CHAPTER–IV

SUMMARY AND CONCLUSION

Vegetables are perishable products with active metabolism during the postharvest period. Number of reports and publications in the field of postharvest physiology, technology and handling have emphasized an important role played by proper postharvest handling in increasing food availability. Most of the publications, however, have covered postharvest physiology of fruits and problems of vegetable postharvest physiology are studied much less often.

Vegetables are any plant products that are consumed fresh, raw or processed without substantial extraction. Fresh vegetables are essential components of human diet. They contain a number of nutritionally important compounds including vitamins which are indispensible for human body. Proper storage of vegetables can contribute to keep these characteristics as unchanged as possible. Therefore determining storage potential and then developing suitable techniques and then exploiting these potentials seems to be the essence of storage improvement. The knowledge of the changes that occur during harvest will therefore help to develop proper method of handling the harvest produces in order to preserve their quality as intact as possible from the time they are harvested to the time they are stored. The knowledge of physiological changes that occur during harvest is of vital importance.

Loss of turgidity is the first sign of stored vegetables which may then lead to biochemical damages. Another consequence during storage is that the superficial cells become inert sacs of nutrients which are then attacked by pathogens. Therefore in the postharvest handling of plant organs, maintenance of turgidity is of the prime concern. During harvest, followed by storage, the cells show an abrupt increase in the rate of respiration, chlorophylls are destructed and phenolic components undergo changes. During storage at lower temperature, normally the photosynthetic activity decreases rapidly with rapid increase in respiratory activity of the cells.Increased chlorophyllase activity, oxidation of phenols followed by superficial browning, polymerization of tannins, blocking of vascular channels by latex and tremendous synthesis of certain proteins, mainly enzymes, are some of the other metabolic events taking place during storage of plants.

Knowledge of various aspects of physiological changes during postharvest period led to develop modern techniques for storage of essential commodities. A number of workers have investigated storage methods for fruits and vegetables to overcome the physiological changes during the harvest periods. One of the common and easily manageable method is the storage of necessary commodities at chilling temperature.

A chilling temperature is any temperature below the criticl threshold temperature, usually above freezing, that causes injury. For most warm season vegetable crops, these threshold temperatures are around 10°C. However, the optimum temperature for any plant process is not necessarily constant. Thus a chilling temperature can be defined as any temperature that is cool enough to produce injury but not cool enough to freeze the plant.

Many vegetables, primarily those of tropical or subtropical origin, are susceptible to low temperature stress referred to as chilling injury. The sensitivity to low but non freezing temperatures poses serious postharvest problems in storage and handling. Refrigeration to slow metabolism is the most manageable way to extend storage life of perishable commodities.

The symptoms shown by the plants in the field are quite different from those shown by them during storage. Direct injury, indirect injury and secondary injury or stress are three major kinds of injuries to the plant during storage. Direct injury is the direct effect of chilling temperature on plants.

Injury due to sudden chilling, which is very rapid is called a cold shock. Membrane damage and apparent increase in cell permeability are the direct chilling injuries. Indirect injury is a gradual and maintained stress. At chilling temperature, in case of plants from tropical and subtropical climates, respiration rate may exceed the rate of photosynthesis and this may lead eventually to starvation. Starvation of non photosynthesizing plant parts may result from the inhibition of translocation by chilling temperatures. Accumulation of α - keto acids, browning (Polyphenols) and accumulation of peroxides have been reported in the peel of the fruits, around vascular tissues and in the leaf tissue respectively. Protein breakdown at low temperature without an equally rapid resynthesis has been suggested as a cause of injury due to a deficiency of certain proteins or a toxicity by the product of hydrolysis.

These are some of the major effects of chilling temperature leading to chilling injuries in plants. However, some of the plants withstand the chilling temperatures.

Chilling resistance observed in some plants is due to an ability of cells to maintain the membrane lipids in the crystalline state at chilling temperatures. A degree of unsaturation of fatty acids in the lipids has been correlated to chilling resistance. Activity of some soluble enzymes, not associated with membranes may be involved in chilling resistance mechanism.

According to the ability of the plants to withstand chilling temperature they are classified into chilling insensitive and chilling sensitive plants.

