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Storage Behavior of Fresh Fruits and Vegetables: A Review

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Introduction

The majority of fresh fruit and vegetable kinds may be produced in India because to its varied environment (Mansuri, 2017). According to the National Horticulture Database, 2019-20 estimates put the nation's fruit and vegetable production at 97.97 million tones and 183.17 million tones, respectively. A total of 92.3% of the production of horticulture is made up of fruits and vegetables. Even though there is a lot of food produced, only 2.1% of it is processed by businesses; the rest is either eaten right away or preserved for use in fresh form at a later time.

Figure 1 Causes of post-harvest losses in fruits and vegetables

Effectively utilizing the processing and export potential of fresh fruits and vegetables requires monitoring their storage behavior, so it's critical to analyses and comprehend the changes in nutrient content that result from postharvest handling of fruits and vegetables. Crop postharvest life is greatly influenced by the quality of the crop during harvest. The harvest ripeness and cultivar or variety, as well as the temperature and soil in which it was produced, pesticides that

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were used on the crop, and its water status, are all elements that impact the quality of the produce (Kader *et al*., 2012). Many of these elements can also interact with time, such as the timing of applying fertilizers or irrigation or the state of the weather.

Fruits and vegetables are excellent sources of vitamins and minerals that the body needs to function properly and build disease resistance (Table 1). For a variety of reasons, people store their fruits and vegetables. It is a component of orderly marketing, where the storage time is often brief to enable a producer or group of growers to accumulate enough fruit to ship to market (Dodson *et al*., 2016). During the time that it is being sold, it could be kept in wholesale marketplaces. Additionally, it may be kept in storage to wait for a price increase when the price is low at the moment. To lengthen the time that certain crops are available, they are kept in storage for extended periods of time.

Table 1 Vitamin and mineral content in common fruits and vegetables

Fruit/ Vegetable	**Vitamin content (mg)**				**Vitamin content (mg/100g)**				
	Vitamin A	Vitamin B complex	Vitamin C	Folic acid	**Ca**	**Iron**	**Mg**	**P**	**K**
Apricots	0.2	0.17	5000	0.004	20	0.8	12	-	283
Apple	0.005	0.08	5000	0.003	3	0.1	3	9.5	129
Banana	0.008	0.43	10.000	0.016	5	0.4	29	27	358
Grapes	0.005	0.12	3000	0.001	14	0.3	8	9	203
Kiwi	0.007	0.15	70.000	0.023	29	0.3	13	71	326
Lychee	0.002	0.17	23.000	-	5	0.3	18	-	182
Mango	0.053	0.11	23.000	0.023	14	0.2	11	23	143
Orange	0.012	0.16	49.000	0.018	37	0.1	10	18	154
Pineapple	-	0.18	25.000	0.004	12	0.4	17	-	180
Pumpkin	0.025	0.12	16.000	0.007	20	0.5	10	-	350

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Strawberry	0.002	0.11	60.000	0.065	15	0.5	13	27	183
Tomato	0.088	0.15	15.000	0.008	32	0.5	23	63	397
Water melon	0.045	0.16	6000	0.001	10	0.4	11	26	158
Broccoli	0.2	0.25	110.000	-	100	1.5	18	46	340
Brussels sprouts	0.031	0.45	66.000	0.087	30	0.6	20	-	382
Cabbage	0.01	0.45	80.000	0.069	75	1	12	36	300
Cauliflower	0.001	0.32	80.000	0.044	15	0.5	12	20	250
Carrot	0.6	0.05	10.00	0.016	29	0.4	7	23	218
Cucumber	0.034	0.06	10.000	0.005	14	0.2	10	1.4	124
Onion	0.001	0.21	10.000	0.01	30	0.5	9	23	200
Peas	0.3	0.16	1000	0.022	29	1	13	187	126
Potato	-	0.46	14.000	0.023	6	0.5	22	78	450
Radish	0.002	0.16	20.000	0.028	30	2	11	-	250
Spinach	0.24	0.21	25.000	0.1	30	2.4	6	7	200

Source- Slavin and Lloyd, 2012; Marles, 2017

Perishable nature of fruits and vegetables.

Due to their live tissue and extreme perishability, fruits and vegetables are vulnerable to respiration, water loss, and cell softening throughout the postharvest system. The high moisture content of horticulture products makes them particularly perishable by accelerating the reactive response (Dodson et al., 2016). According to the outrageous Post Harvest Management (PHM) (XI Planning Commission), there has been a 35–40% loss in fruits and vegetables. Lack of adequate storage facilities for fruits and vegetables after harvest results in a decrease in the amount of produce that reaches the market, which has an immediate effect on the distribution and consumption of the necessary amount for a sound lifestyle (Boyer and McKinney, 2013).

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As a result of harvesting and various post-harvest handling procedures including packaging, shipping, and storage, they are easily bruised or hurt due to their fragile nature. Decreased post-harvest loss of fruits and vegetables is therefore a supplementary strategy for raising output. If post-harvest loss is significantly decreased, it may not be required to significantly increase output of fruits and vegetables in order to meet the rising demand.

