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Factors Affecting Shelf Life of Vegetables: A Review

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ABSTRACT

Immature green cucumber cv. Padmini fruits were individually shrink wrapped with Cryovac D955 (60 gauge) film and stored at 12±1°C temperature, 90-95% relative humidity as well as under ambient room conditions, *i.e.*, 29-33°C temperature and 65-70% relative humidity. At 12±1°C temperature and 90-95% relative humidity, the individual shrink-wrapped cucumber recorded minimum physiological loss in weight (0.66%) as compared to unwrapped fruits (11.11%) at the end of refrigerated storage of 15 days. The softening (loss of firmness) was observed at maximum (1304.6-876.6 g force) in unwrapped cucumbers, whereas, in shrink wrapping, minimum loss in firmness (1304.6-1065.3 g force) was observed after 12 days of storage at 12±1°C temperature and 90-95% relative humidity. However, greater loss of weight and firmness made the control cucumbers unmarketable after 9 days of storage. There was no decaying in shrink wrapped and unwrapped cucumbers up to 15 days of storage at 12±1°C temperature and 90-95% relative humidity. After 15 days storage of shrink-wrapped cucumbers at 12±1°C temperature and 90-95% relative humidity, there was loss of green colour and development of yellowness and decay. The sensory attributes score was noted maximum in shrink wrapped cucumbers as compared to unwrapped cucumbers at end of the both storage conditions. Thus, it can be concluded that individually shrink-wrapped cucumber can be stored well up to 15 days at 12±1°C temperature and 90-95% relative humidity and for 5 days under ambient room conditions (29-33°C temperature and 65-70% relative humidity) with maximum retention of green colour, no spoilage, minimum weight and firmness loss and very good sensory quality attributes, whereas, unwrapped fruits can be stored well up to 9 days at 12±1°C temperature and 90-95% relative humidity and for only 2 days under ambient room conditions with maximum retention of physico-chemical quality attributes.

Key words: Decaying, Firmness, Refrigerated storage, Sensory quality, Shrink wrap.

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Vegetables being rich sources of carbohydrates, minerals, vitamins, phytochemicals and dietary fibres are important constituents of our daily diet. They are grown all over the world including India. Vegetables alone contribute 10.61% of the total value of output from agriculture, which is increasing over the years (CSO, 2013). India is the second largest producer of vegetables with 2.8% of the total cropped area and 15% of the world's production (Kumar *et al.,* 2011). According to National Horticulture Board, India produced 162.89 metric tonnes of vegetables from 9.39 million hectares area during the year 2014-15. After China, India is the world largest producer of fruits and vegetables, however, the fruits and vegetables of worth ` 13300 crores get spoiled every year due to unavailability of appropriate refrigerated transportation and cold storage facilities (Singh *et al.,* 2014). Since vegetables being high in moisture content are highly perishable, hence, to extend their storage life is very imperative. Their storage life can be extended by controlling pre- and post-harvest factors affecting storage life and applying various post-harvest treatments. The most important pre- and post-harvest factors affecting storage life are discussed below.

Pre-harvest factors

Cultivar

The storage life varies with the varieties, thus, the cultivars those having better keeping quality due to their low respiration and transpiration rate because of their thick epicuticular waxy layer should be developed through breeding and selection. Szanto-Nemeth (1975) evaluated string bean varieties for their suitability to quick-freezing and found that the cultivar Impaired Yellow had the longer storage life. Bhatnagar *et al.* (1980) observed more weight loss in cultivar S-12 (13.20%) and Sel.-12 (10.0%) of Tomato. Weichold *et al.* (1981) observed that the red cabbage cv. Maxilla and the white cabbage cv. Kontiki had a 4-6 weeks longer storage life than the standard cultivars, *i.e.*, Dauerrot and Turkis. Banaras *et al.* (1988) reported that among the three pepper varieties tested, Keg Stone had the greatest amount of epicuticular wax and lowest rate of water loss. The cultivar Numex, R-Naky and Santa-Fe-Grande had markedly less epicuticular wax and alternately lost water at considerably highest rate. The French bean cultivars derived from a cross between Green Isle and Blue Lake 274 had good post-harvest life

(Leal, 1989). Kramer (1989) found *Brassica pekinensis* hybrid King-65 the best for storage at 0 to 1°C for 14 weeks.

