wagener Premiat varieties while highest water loss was recorded in Jonathan. Wagener Premiat varieties also result better qualities regarding ascorbic and acid total sugar as compared to other varieties. They reported that apples should be stored in controlled atmosphere (CA) storage to keep the apples in optimum conditions. Ali *et al*. (2004) [2] stored five apple varieties in ordinary storage at room temperature of 25 ºC. An increase was observed in reducing sugar while a decrease was observed in non-reducing sugar and total sugars were increased with the prolonged storage condition. They also observed that total soluble solids significantly increased while as acidity was not significantly affected during storage at room temperature. A decrease was observed in Vitamin C during storage. They recommended Golden Delicious and Amri cultivars of apple for storage to fetch good market price. Khan and Ahmad (2005) [28] stored five apple cultivars under ordinary storage conditions at room temperature in September. The first two weeks of storage did not significantly affect the apple cultivars while gradual change in weight loss and fruit frimness was observed with four weeks of storage. Apple cultivar Amri showed highest weight loss during six weeks of storage while the cultivar Kalakulu result least weight loss. Eisele and Drake (2005) [10] compared 175 apple varieties which are collected from several geographical areas of USA according to their pH, fructose, sorbitol, citric, calcium Brix, glucose, and sodium levels with existing compositional database values. The juices obtained from apple varieties were highly variable in terms of their phenolic compounds. Some of the characteristics were highly matched with one another such as the phloridzin and chlorogenic acid was in same levels in all varieties of apples while as arbutin was in no measurable levels. They reported that the data developed from different apple cultivars is useful with other databases for the development of apple commercial varieties in future to meet the consumer requirements.

Chemical properties

Vursavus *et al*. (2006) [58, 59] observed that chemical properties of fruit are crucial in processing it into different foods. The sugars content, fructose, glucose, sucrose, and sorbitol in fruit flesh contribute to the fruit sweetness and are one of the major characteristics of fruit quality and market value. As per Magein and Leurquin, 2000, apple fruit accumulate starch at the early stages of maturation that is later on hydrolyzed to sugars. Golias *et al*. (2008) [14] stored the apple five cultivars in cold storage and studied the chemical attributes for titratable acidity, firmness, soluble solids, ethylene production and weight loss for 100 days. The changes in titratable acids, ethylene production and loss of firmness significantly differentiated the cultivars, although Golden Delicious, Reinders and Resista still could not be completely separated. Total soluble solids and loss in weight did not contribute to the discriminant resolution. Khorshidi *et al*. (2010) [30] studied the postharvest quality of Red Delicious apple under different temperatures (0, 5 and 12°C) for one month. They found that the fruit diameter, fruit weight, volume, firmness, total titratable acids (TTA), total soluble solids (TSS), elements of sodium and potassium, marketable quality and color surface were significantly affected by different storage temperatures. However, the Red Delicious apple fruit stored at temperature 0ºC maintained the better quality attributes. Rutkowski *et al*. (2008) [48] used optical reflectance spectrometry method for the measurement of chlorophyll and evaluate other quality parameters in (Golden Delicious) apples. They reported that fruit firmness, chlorophyll content and acidity were decreased during vegetative and postharvest period. Significant interaction was observed in chlorophyll content, titratable acidity and fruit firmness. Thammawong and Arakawa (2010) [55] harvested mature and immature apple fruits and treated them with 1-MCP and ethylene for evaluating their response on sugar accumulation. Immature fruits treated with ethylene showed decreased amount of starch while total sugar content was not significantly affected. Ethylene and 1-MCP did not significantly affect the ripening aspects of immature fruit. They reported inverse correlation of sugars accumulation with ripening properties and starch hydrolysis in „Tsugaru‟ fruit during storage.