From a brief account of the literature above it is evident that most of the work is on the fruits stored at the chilling temperatures. Very few vegetables like tomato, potato cabbage, onion and lettuce are so far studied to some extent. There is almost no work on the physiology of leafy vegetables stored at chilling temperatures. Hence in the present investigation an attempt has been made to study the physiological changes imposed by chilling temperatures in two leafy vegetables, namely Amaranthus blitum L. var. oleraceae, Hooker (Tambada pokla) and Trigonella foenum-graecum L. (Fenugreek, Methi). Both these plants are very popular leafy vegetables which form a common man's diet and are rich in nutritive and medicinal values.

In the present investigation the effect of chilling temperature ($5^{\circ} \pm 2^{\circ}C$, refrigeration) during storage of these vegetables for 48 and 96 hours on moisture level, chlorophyll and carotencid contents, absorption properties of photosynthetic pigments, carbohydrate, polyphenols, soulble proteins, vitamin `c', proline and nitrate contents. The influence of chilling temperature during storage in the freeze on the activity of hydroxyperoxidases (peroxidase and catalase) and nitrate reductase in the roots and the leaves has also been investigated.

For analysis the most recent and the advanced methods and techniques were followed.

The significant finding of the investigation are as follows :

1. There was a slight increase in the moisture level of Amaranthus leaves when stored for 48 hours at chilling temperatures, when the material was covered with polyethylene. This was also observed when the plants were kept covered at the room temperature. On the other hand the leaves lost the mositure very rapidly when were stored uncovered, even at chilling temperature. Almost similar type of response was showed by the leaves when stored for 96 hours. Thus Amaranthus is able to maintain its moisture level when stored in polyethylene cover both at chilling as well as normal temperature. NaCl treatment was found to be

beneficial in this direction. The response shown by Trigonella was almost similar to that by Amaranthus. It was noted that when Trigonella roots, stem and leaves were stored with polyethylene cover at chilling temperature there was a slight increase in the moisture content. Interestingly Trigonella exhibited similar response to two days and four days storage indicating that this vegetable can be stored even up to four days without much damage to quality as compared to Amaranthus.

2. Amaranthus leaves exhibited a rapid degradation of chlorophylls at chilling temperatures even after 48 hours of storage. Covering the material with polyethylene bag, also decreased the intensity of the chlorophyll content. NaCl treatment and polyethylene cover prevented the degradation of chlorophylls during storage at chilling temperatures. This was true for 48 hours of storage. Amaranthus was found highly sensitive towards prolonged period of storage in this respect. Water stress / senescence induced by storage temperature affected chlorophyll `b' more than chlorophyll `a' in Amaranthus. Trigonella was found more resistant to chilling temperature, because it lost chlorophylls only after 96 hours of storage and that only to some extent. It was indicated that low temperature delayed the postharvest effect and both the chlorophylls in Trigonella appeared to be equally responsive to chilling temperatures.

3. Carotenoids were degraded more in _Amaranthus_ leaves when stored for 48 hours as well as 96 hours at chilling temperatures. It was more pronouncing after 96 hours of storage. This degradation was irrespective of method of storage. The observations revealed the sensitivity of _Amaranthus_ to chilling temperatures. In _Trigonella_, however, carotenoids were not much damaged during 48 hours of storage, instead a slight increase was observed in case of nontreated and treated uncovered plants.

4. Absorption spectra of photosynthetic pigments in _Amaranthus_ and _Trigonella_ exhibited almost identical pattern with two absorption peaks, one at about 430 and the other at about 660 nm in the visible light spectrum, i.e. in the blue and red regions of light. Part of absorption spectrum in these plants in the UV region, however differed considerably. 48 hours storage at chilling temperatures had a little effect on the energy absorption in both the plants. Energy absorption was markedly affected when kept in freeze uncovered for 96 hours. Salt treatment had a slight influence on the obsorption spectra of the photosynthetic pigments in both the plants.

