STANDARDISATION OF MINIMAL PROCESSING TECHNIQUES FOR SELECTED VEGETABLES

By

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THESIS

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COLLEGE OF HORTICULTURE
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DECLARATION

I, hereby declare that this thesis entitled **"Standardisation of minimal processing techniques for selected vegetables "** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Standardisation of minimal processing techniques for selected vegetables"** is a bonafide record of research work done independently by **Miss. Shibi Varghese** under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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"The Lord is my shepherd I shall not be in want"
(Psalm: 23.1)

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Affectionately dedicated to my beloved family

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ABBREVIATIONS

cfu	–	colony forming unit
CO_2	-	Carbon di oxide
DAS	-	Days after storage
EFY	–	Elephant Foot Yam
Gy	–	Gray
KMS	-	Potassium metabisulphite
MP	–	Minimal Processing
MAP	–	Modified Atmosphere Package
PE	-	Polyethylene
PP	–	Polypropylene
PLW	–	Physiological Loss in Weight
ppm	-	parts per million

Introduction

1. INTRODUCTION

Minimally processed (MP) or fresh cut vegetables are ready to eat vegetables which include fresh, washed and chopped vegetables, ready for use and packaged in sealed polymeric films or trays. The key criteria for a vegetable or fruit product to be considered a fresh cut product is that it must consist of 100 percent usable material and that the tissue is in living, respiring, physiological state. The trade of fresh cut products started in 1980s as a solution to an emerging consumer demand for convenience and for high quality and preservative free products with the appearance of fresh products though less severely processed (Saracino, *et al.,* 1991).

Minimal processing of raw fruits and vegetables has two purposes, first to keep the produce fresh, and supply it in a convenient form, without losing its nutritional quality. Second, the product should have a shelf life sufficient enough to reach its intended consumers.

Minimally processed fruits and vegetables offer a number of advantages such as convenience, time saving and reduction in accumulation of solid waste. Minimally processed products retain their flavor, aroma and nutrition better than conventionally processed fruits and vegetables. Production of fresh cut produce particularly fresh cut vegetable segment has increased rapidly in recent years (IFPA, 2004). Since vegetables and fruits in our diet are the major source of important nutrients maximum utilization through proper fresh cut processing is highly desirable.

Benefits of minimally processed products are offset by the rapid deterioration and short shelf life of the products in the market place and the potential health hazards associated with the spoilage. Minimally processed products prepared unhygienically have a poor quality and a very short shelf life of 1-2 days. Fresh cut vegetables deteriorate faster than intact products, this is due to the wounding associated with processing, which leads to a number of physical and physiological changes affecting the shelf life and quality of the produce. Minimal processing generally increase the rate of metabolic processes that cause deterioration of fresh products. The physical changes or wounding caused by preparation, increase respiration and ethylene production and associated increase occur in rates of other biochemical reactions responsible for changes in colour, flavour, texture and nutritional quality.

Selection of appropriate cultivars, good sanitation,. pre storage treatment with antioxidants, preservatives, edible coating, irradiation, storage systems like low temperature, modified and controlled atmosphere storage can be effectively used to enhance the shelf life of minimally processed products by inhibiting metabolic activity, decay and ethylene production. Temperature maintenance is currently recognized as the most efficient factor.

In the light of the aforementioned issues the present study on "Standardisation of minimal processing techniques for selected vegetables" was undertaken with the following objectives.

1.To develop the protocol for minimal processing of selected vegetables which include

a) Identification of ideal sanitizing agents for surface decontamination of vegetables.
b) Standardisation of pre storage treatments for cut vegetables.
c) Selection of appropriate packaging materials and storage systems for fresh cut vegetables

Review of literature

2. REVIEW OF LITERATURE

Minimal processing of fruit and vegetables is a relatively new and developing part of the fresh produce industry. Growing evidence suggests that increasing dietary consumption of vegetables and fruits has long-term health benefits and may prevent or reduce the risk of some chronic diseases. Since vegetables and fruits are the important source of some nutrients, maximum utilization through proper fresh cut processing is highly desirable. The major thrust area of minimal processing of vegetables and fruits is in terms of their packaging and storage and irradiation as well as the treatments used to maintain fresh cut vegetable and fruit quality.

Research findings already reported by various workers on minimal processing of vegetables and fruits are reviewed here under.

2.1. Significance of minimal processing

Consumers increasingly demand food, which retain their natural flavor, colour and texture and contain fewer additives such as preservatives. In response to these needs, one of the most important developments in the food industry has been the development of minimal processing technologies designed to limit the use of synthetic additives.

Kader (1986) and Shewfelt (1987) described minimal processing as "handling, preparation, packaging and distribution in a fresh like state. Consumer demand for minimally processed produce has been increasing due to premium product quality, convenience, and fresh like character (Ohlson, 1994). Producing fresh cut vegetable involves cleaning, trimming, coring, slicing, shredding, washing centrifugal drying and packaging (Yildiz, 1994). Lightly processed products are also referred to as "precut, cut prepared, convenience, fresh cut and value added products". The term "minimally processed" is now used primarily in reference to products that are retained in a fresh like state following mild processing techniques such as blanching, ultra high pressure treatment, or osmotic dehydration (Tapiadedaza, *et al.*, 1996).