Cleanliness of previous crop residues and stones in field of root crops

Removal of previous crop residues, roots and stones in root crops like carrot, radish and turnip prevent forking and splitting. It improves the quality of root crops and ultimately storage life. Sometime, the previous crop residues are very deep and not incorporated into soil at the time of field preparation and create hurdle in the growth of radish and carrot roots, which cannot be stored for long time.

Cultivation methods used

Cultivation method adopted affects the storage life of vegetables. Kader *et al.* (1974) studied the post-harvest response of vegetables to pre-harvest field temperature and found that freezing temperature in field greatly reduced the storage life and the temperature above freezing but <10°C often caused chilling injury and high temperature induced visible injury. According to Szanto-Nemeth (1975) the temperature, at which a crop is grown, can affect its quality and post-harvest life.

Regular irrigation

Regular irrigation in root and bulbs crops enhances the storage life. Fluctuations in water supply causes splitting of onion bulbs. Excessive irrigation produces onion bulbs with thick neck and leads to misshape in roots with poor colour, surface cracking in tomato, carrot, muskmelon and more hair growth on root crops. Delay in harvesting as well as water stress followed by excessive irrigation application caused forking in root crops. These disorders decrease the storage life of vegetables. Reducing soil moisture content increases skin strength. In contrast, strength of skin is reduced when soil moisture content is increased (Kamimura, 1977; Peet, 1992). Fruit cracking is generally associated with rapid movement of water and sugars towards the fruit when cuticle elasticity and resistance are weak (Dorais *et al.,* 2001). Fruit cracking disorder can be controlled by provision of regular and even watering (Kennelly, 2009).

Withhold irrigation before harvesting

Excess moisture at harvesting causes faster deterioration like decaying, early sprouting, shrinkage, shriveling, *etc.* To improve the storage life and firming of skin of bulbs crops like onions, garlic, *etc.* and tubers crops like potato and sweet potato stop irrigation at least 15 days before harvesting. Withholding of irrigation helps in conditioning and firming the skin of tuber and bulb crops. Farmers tend to irrigate the crop before harvesting for easy pulling of onion bulbs and digging of potato tubers but it increases the moisture content in these crops ultimately shortens the storage life. In storage study of onion, Makhan Lal *et al.* (2014) recorded minimum cumulative sprouting, physiological loss in weight, black mould, decaying and total loss at 150 days after storage while withholding irrigation four week before harvesting. Total soluble solids were also recorded maximum in this treatment.

Fertilizers used

Literature depicts that soil type and fertility affect chemical composition of the crop. Excess or deficiency of certain elements in soil affects the quality and post-harvest life of crop. Application of higher dose of nitrogen has been shown in literature to increase the proportion of bulbs with thick neck thereby reducing the storage life of onion. Bottcher and Kolbe (1975) observed that increasing level of potash up to 166 kg/ha checked sprouting of bulbs up to 7 months under normal storage conditions. On the other hand, they observed that nitrogen above 100 kg/ha increased the sprouting both under ordinary and refrigerated conditions. Painter (1977) observed no beneficial effect of additional dose of nitrogen (320 lb/acre) on storage life of onion.

Removal of weeds

All the weeds of the commercial vegetable crops harbor different types of insect pest and disease pathogens and after harvesting of crops, they shift on weeds. These insect pests and disease-causing pathogens deteriorate the quality of produce, which cannot store longer.

Staking

Staking in indeterminate cultivars of tomato, peas, cucurbits and particularly of bottle gourd, ridge gourd and bitter gourd is necessary to avoid the direct contact of their fruits with moist soil. It also avoids the bending of bottle gourd fruits and asparagus spear if these are placed horizontally without staking and thereby reduces decaying of fruits after harvest.