Purpose of Storage

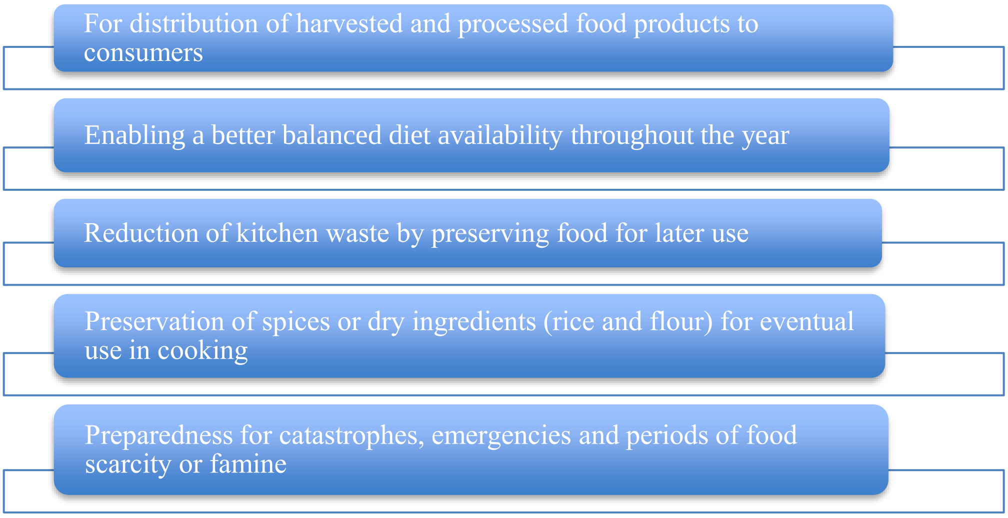

Figure 2 Purpose of storage of fruits and vegetables

Post-Harvest Losses Caused by Certain Factors

In general, a wide range of variables affect post-harvest losses of fruits and vegetables. Losses resulting from physical, physiological, mechanical, and sanitary circumstances are among these variables. Fruits and vegetables are recognized for having a limited shelf life and for having high levels of metabolic activity (Paltrinieri, 2019). These variables cause a significant percentage of the food to be lost between harvest and eating. Post-harvest loss of fruits and vegetables is also a result of other causes, including insect and mite damage, infections brought on by non-infectious pathogens, and pathological rots. The pathological rots, which are the most devastating among the causes, are followed by mechanical harm. The perishables suffer severe damage from pathological rots in addition to mechanical harm. Damage is also significantly influenced by environmental conditions such as temperature, relative humidity, and oxygen balance, particularly during storage. Additionally, environmental factors like temperature and humidity make fruits and vegetables vulnerable to pathological assaults. However, physiological and biochemical harm are both intimately tied to the loss of fruits and vegetables. Therefore, both main and secondary causes of post-harvest loss of fruits and

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vegetables may be investigated. After harvest, the quality of fresh vegetables typically declines. The respiratory activity that persists after harvest may be to blame for the decline in quality. Due to the rising demand for fresh fruits and vegetables as a result of increased consumption, several enterprises are using various techniques to raise the standard of fresh product. To preserve or decrease the post-harvest losses of fresh commodities, a number of techniques are being applied, including temperature management, the use of effective packing materials, product pre-treatment, and the use of fruits with an initial excellent quality (Paltrinieri, 2019).

Table 2 Recommended storage temperature and shelf- life of common fruits

Storage location	Fruits	Shelf life
Refrigerator (set at 5°C or lower)	Apples	>7 days
	Apricots	2-3 days
	Cherries	1-2 days
	Citrus fruits	1-2 weeks
	Cut fruits	2-4 days
	Grapes	3-4 days
	Mango	1 week
	Strawberries	1-2 days
Ripen, then store in refrigerator	Avocados	3-5 days
	Kiwifruit	3-4 days
	Nectarines	3-4 days
	Peaches	3-4 days
	Pears	3-4 days
	Plums	3-4 days

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Store out of direct sunlight and at room temperature	Apples	<7 days
	Banana	Until ripe
	Citrus fruits	10 days
	Mango	3-5 days
	Melons	1-2 days
	Pineapples	5-7 days

(Kader et al. 2012)

Table 3 Recommended storage temperature and shelf- life of common vegetables

Storage location	Vegetables, herbs, spices	Shelf life
Refrigerator	Green onions	1-2 weeks
(set at 5°C or lower)	Asparagus	3-4 days
	Beets	7-10 days
	Broccoli	3-5 days
	Lettuce	1 week
	Cabbage	1-2 weeks
	Beans	3-5 days
	Carrots	3 weeks
	Mushrooms	2 days
	Cauliflower	3-5 days
	Peas	3-5 days
	Cucumbers	4-5 days

	Radishes Brinjal Ginger Summer squash Sweet corn	10-14 days 3-4 days 1-2 weeks 4-5 days 1-2 days
Store out of direct sunlight and at room temperature	Dry onions Garlic Potatoes Pumpkins Tomatoes Sweet potatoes Winter squash	2-4 weeks 1 month 1-2 months 2-3 months Until ripe 2-3 weeks 1 week

Physiology of fruits and vegetables after harvest

All the activities and procedures that take place in the fruits after harvest are referred to as postharvest physiology. It discusses the variations that take place in the produce once they are separated from the plant, how they are sped up or regulated during postharvest handling, and how they affect the final fruit quality throughout storage, distribution, and processing. Fresh produce has a very perishable nature and is a living thing. The most frequent sign of an organism's metabolic activity, despite numerous variations in color, content, and texture, is rate of respiration (Yahaya and Mardiyya, 2019). Fruit ripening involves a number of physical, physiological, and biochemical changes, including both anabolic and catabolic processes.