2.2. Physiological consequences of minimal processing.

The physiology of a minimal processed vegetable is essentially the physiology of wounded tissue (Brecht, 1995). Wounding induce signals that elicit physiological and biochemical response in both adjacent and distant tissue (Saltviet, 1997). This induced response is detrimental to the quality of fresh cut produce.

The earliest physiological response to wounding include increase in ethylene production and an enhanced rate of respiration. Wounding plant tissue makes them more susceptible to attack by plant pathogenic microorganisms and possibly more conducive to survival and growth of food poisoning microorganisms (Wells and Butterfield, 1999). Wounding can also directly compromise flavour and aroma volatile production (Morettie, *et al.*, 2002).

2.2.1. *Ethylene production*

Wounding plant tissue induces elevated ethylene production rates (Abels, *et al.*, 1992), which may accelerate deterioration and senescence in vegetative tissue. The level of ethylene has been shown in several vegetables in proportion to wounding.

Watada and Qi (1999) reported that ethylene production is enhanced when plant tissue is injured by the physical action of fresh cut processing and ethylene accumulate in packages of fresh cut products leading to undesirable effect on quality during subsequent handling. Removal of peel result in a several folds increase in ethylene production by fresh cut slices compared with the whole vegetable and fruits (Gorny *et al.*, 2000)

2.2.2. *Lipid degradation*

Extensive enzymatic degradation occurs in damaged membrane system, causing loss of lipid component and loss of compartmentation of enzymes and substrates (Muragoni, *et al.,* 1996). Wounding of plant tissue in the course of preparation of fresh minimally processed products may cause membrane lipid degradation (Zhuvang, *et al.*, 1997)

2.2.3. *Respiration*

The increase in respiration seen in wounded tissue is thought to be a consequence of elevated ethylene, which stimulates respiration and enhance breakdown of starch.

The respiration rate of minimally processed vegetables is generally from a few to over 100 percent higher than the intact produce (Varaquax and Wiley, 1994). However more extensively damaged tissue can even have greater respiration rates. Other respiration reactions accelerate softening of some tissues and the toughening of others. The breakdown of cell wall components produces soft tissues in tomato.

Minimal processing of vegetables induced stress and undesirable metabolic changes that reduced the product shelf life in relation to that of intact vegetables. The metabolic changes include increase in respiration and transpiration rates, pathological break down, synthesis of secondary compounds and membrane lipid breakdown (Lana, 2000)

2.2.4. *Discoloration*

Browning occurs when phenol and other substrates (eg: anthocyanin) are oxidized, such reactions are catalyzed by enzymes such as poly phenol oxidase (PPO) or peroxidase (Whitakar, 1995).

Browning from oxidation of compounds and yellowing from loss of chlorophyll occur in fresh vegetable and fruit as a result of the disruption of the cell, it will lead to releasing of acids and enzymes (Laurila *et al.*, 1998). Wounding stimulates phenolic compound accumulation and this will lead to browning in these commodities. Oxidative browning at the cut surface may be the limiting factor for many fresh cut vegetables.

Commodities with higher levels of phenol compounds like artichoke and potato brown easily when wounded tissue is exposed to the O_2 in air. Wounding also induces synthesis of a number of enzymes involved in the browning reaction or substrate biosynthesis (Cantose, *et al* 2000).

2.3. TREATMENTS TO EXTEND SHELF LIFE AND MAINTAIN QUALITY OF FRESH CUT VEGETABLES

Fresh cut vegetables and fruits are intended to be " ready to eat" products this implies that they will be at their peak of freshness and quality when consumed. To maintain the quality of these products at an acceptable level through there anticipated shelf life, a number of different treatments have been developed that address the negative quality changes associated with loss of fresh appearance, texture, flavor and nutrition.

The earliest studies have showed the beneficial effect of low temperature control in minimizing the microbial load, ensuring knife sharpness, application of anti browning and firming chemicals, removal of adhering surface liquid and modification of package atmosphere on the stability of various salad vegetables and fruits (Ponting *et al*, 1972, Pripeke, *et al.*, 1976,Bolin, *et al.*, 1977). The shelf life of minimally processed fruits or vegetables should be least 4 to 7 days but preferably be longer up to 21 days depending up on the market (Krishnakumar *et al.*, 2005).

2.3.1.Physical treatments

2.3.1.1 *Heat treatment*

Heat treatment was very effective in preventing browning in plant tissue with constitutively low levels of phenolic compounds (eg: lettuce and celery), it also may similarly prevent enzymatic softening of the fruit tissue.

Breadfruit was minimally processed and half of the quantity was blanched (5 seconds at 100° C) and the remaining was unblanched and stored at three temperatures regimes like 0°C, 5°C and 8°C. The study revealed that marginal changes occurred in the chemical composition of the breadfruit slices irrespective of blanching and venting over the entire storage period. Storage at 0°C resulted in chilling injury (Crane *et al.*, 1998).