Calcium and postharvest performance

Conwey *et al*. (1982) [7] reported that fruits and vegetables require additional cost in value addition, when they are moved from the field to the consumer. Thus, it is an economic necessity to decrease by extending the storage life. While several treatments e.g. heat, chemicals, and irradiation can be used to reduce incidence of microorganisms, but injury to fruit and consumers concerns about chemical residues or ionizing radiation requires the development of alternative methods of protection. Calcium is an important second category macro-nutrient which is involved in variety of different function. Calcium helps to regulate the metabolism in apple fruit, and adequate concentration maintain fruit firmness, delays fruit ripening, lower the incidence of physiological disorders such as water core, bitter pit, and internal breakdown (Bangerth *et al*., 1972; Mason, *et al*., 1975; Reid and Padfield., 1975) [4, 36, 46] and suppress *Erwinia carotovora* (Jones) incidence on apple fruits (Sharples and Johnson., 1977; Conway, 1982) [50, 7]. Mahmud *et al.* (2008) [34] treated Papaya (*Carica Papaya* L.) fruits with 1.5, 2.5 and 3.5 percent solutions of calcium chloride by dipping and vacuum infiltration (33 Kpa) or untreated (0%) as control to study the storage life and postharvest quality characteristics. They reported that the postharvest infiltration of calcium at 2.5 percent has the potential to control disease incidence, prolong the storage life and preserve valuable attributes of postharvest papaya, presumably because of its effects on inhibition of ripening and senescence process and loss of the fruit firmness of papaya. Kadir (2005) [26] sprayed Jonathan apple trees at three commercial orchards with calcium chloride (CaCl2) solution containing 3.2 g/L, starting when apple sizes were between 0.9 and 1.6 cm average diameters. Apples were stored for two and four months in atmosphere storage at 2°C (36°F). Apples stored for two months had better quality than those stored for four months. Depending on the location, five to eight $CaCl_2$ applications and two to seven applications were necessary to retain an average of 26 percent of fruit firmness and an average of 35 percent of the SSC/TA, respectively, in the two-month storage. At least seven applications were required to retain an average of 29 percent of fruit firmness of apples stored for four months. Six to seven applications of $CaCl_2$ retained fruit weight by 22 to 33 percent more than the non-treated control apple. In general, $CaCl_2$ was beneficial for storage quality of Jonathan apples in Kansas. Trentham (2008) [57] stored the apple fruits at 0ºC after dipping for 2 minutes in 0, 2 and 4 percent of $CaCl_2$ at 0 or 68.95 kPa. He recorded the data for different parameters with the interval of four months. Paraffin sections were stained with an aqueous mixture of alcian blue 8GX, Safaranin 0 and Bismark brown Y, or with theperiodic acid-Schiff (PAS) reaction. No histological difference was observed in fruit treated with 2 percent $CaCl_2$ compared with those pressure-infiltrated with greater amounts of Ca. Fruits pressure-infiltrated with 6 percent $CaCl_2$ exhibited the greatest amount of flattened epidermal cells and hypodermal cavities. Cuticles were also affected at the higher $CaCl_2$ treatment levels (with regard to staining with Bismark brown), becoming more condensed and uniform. Cuticle and hypodermis were stained differentially with PAS in the 6 percent $CaCl_2$ treatment. All issues including the cuticle were stained magenta red, indicating a possible chemical alteration of the cuticle and the underlying tissue by calcium. Conway *et al*. (2002) [8] suggested that calcium, the most important mineral element determining fruit quality. It seemed to be especially important in apples where it reduced metabolic disorders. Calcium in adequate amounts helped to maintain apple fruit firmness and decreases the incidence of physiological disorders (water core, bitter pit and internal breakdown). Postharvest decay may also be reduced by increasing the calcium content of apple fruit. Directly applied calcium increased fruit calcium content. Both pre and postharvest calcium treatment methods had inherent problems. Developing a commercially acceptable method of successfully increasing calcium concentration in fruit is a continuing challenge. Freitas *et al*. (2010) [13] examined that bitter pit, a Ca_{2+} deficiency disorder of apple fruit is a complex process that involves not only the total input of Ca_{2+} into the fruit, but also a proper Ca_{2+} homeostasis at the cellular level. Hayat *et al*. (2003) [16] investigated the effect of different concentrations of calcium chloride (1%, 1.5%, 2%), paraffin wax coating and different wrapping materials (polyethylene, carton paper) to increase the shelf life and to avoid the postharvest losses of apple. All the treatments had a significant effect on the shelf life of fruits. Calcium chloride (2%) proved very useful for reducing weight loss and shrivelling and retained consumer acceptability even after 60 days of storage. Polyethylene packaging stood second position after 2 percent calcium chloride treatment. Swiątkiewicz and Błaszczyk (2007) [53] studied the effect of late spraying with 0.8 percent Ca $(NO_3)_2$ on calcium content as well as nutrient mutual relations between mineral constituents in Elise fruit of 5 year old apple tree. Sprays with calcium nitrate significantly decreased N/Ca and K/Ca ratio in fruits analyzed after treatments as well as freshly harvested fruits. Castro *et al*. (2008) studied the biochemical factors associated with a CO_2 induced internal flesh browning (FB) disorder of Pink Lady apples. Pink Lady apples were stored in air or controlled atmosphere (CA) with 1.5 kPa O_2 and 5 kPa CO_2 at 0.5ºC for 2 and 4 months. They observed that both brown and surrounding healthy tissues in apples with FB showed a decrease in ascorbic acid and an increase in dehydroascorbic acid during the first 2 months of storage in CA, the time period when FB developed. Undamaged, CA-stored apples retained a higher concentration of ascorbic acid after 2 months in storage. The level of hydrogen peroxide (H_2O_2) increased more in the flesh of CA stored apples than in air stored apples, an indication of tissue stress. Biggs *et al*., (1993) [5] treated apple cultivar Nittany by *Alternaria* spp. with the calcium chloride ($CaCl_2$) for its efficacy in reducing the incidence and severity of infection. They observed that $CaCl_2$ reduces the incidence of rot from 61 percent in the controls to 27 and 33 percent, respectively. Dip treatments alone reduced rot incidence to 17 and 12 percent for the $CaCl_2$ and liquid $CaCl_2$ treatments, and seasonal sprays followed by dip treatment reduced incidence to 5 percent. In postharvest tests, fruit treated with $CaCl_2$ alone and in combination with iprodione exhibited the lowest incidence and severity of *Alternaria* rot. At harvest, isolation frequency from surface-disinfested fruit averaged 34 percent. Perring (1989) [45] examined the development of physiological disorders in particular zones of apples that might be allied to changes in the chemical composition in these and other zones. The flavour and texture of the various zones of the fruit may alter differently during storage because of changes in the distribution of dry matter, water and organic acids.