Respiration

The breakdown of stored organic resources (carbohydrates, proteins, and lipids) into simple byproducts during respiration results in the release of energy. This process uses oxygen (O_2) and generates carbon dioxide (CO_2). Additionally, energy is released during this chemical

reaction, which may be employed for a variety of biological procedures. The following diagram illustrates the reaction: 6 O2 and C6H12O6 result in 6 CO2, 6 H2O, and 6 energy.
As the stores that supply energy to support the fruit or vegetable metabolism are depleted and deterioration occurs in, the loss of stored food reserves in the commodity during respiration entails the progressive hastening of senescence. For the customer, this eventually results in decreased food value (energy value), loss of flavour quality, particularly sweetness, and loss of salable dry weight, which is crucial for commodities going through dehydration in particular (Yahaya and Mardiyya, 2019).

Each product has a different respiration rate. The speed of chemical reactions is determined by a product's respiration rate. The pace at which glucose is converted and the availability of nutrients are decreased increases with respiration rate. Therefore, fruit and vegetable storage that is effective aims to keep respiration rates as low as feasible while protecting the food. Vital heat, or energy released as heat, has an impact on postharvest technological decisions, including predictions of refrigeration and ventilation needs.

Table 4 Classification of fruits and vegetables according to their respiration rate

Class	Range at 5°C (mg CO_2 kg^{-1} hr^{-1})	Commodities
Very low	< 5	Dates, Dried fruit and vegetables, Nuts, *etc.*
Low	5 - 10	Apple, Beet, Celery, Citrus, Garlic, Grapes, Kiwi, Onion, Papaya, Pineapple, Potato, Sweet Potato, Watermelon *etc.*
Moderate	10 - 20	Apricot, Banana, Cabbage, Carrot, Cherry, Fig, Lettuce, Mango, Peach, Pear, Plum, Potato (immature), Radish (topped), Tomato, Summer squash
High	20 - 40	Avocado, Strawberry, Carrot (with tops), Cauliflower, Leeks, Lettuce (Leaf), Radish (with tops), Raspberry
Very high	40 - 60	Artichoke, Broccoli, Brussels sprouts, Green Onion, Okra
Extremely high	> 60	Asparagus, Parsley, Peas, Spinach

Production of Ethylene

All tissues of higher plants and some microorganisms naturally produce ethylene (C2H4), the most basic organic compound that affects a plant's physiological processes. Acting as a plant hormone, ethylene controls many aspects of growth, development, and senescence and is physiologically active in trace amounts (less than 0.1 ppm). It also has a significant impact on how plant organs abscess (Paltrinieri, 2019). The amino acid methionine is transformed to S-adenosylmethionine (SAM), which is the precursor of l-amino cyclopropane-l-carboxylic acid (ACC). C2H+ ACC synthase is the primary enzyme that regulates ethylene production by converting SAM to ACC. ACC oxidase facilitates the conversion of ACC into ethylene. The environmental variables, such as temperature, oxygen and carbon dioxide concentrations, and genetic factors have an impact on the synthesis and activity of ACC synthase and ACC oxidase.

Compositional Changes

Many pigment changes occur as a product grows and matures on the plant; some may persist after harvest and may be desirable or unpleasant. For fruits but not for vegetables, losing chlorophyll (the green color) is a desirable change. Fruits like apricots, peaches, and citrus are particularly desired because they develop carotenoids, which are the yellow and orange colours. A particular carotenoid (lycopene) is responsible for the red color development in tomatoes and pink grapefruit; beta-carotene is a provitamin A and is thus significant for nutritional quality. Fruits like red-fleshed oranges, cherries, strawberries, cane berries, and apples (red varieties) are examples of foods where the development of anthocyanins (red and blue colors) is beneficial. Compared to carotenoids, these water-soluble pigments are substantially less stable (Yahaya and Mardiyya, 2019). Browning of tissue, which is unfavorable for aesthetic quality, may occur as a result of changes in anthocyanins and other phenolic chemicals. On the other hand, these ingredients help the product's overall antioxidant capacity, which is good for people's health.