Blanching

In a gardening context, blanching is the process of hiding part of a plant from light, which prevents it from developing colour. In case of cauliflower, this process results in white edible portion with a less overpowering taste.

Chemicals used

Chemicals are applied to growing plants to control insect-pests and diseases. Use of fungicides can have a considerable effect on post-harvest life of the crop. The insect-pests and diseases affected fruits have very short shelf life since any injury to the fruits increases the enzymatic reaction and senescence of the fruit. Marks *et al.* (1957) reported that ripening could be deferred in tomato fruits by applying growth inhibitors such as di-nitrophenol. Fuchs and *Borkai-Golan* (1979) reported that spray of mancozeb 0.1% and imazalil 0.2% was very effective for extending the shelf life of tomato fruits and protecting them from post-harvest diseases. Sandooja *et al.* (1987) studied the effect of $KMnO_4$ 1000 ppm to extend the shelf life of tomatoes harvested at 3 stages of maturity, *i.e.*, red, pink and green.

Plant growth regulators sprays

Pre-harvest foliar application of MH 2500 ppm decreased sprouting of bulbs significantly during storage (Wittwer and

Sharma, 1950). Coggins *et al.* (1960) suggested that gibberellins deferred ripening and this view was also supported by Hashimoto and Rappaport (1966) and Jackson and Coombe (1966). Abdel-Kader *et al.* (1966) noticed that potassium gibberellate (K-GA) 10-100 ppm delayed ripening and extended the shelf life of tomato fruits. Tzeng (1974) reported that spraying 0.25% MH two weeks before harvesting increased onion storage. Safi (1978) observed that onions of Faislabad cultivar sprayed with 4000 and 5000 ppm MH 15 days before harvest could be stored up to 6.5 months at ambient room temperature. Iordachescu and Mihailescu (1980) found least sprouting during storage in onions sprayed with 0.43% MH 15-18 days before harvest. Shelf-life extension may be achieved by retarding deterioration of physiological process by minimizing mechanical damage, optimizing environmental conditions and applying chemicals (Shewfelt, 1986). Spray of MH 3000 ppm and Tecto 1200 ppm alone and in combination gave effective control of decaying and reduction of sprouting and total weight loss caused by decaying, sprouting and drying and prolonged the storage life of onion bulbs (Singh and Dhankhar, 1995). Singh *et al.* (2014) found the the growth regulator NAA 100 ppm most effective treatment with respect to vine length, number of nodes to first male and female flower appearance, number of male and female flowers per vine, days to initiation to first male and female flower, diameter of fruit, highest fruit length and weight, number of fruits per plant, fruit yield per plant and total fruit yield.

Proper harvesting time

Harvesting preferably during cooler part of the day and immediately shifting the produce to shade or packing station extend the storage life of vegetables. Harvesting during rains or immediately after rains develop the conditions most favourable for the multiplication of microbes results in decaying of vegetables during storage particularly leafy vegetables. Care should be taken that there should be no mechanical injury while harvesting.

Proper harvesting method

Several factors are considered important in deciding the appropriate method of crop harvesting. Some crops offer no choice since machines have not yet been developed for harvesting them. The product is so delicate that mechanical harvesting become a great challenge and is not cost effective. Harvesting is done by adopting a very gentle way so that damage to the produce may be avoided because any mechanical damage to the produce during harvesting may invite microorganisms, which results in reduced shelf life of the produce. In mixed and intercrops, mechanical harvesting is not possible otherwise it may cause huge economic losses. Skilled manpower is required for the handling of machines to escape economic losses.