Physical characters

Jordan *et al*. (2000) [25] determined the density of unripe kiwifruit (*Actinidia deliciosa* cv. Hayward) early in storage as a means to find out the current fruit dry matter (DM) and total sugar-plus-starch concentrations, and of predicting DM and soluble solid concentrations later when the fruit fully matured. As fruit taste is related to sugar concentration, and sugars make up the bulk of the soluble solids in fruit. Density to both DM and ripe fruit soluble solids in the composition trial had similar parameter values to those of the survey trial and gave S.E. of prediction of about 0.3 percent FW. DM levels were about 3.2 percent FW above the sum of soluble solids and starch concentrations in both ripe and unripe fruit, a difference largely independent of DM concentration. Starch lost during ripening was accounted for by the increase in the glucose and fructose sugar pools, and these two sugars had near equal concentrations at each DM level. Sucrose and minor sugar levels were independent of DM and ripeness. McGlone *et al*. (2007) [37] measured non-destructive density and Visible-Near Infrared (VNIR) on yellow-fleshed kiwifruit (*Actinidia chinensis*) harvested on four occasions across a commercial harvest period. Density measurements were made by flotation and the VNIR measurements using a polychromatic spectrometer system operating over the range 300–1140 nm, although much smaller spectral regions were better for predicting DM and SSC (both 800–1000 nm), or Hue (500–750 nm). Harvest-time and post-storage data sets were formed and used to develop models for predicting harvest-time and/or post-storage quality parameters. The VNIR method proved superior to the density method in every case, especially for DM and SSC predictions where the VNIR method was close to twice as accurate. The VNIR method yielded accuracies (standard errors in prediction) of ± 0.40 percent, ± 0.71 percent and ± 1.05° for predictions of harvest DM, SSC and Hue, respectively. Predictions of post-storage DM, SSC and Hue, from post-storage spectra, had improved accuracies of ± 0.24 percent, ± 0.31 percent and ± 0.98 percent respectively. The increased accuracy for SSC prediction, from ± 0.71 to ± 0.31 percent, is theorized to be a consequence of the VNIR method being better at predicting the total carbohydrate concentration, which comprises starch and soluble sugars in about equal amounts at harvest but is mainly soluble sugar after the fruit ripens during cold storage.