5. _Amaranthus_ has more amount of soluble sugars in their different parts as compared to _Trigonella_. On the other hand _Trigonella_ is richer in starch. It was found that invariably there was an accumulation of soluble

sugars in different parts of *Amaranthus* and *Trigonella* plants when the duration of storage was increased to 96 hours. On the other hand there was a slight effect of storage at chilling temperature on starch content of both the vegetables. It is suggested that storage of *Amaranthus* and *Trigonella* at chilling temperatures may adversely affect the quality of vegetables.

6. *Trigonella* leaves contain more polyphenolics as compared to *Amaranthus* leaves. The polyphenol content of the *Amaranthus* leaves was remarkably reduced after 96 hours of storage at chilling temperature when stored uncovered. Storage of plant material with polyethylene cover protected polyphenolics. Salt treatment also helped to maintain the polyphenol level in the vegetables. *Trigonella* also responded similar to *Amaranthus*.

7. There was accumulation of soluble proteins after 48 hours of storage in almost all modes of storage both at chilling as well as normal temperatures. However, a decrease in soluble protein content was observed after 96 hours of storage at chilling as well as room temperatures. *Trigonella* exhibited a pronounced increase in protein content after 48 and 96 hours of storage in the roots, stem and leaves.

8. There was remarkable proline accumulation most of the times in almost all parts of *Trigonella* and *Amaranthus* plants stored for 48 and 96 hours at chilling temperatures.

9. In *Amaranthus* nitrate accumulation in leaves, stem and roots was observed during storage for 48 as well as 96 hours at chilling temperatures. This might have affected the quality of *Amaranthus* as a vegetable. On the other hand nitrate metabolism in *Trigonella* appeared to be poor. In this vegetable there was a decline in the level of nitrate in different parts as a result of storage at chilling temperatures.

10. The level of ascorbic acid (Vitamin `c') was decreased in *Amaranthus* leaves when stored at chilling temperature thus affecting the nutritive value of this vegetable. However, vitamin`c' content of *Trigonella* leaves was slightly influenced by chilling temperature during the storage for 48 hours. In this vegetable the vitamin content was adversely affected by chilling temperature when the duration of storage was increased to 96 hours.

11. Storage of *Amaranthus* for 48 and 96 hours at chilling temperature led to increase the activity of peroxidase in the roots as well as leaves. Activity of this enzyme remained elevated even after 96 hours of storage. In *Trigonella*, however, activity of the enzyme was declined during storage at chilling temperature. Salt treatment was able to maintain the activity of this enzyme at normal to some extent in *Trigonella*. *Amaranthus* seems to be rather sensitive to chilling temperatures in this regard.

12. Catalase activity was not much hampered during 48 hours of storage in the leaves of <u>Amaranthus</u> at chilling temperatures. However, 96 hours of storage led to a tremendous decline in the activity of this enzyme irrespective of method of storage. This enzyme in <u>Trigonella</u> however, appears to be sensitive to chilling temperatures during storage.

13. Nitrate reductase is more active in the roots of <u>Trigonella</u> than in <u>Amaranthus.</u> Contrary to this the leaves of <u>Amaranthus</u> are highly rich in this enzyme. Activity of this enzyme was enhanced in <u>Amaranthus</u> roots stored for 48 hours, irrespective of the method of storage. Extended period of storage caused a decrease in the activity of this enzyme. Nitrate reductase from <u>Amaranthus</u> leaves is sensitive to chilling temperatures. Nitrate reductase from <u>Trigonella</u> roots showed a behaviour similar to that in <u>Amaranthus.</u> This enzyme from the leaves of <u>Trigonella</u> seems to be sensitive to chilling temperature.

From the present study it is concluded that in between two vegetables, <u>Amaranthus</u> a C_4 plant, seems to be sensitive to chilling temperatures and cannot be stored in refrigerator for more than one or two days. <u>Trigonella,</u> basically a C_3 plant prefering lower temperatures for its normal growth, seems to be relatively resistant to chilling temperatures and can be stored up to four days, in refrigerator. The studies also indicated that storing the plants covered with polyethylene bag with or without NaCl treatment may be beneficial. However, it is certain that storage of vegetables at chilling temperature, leads to affect their quality, with respect to their nutritive and medicinal values.