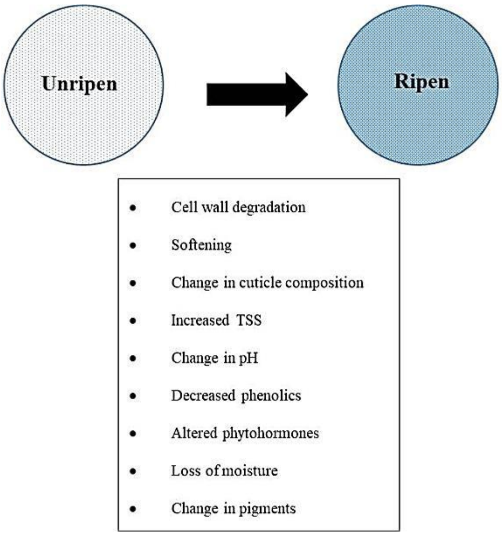

Figure 3 Compositional changes during ripening

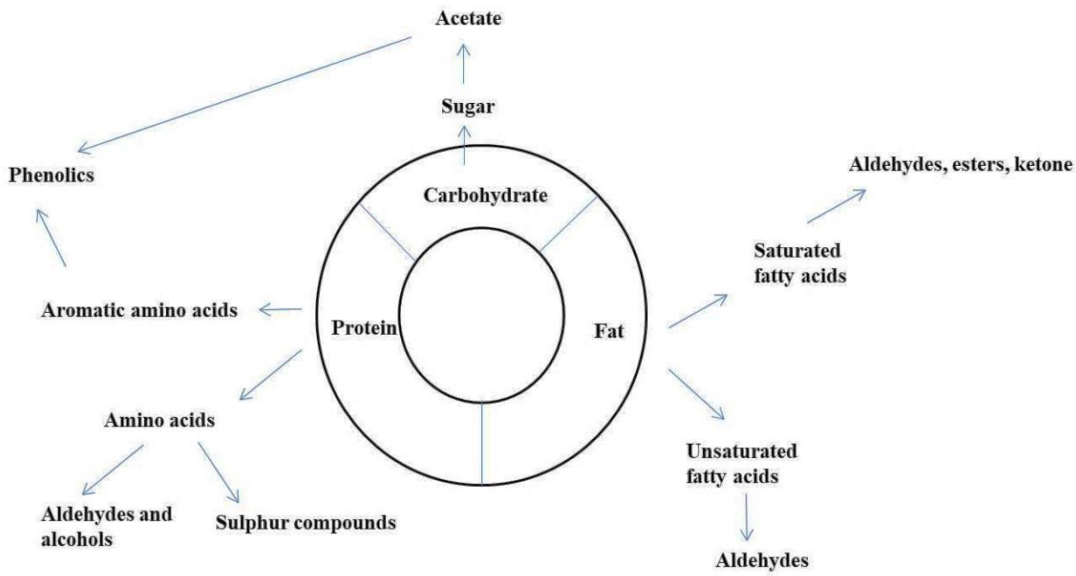

Figure 4 Degradation of chemical constituents

Undesirable development and growth during storage

Potatoes, onions, garlic, and other root crops that are sprouted have a significantly lower nutritional value and deteriorate more quickly (Figure 5). Onion and root crop rooting is also not ideal. After harvest, asparagus spears continue to develop, elongating and curving (if held horizontally), which is associated by a rise in roughness and a fall in flavor (Hayatu, 2000). Cut gladiolus and snapdragon flowers kept horizontally show similar geotropic reactions. Fruits like tomatoes, peppers, and lemons should not have seed germination take place.

Figure 5 Sprouting of potato and onion reduces their food value

Exhaled Gases or Water Loss

Water loss is a major contributor to degradation since it causes losses in nutritional value, appearance (shrivelling and wilting), textural quality (softening, flaccidity, limpness, loss of crispness and juiciness), and direct quantitative losses (loss of salable weight). The management of water loss is controlled by the dermal system of the commodity (outer protective coatings). The cuticle, epidermal cells, stomata, lenticels, and trichomes are all part of it. According to (Hayatu (2000), the cuticle is made up of surface waxes, cut in embedded in wax, and a layer of combinations of these three substances. The cuticle's structure, chemical makeup, and thickness vary substantially amongst commodities and between phases of a particular commodity's growth. Anatomical and morphological traits, the surface-to-volume ratio, surface injuries, and the maturity stage are examples of internal, or commodity, factors that affect transpiration rate. External, or environmental, factors include temperature, relative humidity [RH], air movement, and atmospheric pressure. Transpiration is a physical process that may be managed by treating the commodity (with waxes and other surface coatings or wrapping in plastic films, for example) or by modifying the environment (keeping the relative humidity high and regulating air flow, for example).