Harvesting stages and handling

Quality cannot be improved after harvest though it can only be preserved. Thus, it is important to harvest vegetables at the right stage, right time and by adopting right method. Harvesting and handling carefully extend the storage life. Where these operations are not carried out with sufficient care and attention, the produce can develop unwanted changes, which include shortening of storage life due to increased respiration or bio-synthesis of ethylene and increased level of microorganisms. Sandooja *et al.* (1987) reported that among three maturity stages of tomato fruits, *i.e.*, red, pink and green, the green mature fruits kept in wooden boxes with paper lining as cushioning material maintained longer shelf life at room temperature.

Post-harvest factors

Curing

Curing is an important process especially when vegetables are to be stored for longer period. During curing, the cut or injured portion of the harvested produce is allowed to heal up and form periderm. Lurie *et al.* (1993) studied that pre-storage heating of tomatoes extended their shelf and storage life as there is correction between the maintenance of heat shocked protein mRNA during storage and the inhibition of chilling injury in heated tomatoes.

Dumping

The first step of handling is known as dumping. It should be done gently either using water or dry dumping. Wet dumping can be done by immersing the produce in water. It reduces mechanical injury, bruising, abrasions on the vegetable since water is gentle on produce. The dry dumping is done by soft brushes fitted on the sloped ramp or moving conveyor belts. It will help in removing dust and dirt on the fruits ultimately increases the shelf life of fruits.

Pre-sorting

It is done to remove injured, decayed and misshapen vegetable. It will save energy and money because these will not be handled, cooled, packed, or transported. Removing decayed vegetables is especially important because these will limit the spread of infection to other healthy fruits during handling.

Washing, cleaning and drying

Some vegetables require washing to remove the soil particles adhered to produce. Washing with chlorine solution (100-150 ppm) can also be used to control inoculums build up during pack house operations. For best results, the pH of washing solution should be between 6.5 and 7.5 for best results, *e.g.*, root crops, tuber crops, tomato *etc.* After washing, excess water should be removed otherwise it encourages microbial spoilage.

Sizing/Grading

Generally, grading based on size, weight, colour, defects and combination of these factors increases storage life of vegetable produce. Ward (1979) studied the effect of bulb size on the storage life of onion and showed that the number of decayed and sprouted bulbs increased with increasing

bulb size. Graded tomato fruits had better storage life (Gaur and Bajpai, 1982). Joshi *et al.* (1998) concluded that tomatoes of any cultivar with moderate fruit weight (around 61 g) and pericarp thickness 5 mm could be stored for 14 days under ambient room conditions (31°C temperature and 55-60% relative humidity) with a weight loss of 29%.

Waxing

Waxing is very important process to extend the storage life because it gives an extra-discontinuous layer of wax applied artificially with sufficient thickness and consistency to protect against decaying. The wax treated brinjal fruits had the best appearance and least physiological weight loss (Singh *et al.,* 1989). Hershko and Nussinovitch (1998) studied that alginate and alginate-sitosterol coating extended the shelf life of onion, reduced water loss and improved gloss. Huyskens-Keil (2001) reported that sucrose ester as a post-harvest surface coating prolonged the shelf life of pepino but found it less effective than the PE-foodtainer and biodegradable polysaccharide film. Tomato wax (tomato wax is a wax formulated from 99% good grade mineral oil and 1% water) treatment limited the weight loss and respiration rate, preserved firmness and kept the bunch tomatoes in good condition for 12 days (Dilmaçünal *et al.,* 2011).

Blanching

Hot water (42-46°C) treatment significantly reduced yellowing and increased the shelf life of broccoli stored at 10 or 20°C (Wu and Wu, 2003).

Trimming

Removing diseased leaves in leafy vegetables and radish is of great significance in controlling the disease and it also improves the appearance of produce and storage life.

Degreening

Degreening is the process of decomposing green pigment in tomato fruits usually by applying ethylene or any other similar metabolic inducers to give a fruit its characteristics colour as preferred by the consumers. Degreening is carried out in special treating rooms under controlled temperature and humidity conditions, in which, low concentration ethylene (20 ppm) is applied to keep the CO_2 level below 1%. The best degreening temperature is 27°C and relative humidity is 85-90%.