Harvesting time

Apples should be picked when mature but not fully ripe to ensure maximum storability. If apples are picked when they are too ripe, physiological processes are underway which complicate storage even under optimal conditions (Ingle *et al*., 2000) [22]. Apples picked at right stage have the organoleptic qualities which enable them to survive more than six months of storage. Apples which were harvested the earliest were firmest both before and after storage but lost a greater percentage of their firmness during storage. Apples harvested 100 days after full bloom (DAFB) had a firmness of 10.2 kg at harvest and 5.0 kg after storage and lost 51% percent of their initial firmness. Apples harvested 128 DAFB had a firmness of 8.2 kg at harvest and 4.7 kg after storage and lost 43 percent of their initial firmness. Apples harvested 114 and 21 DAFB lost only 41 percent of their initial firmness (Meresz *et al*., 1993) [41]. Fruits that are picked before physiological maturity will not ripen satisfactorily (Robertson *et al*., 1990) [47] while as those harvested at more mature stage have a shorter shelf life (Meredith *et al*., 1989) [40] and did not ship well because of reduced shelf life (Murray *et al*., 1998). Gupta and Jawandha (2010) [15] studied the response of peach cultivar Earli Grande to three stages of fruit harvest and they evaluated their physical and chemical characteristics to cold storage of 0-20ºC temperature 85-90 percent relative humidity for 21 days. They observed that fruit quality parameters were significantly affected by different stages of fruit harvest. While as an increase in physiological loss in weight, acid ratio, spoilage, TSS and anthocyanins was observed with the delay in harvesting stage and increase in storage time. With the advancement in maturity and storage duration a linear decline in Vitamin A content was observed. A gradual decrease of reducing sugars was observed in fruits with the increase in storage period picked after optimum maturity. They reported that peach fruits harvested at optimum maturity retained maximum TSS acid ratio and could be stored for three weeks in cold storage. McLellan *et al*. (1990) [38] harvested apple fruits at three different stages. The harvested fruits were at cold storages with a 95 percent relative humidity. The slices of apples were taken from different treatments for analyzing their Brix/acid ratio. Raw slices of apples were analyzed though Sensory analysis. Slice firmness was due to CA delay and harvesting date. With the delay of storing at CA storage the un-blanched raw slices, showed softening, while late harvest also resulted higher softening. Blanching of slices greatly increased the softening. A significant increase in apple flesh browning was recorded at delay in storage at CA and due to later harvest. There was no significant difference in acceptability rating of raw slices of apples before freezing. Erkan and Pekmezcu (2004) [11] studied the effect of harvest dates (15 days interval) on superficial scald development and postharvest quality in Granny Smith apples stored at 0ºC with 90 percent relative humidity for 8 months. A significant variation was observed for weight loss, titratable acidity, soluble solids and flesh firmness among the different harvest dates. Increased soluble solids were achieved with Delay harvest. Flesh firmness, titratable acidity and soluble solids remained at acceptable levels regardless of harvest dates and storage durations. Early harvested fruits were decayed at a lower rate. The Granny Smith apples could be stored for 8 months with minimal scald incidences (0% to 14.2% depending on storage length). Hernandez *et al*. (2005) [17] harvested apple fruits at two or three different maturity stages stored at 33 ºF in air or in controlled atmosphere (CA). Fruit stored in CA conserved higher firmness and produced less CO2. Internal browning was not seen in fruit stored in air, but appeared in fruit after two months storage in CA. The incidence did not increase after longer storage times. It did not affect the incidence of internal browning, but DPA inhibited internal browning completely. A mineral analysis of the apple flesh showed differences among the seasons. Concentrations of calcium (Ca), boron (B) and magnesium (Mg) were significantly higher, corresponding with a lower incidence of internal browning. Tomala (1999) [56] investigated the effect of several renowned factors on the quality of pome fruits at harvest and following storage. Sensitivity to low calcium and susceptibility to physiological disorders during storage was observed by the apple fruits. Calcium content of apple at maturity was influenced by environmental and cultural factors. Important factors (fertilization, pollination, seed number and fruit set) played a crucial role in fruit quality after breakage of dormancy and appearance of bloom. Fruits, which develop from terminal flowers, are richer in calcium than those developing from lateral ones. The location of fruits in the tree crown is also influencing calcium concentration, and incidence of physiological disorders; more fruits are affected in the upper parts of canopy. Calcium treatments reduced the occurrence of physiological disorders. Apples low in calcium showed an earlier onset of the endogenous ethylene climacteric as fruits mature on the tree as compared to early blooming ones. Fruits from late blooming flowers produced less ethylene, exhibited a lower starch index and developed superficial scald during storage. Steenkamp *et al.* (1983) [51] recorded that bitter pit tissue had a higher concentration of calcium, potassium and magnesium than sound tissue as well as higher concentrations of oxalic and citric acid but a lower concentration of malic and succinic acid. It appeared that localized excessive concentrations of oxalic and citric acid could induce bitter pit. Kvikliene *et al.* (2008) [32] studied the effect of fruit maturity on apple fruit cv. Ligol storage ability and rot development. Fruits for storage were harvested 5 times at weekly intervals before, during and after predictable optimum harvest date. The fruits quality parameters changed according to harvest date. Later harvested fruits were softer. Content of soluble solids did not depend on harvest time. Fruit storage ability was closely connected to fruit maturity. The best quality apple fruits one week before climacteric peak were picked after 180 days of storage.