Mechanical Damage

Careless handling during harvesting, packaging, shipping, storage, etc. can result in mechanical damage to fruits and vegetables, as can some insects and birds (Alao, 2000; Yahaya, 2005). In many circumstances, mechanical damage to fruits and vegetables, such as bruising and cracking, makes them more vulnerable to organism assault and accelerates the rate of water loss and gas exchange. Many times, albeit frequently imperceptible, the mechanical damage done to fruits and vegetables as a consequence of pressure pushed during transportation results

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in rupturing of interior tissues and cells. During the normal ageing process, such product degrades more quickly (Hayatu, 2000). If suitable picking and harvesting techniques are not used, it is extremely likely that fruits and vegetables will sustain the most mechanical damage throughout the process. Therefore, due to improper techniques of digging them out, a significant amount of tuber and root crops, such as potato, sweet potato, etc., become damaged and unmarketable. Fruits like apples have a fragile outer shell that is very vulnerable to mechanical harm. As a result, decaying pathological attacks are more likely to occur on damaged fruits (Hayatu, 2000; Yahaya, 2005). Fruits gradually lose quality, resulting in lower market values for the commodity. The loss of the commodity is increased by processing procedures such spillage, abrasion, excessive polishing, peeling, and cutting. Mechanical failure is also brought on by puncturing of the containers and flawed seals (Alao, 2000; Yahaya, 2005). Biological Activity Vegetables and fruits can also be harmed by microbial invasion. The principal microorganisms that induce spoiling include fungus, bacteria, yeast, and molds. However, fungus and bacteria-caused illnesses are responsible for a sizeable share of the losses of fruits and vegetables during the post-harvest period. Fruits and vegetables are quickly colonized by these organisms due to their succulent character (Elias et al., 2010). However, in addition to harming canned and processed goods, these organisms also destroy fresh fruits and vegetables. Serious post-harvest illnesses frequently strike quickly and may result in substantial degradation of the product, perhaps destroying the entire shipment (Alao, 2000; Yahaya, 2005). According to estimates, soft rot bacteria are responsible for 36% of vegetable degradation. Similar to this, fungal rot in delicate fruits may be quite damaging. Vegetables are inherently susceptible to infection from the field, water used to clean the surface, equipment contact, and storage conditions. Fungi like Alternaria, Botrytis, Diplopia, Molinia, Phomopsis, Rhizopus, Penicillium, Fusarium, etc. are the most frequent pathogens responsible for rots in fruits and vegetables. Erminia, Pseudomonas, and other bacteria inflict serious harm. High relative humidity and temperature encourage the growth of postharvest degradation microbes. While fungi often attack more acidic tissue, bacteria mostly attack fruits and vegetables with pH levels over 4.5 (Yahaya and Mardiyya, 2019).

Environmental Factors

The post-harvest loss of fruits and vegetables is significantly influenced by environmental variables such as temperature, humidity, composition, and percentage of gases under controlled atmospheric storage. The product sustains severe damage as a result of the microorganisms that thrive in the high temperatures and relative humidity. High temperatures also speed up the pace at which fruits and vegetables breathe, which causes the interior tissues to break down.

Additionally, high temperatures and high relative humidity speed up the deterioration of fruits and vegetables, whereas low temperatures, especially below 5 °C, slow down the pace of microbial assault on many crops. Tropical and subtropical fruits and vegetables seem to be the most commonly affected by chilling damage, which is caused by low but not freezing temperatures. The signs of chilling injury, however, could not be noticeable when the fruits and vegetables are kept at chilling temperatures; instead, they might not be noticeable until the fruits and vegetables are brought to room temperature (37 °C). Relative Humidity (RH) has a similar impact in the post-harvest environment to temperature. The ability of air to store moisture fluctuates with temperature, making the effects of temperature and relative humidity mostly equivalent and connected. The aeration in storage containers or in retail spaces affects RH and, in turn, indirectly influences the onset of illness. For many fruits and vegetables, relative humidity close to saturation causes deterioration, which is strongly tied to the effects of temperature. only when the temperature gets close to 0 °C do decay losses decrease. However, microorganisms cannot develop on the surface of fruits and vegetables when the relative humidity is below 90% (Danladi, 2000). As a result, each fruit and vegetable has a different processing heat need. Physical harm results from tissue breakdown owing to excessive or inadequate heat supply during processing, incorrect cold storage temperature, and undesirable gaseous composition of controlled atmosphere during storage (Cho, 2008).

Post-harvest Management

Temperature management practices

The most crucial instrument for extending the shelf life of fresh horticulture goods after harvesting the crop is temperature control. With one of the cooling techniques such as hydro-cooling, in-package ice, top icing, evaporative cooling, room cooling, forced air cooling, serpentine forced air cooling, vacuum cooling or hydro-vacuum cooling, the field heat must be quickly removed in order to regulate temperatures. Facilities for cold storage should be well-built and furnished. These have to have sturdy floors, suitable loading and unloading doors, decent construction, insulation, and a vapour barrier. It's crucial to distribute chilled air efficiently. A suitable amount of chilled coil surface must be guaranteed, as well as properly placed controls. The storage space should be sufficient to meet the anticipated requirements for suitable production of a stack.

Control of the relative humidity

The regulation of water losses, the development of decay, the occurrence of various physiological problems, and the uniformity of ripening all depend on the relative humidity being at the proper level. With the exception of dry onions and pumpkins, which should be kept at 70–75% relative humidity, most fruits should be kept at 85–95% relative humidity, vegetables at 95–98%, and certain root vegetables at 95–100%. There are a variety of suggested techniques for controlling relative humidity (Figure 6).