Pre-cooling

Pre-cooling of the produce soon after their harvest is one of the important components of the cool chain, which ultimately affect shelf life of the produce. The main purpose of pre-cooling is to immediately remove the field heat from the produce.

Storage temperature

Temperature is the most important factor that affects physiology and shelf life of the produce. The respiration rate and enzymatic reactions responsible for spoilage of vegetables increase exponentially with the increase in temperature. The storage of mature green and turning red tomatoes was satisfactory at 4.4°C temperature than at 15.6°C but the mature green fruits could be stored for 6 weeks at 7.2°C temperature and for 5 weeks at 18.3°C temperature (El-Shiati *et al.,* 1959). Mature green tomatoes under controlled storage conditions (5% CO_2 + 10% O_2, 10% CO_2 + 10% O_2 and 25% CO_2 + 10% O_2 short term treatment at 6.5±0.5°C temperature) ripenened slowly and reached a light pink stage after 6 weeks (Murata *et al.,* 1968). Modified atmosphere extended the ripening time, improved firmness and maintained quality of mature green tomato fruits (Hobson, 1981). Eggplant stored at 15°C temperature did not show any sign of deterioration (Jha and Matsuoka, 2002).

Ethylene scrubber

Potassium permagnate ($KMnO_4$) can be used as ethylene absorbent within polymeric film package, which extends the storage life (Scott *et al.,* 1968, 1970). Application of $KMnO_4$ as ethylene absorbent has been reported to play an important role in enhancing the shelf life of green and red ripe tomatoes (Giraldo *et al.,* 1977).

Storage atmosphere and composition of gases

The composition of gases in storage atmosphere affects the storage life of horticultural produce and alternation in concentration of respiratory gases, *i.e.*, O_2 and CO_2, may extend storage life. The onion stored at low temperature in 5% CO_2 and 3% O_2 usually gave the best result and the bulbs stored early had a longer storage life than late stored one (Adamicki and Kepka, 1974). Sandooja *et al.* (1987) found the mature green tomatoes packed in egg trays in best marketable conditions even after 8 days of storage under zero energy chamber as compared to fruits packed in wooden box under ambient storage conditions. Gorini (1988) reported that controlled atmosphere storage containing 1.8-10% CO_2 + 2% O_2 prolonged the storage life of broccoli up to 3-4 weeks. Controlled atmosphere extended the storage life of vegetables by minimizing their respiration rate (Adamicki, 1989; Wolfe and Black, 1990). Modified atmosphere is very cheap device and has been found helpful in enhancing shelf life of different fruits (Day *et al.,* 1990). Sanchez-Mata *et al.* (2003) selected the air composition 3% O_2 + 3% CO_2 the best at 8°C to extend shelf life of vegetables.

Packaging

Certain types of packaging such as plastic film to modify the atmosphere can be used to extend the storage life of crops and to protect the crop from infection. Haeseler *et al.* (1966) reported that polyethylene bags provide conditions like controlled conditions and extend the shelf life of red ripe tomato fruits and as such the storage conditions could extend the shelf life for 4 weeks and two weeks in 1.5 mm polyethylene base liner at 13°C temperature. Similar results were also reported by Gorini and Buonocore (1970) on the

storage of cabbage heads. Ogura and Takehana (1973) and Hinsch *et al.* (1976) stored lettuce in polyethylene film bags for 7-8 days at 3.3°C temperature. Lester and Bruton (1986) used shrink polythene films for extending shelf life of musk melon cv. Mangonum up to 40 days at 4°C temperature and relative humidity 85-90%.