Conclusion

1. Calcium chloride (2%) proved very useful for reducing weight loss and shrivelling and retained consumer acceptability even after 60 days of storage.
2. Relative humidity should be taken to decrease the rate of weight loss during long term storage of apple cultivar.
3. Harvesting at the optimum maturity stage (Mid harvesting stage) should be taken to ensure both quality and longer storage life.
4. Pre and post-harvest calcium application should be a regular exercise to minimize the better pit and soft rot incidence during storage.

References

1. Ali M, Ayub M, Zeb A, Durrani Y, Javid U, Afridi SUR. Physicochemical analysis of apple pulp from Mashaday variety during storage. Agriculture Biological Journal of North America. 2011; 2:192-196.
2. Ali MA, Raza H, Khan MA, Hussain M. Effect of different periods of ambient storage on chemical composition of apple Fruit. International Journal of Agricultural Biology. 2004; 6(2):568-571.
3. Amarante C, Banks NH, Ganesh S. Relationship between character of skin cover of coated pears and permeance to water vapour and gases. Post. Bio. Technol. Amsterdam. 2001; 21(3):291-301.
4. Bangerth F, Dilley DR, Dewey DH. Effect of postharvest calcium treatments on internal breakdown and respiration of apple fruits. Journal of American Society of Horticulture Science. 1972; 97:679-682.
5. Biggs AR, Ingle M, Solihati WD. Control of Alternaria infection of fruit of apple cultivar Nittany with calcium chloride and fungicides. Plant Diseases. 1993; 77:976-980.
6. Chang-Hai JIN, Biao SUO, Juan K, Mei WH, Jun WZ. Changes in cell wall polysaccharide of harvested peach fruit during storage. Journal of Plant Physiology and Molecular Biology. 2006; 32:657-664.
7. Conway WS. Effect of postharvest calcium treatment on decay of Delicious apples. Plant Diseases. 1982; 66:402-403.
8. Conway WS, Sams CE, Hickey KD. Pre- and postharvest calcium treatment of apple fruit and its effect on quality. Acta Horticulture. 2002; 594:413-419.
9. Crouch I. Research and commercial experience with Smart Fresh™ in south a Washington tree fruit postharvest conference. Wenatchee, WA, 2003.
10. Eiselea TA, Drake SR. The partial compositional characteristics of apple juice from 175 apple varieties. Journal Food Composition and Analysis. 2005; 18:213-221.
11. Erkan M, Pekmezcu M. Harvest date influences superficial scald development in Granny Smith apples during long term storage. Turkish Journal of Agriculture. 2004; 28:397-403.
12. Eugenia H, Sestras R, Somsai PA, Barbos A, Sestras A. Research regarding the principal chemical component