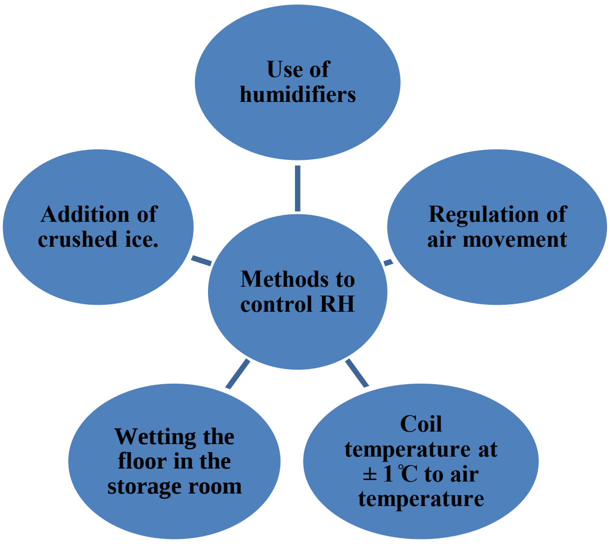

Figure 6 Recommended methods to control Relative humidity (RH)

Controlled atmosphere

Controlled atmosphere refers to the addition or removal of gases to create an environment that is distinct from the air's 79% nitrogen, 21% oxygen, and traces of carbon dioxide composition that surrounds the commodity. Typically, this entails raising carbon dioxide levels while lowering oxygen levels in a completely enclosed space. The utilization of a controlled environment should only be viewed as an addition to correct temperature and humidity protocols. For a select few crops, controlled environment is utilized to increase shelf life, eliminate illnesses such chilling injuries, reduce infections, and control some insects.

Supplemental procedures

For use on horticultural commodities, a variety of treatments have been suggested (Yahaya and Mardiyya, 2019). These include the curing of specific crops' roots, tubers, and bulbs, sifting to get rid of bad products, and waxing or other surface treatments. Proper cultural operations, harvesting, transportation, storage, and pre- and post-harvest treatments can decrease the amount of post-harvest loss in fruits and vegetables.

Cultural Operations

A good set of cultural operations is desired to guarantee proper growth and extend the shelf life of fruits and vegetables. To prevent root forking, it is important to prepare the soil for perishables to a fine tilth of porous nature, especially for vegetables like root crops like carrot and radish. It is crucial to maintain constant watering during the growth stage of fruits, vegetables, bulbs, and tubers (Cho, 2008). Onions' outer scales fracture and carrot, radish, and tomato skins crack due to insufficient water availability. Tomatoes and watermelons, particularly those that are late in maturing after a protracted dry season, might break when there is excessive or intense watering. These perishables have a short shelf life and little visual appeal. Three weeks before harvest, irrigation should be halted to promote improved keeping quality for onions and garlic (Opadokun, 1987; Cho, 2008). When nitrogenous fertilizers are applied heavily, fruits and vegetables often experience faster tissue degradation; nevertheless, a regular potassium fertilizer supply increases the quality of fruits and vegetables' storage life (Danladi, 2000). Physiological problems like greening of the almond and heart rot of the cabbage are caused by molybdenum and boron deficiencies in several fruits and vegetables, including cabbage and almond. Such fruits often have a relatively short shelf life and may noticeably deteriorate in quality. Therefore, it is advised to meet the optimal demand for these micronutrients at the appropriate moment. The provision of water, nutrients, and sunlight in orchards and vegetable fields was enhanced, as was the natural growth of fruits and vegetables. Fruit trees need adequate sunshine to develop their color and size, thus careful training, pruning, and removal of dead or diseased branches ensure that the trees receive this light.

Fieldwork and Harvesting

According to (Hayatu 2000), consumers indispensably choose fresh, adequately ripened, insect- and disease-free fruits and vegetables with a pleasing look. Vegetables should thus be harvested as soon as they reach their ideal and maximum size and are still delicate. While over-maturing causes pithiness and sponginess in root crops like carrot and radish, their harvest should not be postponed. Onion and garlic have a shorter shelf life because of the delayed harvest. But because of the delayed harvest, practically all crops are negatively impacted. Fruits ripen in trees more preferentially when they are red. The majority of fruits are collected at the right point of maturity but far before they have fully ripened, and they are then artificially ripened to meet market needs.