Chemical treatment and packaging

Non-fungicidal chemicals can be used to increase the shelf life of perishables. Wrapping of tomato fruits in plastic film after dipping in sodium hypochlorite @ 25 g/litre extended the shelf life up to 21 days (Saguy and Mannheim, 1975). Giraldo *et al.* (1977) received best results when green mature tomatoes packed in perforated sealed bags with $KMnO_4$ in a ratio of 100 to 1 g $KMnO_4$ and stored the fruits for 13 days in contrast to 7 days in sealed bags without $KMnO_4$. The mature green tomato fruits wrapped individually in plastic film after treating with ethylene could be stored for 1-3 weeks at 15°C and for 7 days at 21°C temperature (Risse *et al.,* 1985). Majoka *et al.* (2012) studied the effect of packaging materials and sesame oil on shelf life of brinjal cv. Hisar Shyamal and concluded that brinjal fruit can be store better under ambient room conditions after wrapping with cling film. Dipping fruits in sesame oil recorded slightly lower loss as compared with control (without dipping).

Condition of fruits

In a study on post-harvest storage life of *Kharif* onion under ambient conditions, Chadha and Sidhu (1989) observed that the per cent sprouting at the end of storage was maximum in bulbs with the tops intact (35.78%) and minimum (7.42%) in those with the tops removed 15 days after harvest.

Storage technique

Storing vegetables in cold store increased their life by 20% and reduced 3% losses caused by evaporation and rots (Drozdowicz, 1976). Mangal *et al.* (2002) recorded lesser physiological loss in weight and decay loss under evaporative cool chamber than under ambient room temperature conditions and lowest PLW with Kufri Chandramukhi.

Chemical treatments

Chemical application as pre- and post-harvest sprayed or dip offered great promise in the improvement of fruit quality and shelf life (Scott *et al.,* 1970; Mason *et al.,* 1975). By using salicylic acid (1 and 2 mM) and calcium chloride (1.5%), the ripening process can be delayed and the shelf life of *Capsicum* fruits (stored at 10°C) can be extended up to 71 days without any spoilage and off-flavour, thus, it may be concluded that the salicylic acid and calcium chloride treatments may aid in delaying softening process, enhancing keeping quality while retaining the nutritional quality of sweet peppers more than that of controlled fruits at 25 and 10°C storage temperature (Rao *et al.,* 2011).

Packaging

Storage in plastic box liners extends the self-life of green tomatoes (Haeseler *et al.,* 1966). Saguy and Mannheim (1975) investigated the beneficial effect of sealing tomatoes in plastic bags to create modified atmosphere. Saguy and Manneim (1975) and Wiber (1977) found that PCV Klarpac packaging extended the shelf life from 7 to 21 days. Wrapping of vegetables in polyethylene film extended their self-life by 1-15 times (Golias, 1977).

Perforated polythene bags (0.002½ thick) were considered better for prolonging the shelf life of tomatoes at varying temperature and humidity (Collazos *et al.,* 1984). Perforated plastic bags having ten vents were ranked most effective in prolonging shelf life of okra (Tamura and Minamide, 1984). Polyethylene packaging was most effective in reducing moisture loss from tomato fruits (Lester and Bruton, 1986). Magee (1987) stored kale for 21 days or longer in a Styrofoam container under refrigerated conditions. The modified atmosphere packaging could be beneficial to store the fruits and extend the shelf life (Varquaux *et al.,* 2002).

Miscellaneous

Shelf life of tomato fruits is also closely related with the change in various biochemicals constitutes during storage (Okubo and Maezawa, 1967; Hall, 1968; Kaur *et al.,* 1971; Favorov, 1972; Ogura *et al.,* 1975; Nandpuri *et al.,* 1978; Adsule *et al.,* 1979; Bhatnagar *et al.,* 1980).

CONCLUSION

It can be concluded that individually shrink-wrapped cucumber can be stored well up to 15 days at 12±1°C temperature and 90-95% relative humidity and for 5 days under ambient room conditions (29-33°C temperature and 65-70% relative humidity) with maximum retention of green colour, no spoilage, minimum weight and firmness loss and very good sensory quality attributes, whereas, unwrapped fruits can be stored well up to 9 days at 12±1°C temperature and 90-95% relative humidity and for only 2 days under ambient room conditions with maximum retention of physico-chemical quality attributes.

Conflict of interest

All authors declare that they have no conflict of interest.

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