loss in the apple fruit during storage. Notulae Botanicae. Horti. Agrobotanici. 2006; 10:34.
13. Freitas ST, Cassandro VT, Amarante JM, Labavitch, Elizabeth J, Mitcham. Cellular approach to understand bitter pit development in apple fruit. Post. Bio. Tech. 2010; 57:6-13.
14. Golias J, Mylova P, Nemcova A. A comparison of apple cultivars regarding ethylene production and physico-chemical changes during cold storage. Horticultural Science. 2008; 35(4):137-144.
15. Gupta N, Jawandha SK. Influence of maturity stage on fruit quality during storage of Earli Grande peaches. Notulae Scientia Biologicae. 2010; 2:96-99.
16. Hayat I, Masud T, Rathore HA. Effect of coating and wrapping materials on the shelf life of apple (*Malus domestica* cv.Borkh). Internet Journal of Food Safety. 2003; 5:24-34.
17. Hernandez EC, Biasi B, Mitcham E. Quality of pink lady brand apple. Washington Tree Fruit Postharvest Conference, Wenatchee, WA, 2005.
18. Ho Q, Verboven T, Verlinden P, Bert E, Schenk Delele A, Mulugeta A, *et al*. Genotype effects on internal gas gradients in apple fruit, J Exp. Bot. 2010; 61:2745-2775.
19. Hoehn E, Guggenenbuhl FG, Kunsch U. Efficacy of instrumental measurements for determination of minimum requirements of firmness, soluble solids, and acidity of varieties in comparison to consumer expectations. Post. Bio. Tech. 2003; 27:27-37.
20. Hulme AC. The biochemistry of fruits and their products. Academic press London and New York. 1970; 1(1-12):64-68.
21. Hussain T. Food composition table for Pakistan. Govt. of Pakistan, Ministry of P & D Islamabad, Pakistan, 2001.
22. Ingle M. D‟‟ Souza MC and Townsend EC. Fruit characteristics of York apples during development and after storage. Horticulture Science. 2000; 35(1):95-98.
23. Ioannides Y, Howarth MS, Raithatha C, Defernez M, Kemsley EK, Smith AC. Texture analysis of Red Delicious fruit: Towards multiple measurements on individual fruit. Food Quality and Preference. 2007; 18:825-833.
24. Johnston DS, Hewett EW, Banks NH, Harker FR, Hertog MLATM. Physical change in apple texture with fruit temperature: Effect of cultivar and time of storage. Post. Bio. Tech. 2001; 16:107-118.
25. Jordan BR, Walton FE, Klages UK, Seelye JR. Postharvest fruit density as an indicator of dry matter and ripened soluble solids of kiwifruit. Post. Bio. Tech. 2000; 20:163-173.
26. Kadir SA. Influence of pre harvest calcium application on storage quality of Jonathan apple in Kansas. Transactions of the Kansas Academy of Science. 2005; 118:129-36.
27. Karathanos VT, Kostaropoulos AE, Saravacos GD. Air drying kinetics of osmotically dehydrated fruits. Drying Tech. 1995; 13(5-7):1503-1521.
28. Khan MA, Ahmad I. Morphological studies on physical changes in apple fruit after storage at room temperature. Journal of Agriculture Social Science. 2005; 1(2):102-104.
29. Kheiralipour K, Tabatabaeefar A, Mobli H, Rafiee S, Sahraroo A, Rajabipour A, *et al*. Some Physical Properties of Apple. Pakistan Journal Nutritents. 2008; 7(5):667-672.
30. Khorshidi J, Mohammad FT, Ahmadi FM. Storage temperature effects on the postharvest quality of apple (*Malus domestica* Borkh. cv. Red delicious). New York Science Journal. 2010; 3(3):67-70.
31. Konopacka D, Plocharski WJ. Effect of picking maturity, storage technology and shelf-life on changes of apple firmness of Elstar, Jonagold and Gloster cultivars. Journal of Fruit Ornamental Plant Resistance. 2002; 10:11-22.
32. Kvikliene N, Valiuskaite A, Viskelis P. Effect of harvest maturity on quality and storage ability of apple cv. Ligol. Sodininkyste Ir Darzininkyste. 2008; 27(2):339-346.
33. Kvikliene N, Kviklys D, Viskelis P. Changes in fruit quality during ripening and storage in the apple cultivar Auksis. Journal of Fruit Ornamental Plant Resistance. 2006; 14(2).
34. Mahmud TMM, Raqeeb AE, Omar SR, Zaki M, Eryani A, Rahman A. Effects of different concentrations and applications of calcium on storage life and physicochemical characteristics of papaya (*Carica Papaya* L.). American Journal of Agriculture and Biological Science. 2008; 3(3):526-533.
35. Markuszewski B, Kopytowski J. Transformations of chemical compounds during apple storage. 2008; 27(2).
36. Mason JL, Jasmin JJ, Granger RL. Softening of McIntosh apples reduced by a postharvest dip in calcium chloride solution plus thickness. Horticulture Science. 1975; 10:524-525.
37. McGlone VA, Christopher JC, Robert BJ. Comparing density and VNIR methods for predicting quality parameters of yellow fleshed kiwifruit (*Actinidia chinensis*). Post. Bio. Tech. 2007; 46(1):1-9.
38. McLellan MR, Blanpied GD, Massey LM. Harvest date and CA storage management effects on quality of processed apple slices. Journal of Food Science. 1990; 55(4):1046-1048.
39. Meisami E, Rafiee S, Keyhani A, Tabatabaeefar A. Some physical properties of apple cv. Golab. Agricultural Engineering International: Ejournal. Manuscript. 2009; 11:1124.
40. Meredith FI, Robertson JA, Horvat RJ. Changes in physical and chemical parameters associated with associated with quality and postharvest ripening of Harvester peaches. J Agri. Food Chem. 37: 1210. Meresz, P., O.K. El Abbasi and P. Sass. 1993. Quality changes of apples during storage. Acta Agronomica Hungarica. 1989; 42(3-4):293-301.
41. Meresz P, El Abbasi OK, Sass P. Quality changes of apples during storage. Acta Agronomica Hungarica. 1993; 42(3, 4):293-301.
42. Nislihan E, Celik S. The effect of heat application on the quality of Golden delicious and Starking delicious apple varieties. Journal of Agronomy. 2006; 5(3):509-514.
43. Oey ML, Vanstreels E, Baerdemaeker DJ, Tijskens E, Ramon H, Hertog ML, *et al*. Effect of turgor on micromechanical and structural properties of apple tissue: A quantitative analysis. Post. Bio. Tech. 2007; 44:240-247.
44. Omaima, Hafez M, Karima HE. Quality improvement and storability of apple cv. Anna by pre-harvest applications of boric acid and calcium chloride. Research Journal of Agriculture Biological Science. 2007; 3(3):176-183.
45. Perring MA. Apple fruit quality in relation to fruit chemical composition. Acta Horticulture. 1989; 258:365-372.