Fruit and vegetable picking is best done during the cooler sections of the day, and the product should be moved to the packing shade as soon as possible after harvest. However, picking during the hottest part of the day typically increases the produce's field temperature and speeds up withering and shriveling. Vegetables shouldn't be harvested during or right after a rainstorm since it fosters circumstances that encourage the growth of microbes. Manual fruit harvesting using a spade, knife, and clippers is still widespread in underdeveloped nations like India. Therefore, it is important to take precautions to prevent mechanical harm when picking vegetables. However, the usage of motorized diggers like the potato digger is advised for the large-scale harvesting of tuber crops like potatoes or the subterranean vegetables. Many harvesting aids have been designed for fruit picking that prevent the usage of ladders in favour of movable platforms, which puts the picker in the proper harvesting posture. However, manual fruit picking is quite difficult due to the big size of fruit trees, which causes more harm to the collected fruits. However, for high density fruits, hand picking is quicker and more effective (Alao, 2000). Produce collecting containers should be made such that they do not interfere with field activities in order to ensure excellent quality. Additionally, a high level of field cleanliness should be maintained. Produce that is unsuitable for the market should also be sorted. since a result, it is best to avoid letting fruits and vegetables sit on the ground for a lengthy period of time since this can become an infection source. Elias et al. (2010) recommend that all disease-infected items be thoroughly cleaned or destroyed.

Grading and Washing

Before being transported, fruits and vegetables require careful treatment. Produce like root and tuber crops are frequently cleaned to get rid of the dirt that has adhered to them. Before being packaged, fruits and vegetables that have been treated with toxic chemicals need to be thoroughly washed. Fruits and vegetables look better after being washed in clean water because it prevents wilting (Yahaya and Mardiyya, 2019). Therefore, grading is a crucial element that shouldn't be overlooked in the development of strong and efficient marketing tactics. Therefore, the fruit is separated into various grades and appealing forms in order to command a high price. Fruits and vegetables may occasionally be ranked according to their size, shape, and colour. whereas veggies and fruits like In addition to maturity, ripeness in the mango and tomato fruits, and general look, okra, cucumbers, and ridge gourds can also be assessed (Yahaya and Mardiyya, 2019).

Packaging

Good packaging has been shown to significantly reduce fresh fruit and vegetable waste. The freshness, succulence, and flavour of fruits and vegetables can be preserved for a longer period

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of time through good and effective packaging, as well as protection against mechanical damage, undesirable physiological changes, and pathological deterioration during storage, transportation, and marketing (Dodson et al., 2016). Many developing nations, like India, employ a variety of containers, including wooden boxes, corrugated fiber board boxes, jute bags, bamboo baskets, and clay pots. Fruits and vegetables may be packaged inexpensively with polythene films, paper board boxes coated with polyethylene, and other materials in order to extend their shelf life useful and significant. Additionally, plastic sheets shield the veggies from dry air well.

To stop the physiological breakdown of the product, some level of ventilation must be given in every package. There may be the formation of an off-flavor if there is an impermeability to carbon dioxide (CO2), oxygen (02), and water vapor inside the packaging. Fruits should be packaged carefully to prevent bruising and damage during shipment (Dodson et al., 2016). Between the layers of fruits, dried grasses or paddy straw can be utilized successfully for this purpose. However, packaging is a very inventive technology, and better methods and materials are always being developed, both for processed goods and fresh produce. Packages can be flexible or rigid, and each kind has certain benefits and restrictions.

Pre-Cooling

The fresh product is kept from prematurely ripening and ageing by pre-cooling. Therefore, it's critical to remove field heat from the veggies that have been gathered, especially if it's a hot day for harvesting. Therefore, cooling preserves the fresh produce's weight, giving an extra benefit over the prolonged storage time. Pre-cooling before storage can lower physiological weight loss from 6 to 2.9 percent in fruits like tomatoes. While effective cooling can lower storage losses in veggies that decay rapidly. The necessity for pre-cooling might occasionally depend on ripening stages and the heat of the field.

As a result, produce may be effectively pre-cooled by (1) being placed in refrigerated trucks with forced humidified air circulation, (2) having ice placed in packages, (3) having ice placed in water and then passing through a spray of cool water and (4) having food pass via vacuum cooling. While hydro-cooling may be performed by flooding the field, spraying or immersing is a quicker and more effective control approach since water is a suitable substance for transferring the heat from the product to the cooling medium. In order to suppress fungal development, a small quantity of the appropriate fungicide can also be added to the water used for hydro-cooling. In order to suppress fungal development, a small quantity of the appropriate fungicide can also be added to the water used for hydro-cooling. It is common practice to chill salad and other leafy vegetables by reducing the air pressure in a hermetically sealed room until the lowered vaporizing point of water produced at low pressure in the cooling chamber cools the product. Vacuum cooling may be used to field pack and quickly and evenly chill fruits and vegetables like grapes that are often very difficult to cool with water or air (Mansuri, 2017).

Transportation

Transportation Perishable goods are now at the most dangerous stage of transportation in India. The product is delivered to our local marketplaces in India either by tram, bus, motorbike or tricycle. Rails and trucks are the principal modes of long-distance transportation, but they are also quite expensive. However, the fundamental justification for choosing road transport over rail or truck is that it has a shorter transit time. Quick delivery of fruits and vegetables is essential for successful marketing and the preservation of high quality. The majority of losses that happen during transit are caused by mechanical and physical damage as well as uncontrolled circumstances, namely temperature and humidity. Therefore, suitable long-distance infrastructure, particularly by trains, should be constructed to assure reduced losses of the goods. Additionally, the fruit must be correctly stacked and packaged in containers that are sanitary and well-ventilated. It's crucial to regulate the relative humidity and refrigeration in containers. Additionally, it is advised to maintain decent roads for smooth movement with little to no vibration and shocks. Therefore, a solid and effective transportation infrastructure may significantly help to stabilize the price fluctuations of various commodities accessible in the country's numerous marketplaces as well as to reduce the post-harvest loss of horticultural products.

Reducing moisture loss

One of the main benefits of consumer packaging is the avoidance of weight loss of fresh product, especially when moisture retentive films are employed, especially for leafy green vegetables and root crops. Produce that is packed has a longer shelf life than produce that is not, especially when it is sold from refrigerator display cases. According to certain reports, moisture-proof cellulose film cut tomato weight loss in half compared to unwrapped tomatoes. Compared to lettuce that isn't packaged, lettuce that is packed in polythene or polystyrene may lose less weight and last longer on the market. For the packed veggies, controlling collecting humidity is particularly crucial. To prevent fruit and vegetable losses, as well as to ensure that the market receives the produce when it is most needed and to maximize return on investment, a faultless and effective marketing strategy is required. However, compared to other agricultural goods that are more durable, marketing fresh perishables has additional challenges. The interests of producers and consumers are generally not well-served in emerging nations like India; farmers receive less compensation for their time and money spent while consumers pay more than is necessary. However, a lot of wastage or loss occurs at the height of the season when the market is overstocked with a specific vegetable or fruit.

Ionizing Radiation

The ability of ionizing radiation to eliminate harmful organisms without significantly increasing the temperature of the product is one of its most significant benefits. However, a key barrier to its use is the large initial capital requirement (Mansuri, 2017). Ionizing radiation slows the ageing process, inhibits sprouting, and extends the shelf life of perishables by pasteurizing their surfaces. It has been discovered that irradiating bananas with 25–35 cards effectively delays the start of natural ripening without degrading the fruit's quality.

Waxing

Reduced evaporation and respiration is the fundamental benefit of wax coating. Wax skin coating is another technique used to extend the shelf life of fresh food in situations when refrigerated storage facilities are unavailable or inadequate. Many fruits and vegetables, including tomatoes, okra, mangoes, and other produce, have longer shelf lives after they have been processed through water emulsified with mustard oil.

Chemical Treatment

Other than fungicides, a variety of compounds extend the shelf life of fruits and vegetables by postponing the ripening and senescence processes. After harvest, gibberellic acid treatment significantly slowed down the ripening of bananas (Elias et al. 2010). The usage of potassium per magnate as an ethylene absorber helps to keep the amount of ethylene below the critical point. It has been discovered that the maleic hydrazide is particularly efficient at hastening the ripening of several fruits. Maleic hydrazide, at 1000–2000 ppm (parts per 1 million), slows down the ripening of mangoes. Vegetables' shelf life has been proven to be increased by the use of post-harvest plant hormones. Although cytokinin has a noticeable impact, particularly on leafy vegetables, post-harvest administration of gibberellins slows down tomato ripening (Mansuri, 2017). The use of an Indole Acetic Acid (1AA) solution aids in preserving the green color of numerous vegetable pods. However, the application of 2, 4-D together with BA (M6-benzyladenine) will prevent cauliflower and several other green crops from becoming yellow.

Additionally, maleic hydrazide (MH) sprays used before to harvest prevent potato and onion sprouting during storage (Mansuri, 2017).

Dill (Sowa)

Dill, or Anethum graveolens L., is a green vegetable and a fragrant annual plant. The investigation was carried out in 2009. The study assessed the efficiency of various packing materials both with and without open pore space areas in prolonging the shelf life of dill. While HDPE with 3 pores maintains the color and scent the longest during storage, the control sample lost its green color and perfume on the fourth day. HDPE (3P) sample weight loss was just 3.5% as a percentage. 10.47 mg of total chlorophyll per 100 grammes were found in it. This study demonstrated how leafy vegetables might be kept using cutting-edge packing techniques to minimize qualitative and quantitative losses.

In-Package Desiccants' Effect

Fruits and vegetables are partially dehydrated to keep them luscious and soft, and then the moisture content is reduced using in-package desiccants. The shelf life of dried fruits and vegetables can be extended by using in-package desiccants such calcium oxide or fumed silicas to reduce the moisture content of the storage environment to 1% or lower (Elias et al., 2010).

Conclusion

Fruits and vegetables lose quality after harvest because improper harvesting, transportation, storage, and distribution methods were used. After harvest, water content, respiration rate, ethylene production, endogenous plant hormones, and external variables including microbial growth, temperature, relative humidity, and atmospheric components all affect how fresh fruits and vegetables stay. Therefore, by carefully manipulating these parameters, post-harvest loss of fruits and vegetables may be significantly decreased and their shelf life enhanced. The loss may be minimized by using crucial cultural practices, as well as cautious handling and packing. By defending them against diseases and other environmental conditions during the pre- and post-harvest stages, the application of the proper pesticides may significantly extend the amount of time that fresh food is available. also in a controlled environment Fruits and vegetables may be successfully stored at low temperatures.

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