46. Reid MS, Padfield CAS. Control of bitter pit in apples with lecithin and calcium. New Zealand Journal of Agricultural Research. 1975; 18:383-5.
47. Robertson JA, Meredith FI, Horvat RJ, Senter SD. Effect of cold storage and maturity on the physical and chemical characteristics and volatile constituents of peaches (cv. Cresthaven). Journal Agriculture Food Chemical. 1990; 38:620-624.
48. Rutkowski KP, Michalczuk B, Konopacki P. Non-destructive determination of Golden delicious apple quality and harvest Maturity. Journal of Fruit Ornamental Plant Resistance. 2008; 16:39-52.
49. Saleh AM, Ghafir, Suliman O, Gadalla, Benissa N, Murajei, *et al*. Physiological and anatomical comparison between four different apple cultivars under cold storage conditions. Acta Biologica. 2009; 53(1):21-26.
50. Sharples RO, Johnson DS. The influence of calcium on senescence changes in apple. Annual Applied Biology. 1977; 85:450-453.
51. Steenkamp J, Terblanche JH, de Villiers OT. The role of organic acids and nutrient elements in relation to bitter pit in golden delicious apples. Acta Horticulture. 1983; 138:35-42.
52. Surmacka-Szczesniak SA. Texture is a sensory property. Food Quality and Preference. 2002; 13:215-225.
53. Swiątkiewicz ID, Blaszczyk J. The effect of late spraying with calcium nitrate on mineral contents in „Elise" apples. Folia Horticulturae. 2007; 19(2):47-56.
54. Tabatabaeefar A, Rajabipour A. Modeling the mass of apples by geometrical attributes. Scientia Horticulture. 2005; 105:373-382.
55. Thammawong M, Arakawa A. Starch to Sugar Conversion in Tsugaru Apples under Ethylene and 1-Methylcyclopropene Treatments. Journal of Agriculture Science and Technology. 2010; 12:617-626.
56. Tomala K. Orchard factors affecting fruit storage quality and prediction of harvest date of apples. Acta Horticulture. 1999; 485:373-382.
57. Trentham WR. Histological effects of calcium chloride in stored apples. Journal of American Society for Horticultural Science. 2008; 133(4):487-491.
58. Vursavus K, Kelebek H, Selli S. A study of some chemical and physico-mechanic properties of three sweet cherry variety (*Prunus avium* L) in Turky. Journal of Food Engineering. 2006; 74:568-575.
59. Vursavus K, Kelebek H, Selli S. A study of some chemical and physico-mechanic properties of three sweet cherry variety (*Prunus avium* L) in Turky. Journal of Food Engineering. 2006; 74:568-575.
60. Weibel F, Widmer F, Husistein A. Comparison of production systems: integrated and organic apple production. Part III: Inner quality: composition and sensory. Obst-und Weinbau. 2004; 140:10-13.