Mild heat treatment (45°Cfor 1.75hours) of whole fruit prior to cutting retained greater firmness in fresh cut apple during storage for 21 days at 2°C(Kim *et al.,* 1994). When muskmelon was dipped for 1 minute in 2.5$CaCl_2$ solution at 20,40 or 60°C fresh cut firmness was improved during storage at 5°C especially with higher dip temperatures (Luna, *et el.*, 1999).

Heated water would also be useful alone or as a supplement to sanitizer treatment in reducing microbial population on fresh cut products (Delaquis, *et al.*,1999). Three log reduction in microbial population on fresh cut lettuce washed in chlorinated water at 47°C for three minutes was observed compared to one log reduction using 4°C chlorinated water (Delaquis *et al.*, 2002).

Li *et al.*, (2002) recorded a 1.7-2 log reduction of mesophilic aerobic micro flora upon treatment of fresh cut iceberg lettuce with chlorinated (20ppm) or non-chlorinated 50°C water for 90 minutes.

2.3.3.2. *Irradiation*

Food irradiation is an important application of nuclear energy for the benefit of food preservation, which can be used to extend the shelf life of fresh food and to improve microbiological safety by eliminating several pathogens from it (Ingram and Roberts, 1966). Radiation processing of food has been thoroughly studied to ensure its toxicological safety (Maxy, 1982). Irradiation delays ripening, inhibits growth and sprouting and disinfects fresh produce (Kader, 1986).

Chuanyo, *et al.*, (1993) irradiated Golden Delicious apple and found that firmness of apple irradiated at 0.3 to 0.9 K Gy was higher than that of non-irradiated apples. Irradiated apples softened at a much lower rate than non-irradiated fruit during storage.. Irradiation dose of 1KGy resulted in acceptable apple quality for marketing after 11 month storage.

Exposure of minimally processed carrots and lettuce to irradiation extended shelf life (Hagenmaier and Baker, 1997). Ionizing radiation effectively inactivate food born pathogens in various fruits and vegetables (Prakash, *et al.*, 2000, Niemira, *et al.* 2003).

Minimally processed melons were exposed to gamma irradiation (0.1,0.2,0.3,0.4 or 0.5 KGy), those irradiated with 0.1 and 0.2 KGy gave best results. Exposed to a dose of 0.4 and 0.5 KGy was not considered suitable for minimally processed melons (Vieites and Silva, 2000).

Gunes *et al.*, (2000) reported that irradiation stimulated respiration but inhibited ethylene production in apple slices from different cultivars. The result suggested that irradiation dose upto 2.4 K Gy can be used with minimum effect on respiratory physiology of tissues. Although irradiation can inactivate food born pathogens it may impact product quality if high doses are used. The major quality concern of irradiated food includes softening, tissue injury, changes in flavour (Gunes, *et al.*,.2001) and enzymatic browning (Hanotel, 1995)

Bonas *et al.*, (2003) reported that irradiation at a dose of 1 K Gy can be used to enhance microbial safety of fresh cut onions without loss in quality attributes. Although 2 and 3 K Gy of irradiation completely eliminated microflora the treatments resulted in increased loss of aroma and deterioration. Sensory quality of aerobically packaged precut vegetables were unaffected when subjected to irradiation at 1 K Gy. The low dose irradiation was able to improve the microbiological safety and stability of the product (Farkas and Saray, 2003).

In cucumber, gradual decrease in firmness was observed with increasing radiation dose, whereas the texture remained within acceptable limits upto a radiation dose of 2.5K Gy. The appearance and flavour scores of cucumber decreased with increasing radiation dose and the overall acceptability was better after radiation at 2.5 and 3.0 K Gy (Khattak. *et al.*, 2005).

2.3.3.4. *Manufacturing practices*

Other techniques, which substantially reduce damage include use of sharp knives, maintenance of stringent sanitary conditions etc. Increased injury during preparation may directly affect visual appearance and shelf life of fresh cut products

Tatsumi (1991) reported that cutting with very sharp knives resulted in clean cut surface, reduced the number of cells damaged and the appearance of white blush on carrot.

Slicing and using sharp knife increase storage life of shredded and salad cut lettuce compared to chopping and using dull knife blade (Bolin and Huxsol, 1995).

Saltveit (1997) considered that very sharp cutting tools should limit the number of injured cells while blunt cutting instrument could induce injury to cells many layers removed from the actual cut

Carrots prepared with sharp blade had reduced microbial load and little off odour development, higher cellular integrity and an extended shelf life compared to slices prepared with blunt blades (Barry-ryan, 1998)

2.3.2. Chemical treatments

2.3.2.1. Antimicrobials

2.3.2.1.1. Sanitizers

The primary purpose of chemical sanitizers is to prevent contamination of food product by maintaining low levels of microorganisms in processing environment. Bolin *et al.*, (1977) reported that the initial microbial load of lettuce influenced the storage life of the product. Besides the elimination of soil residues, plant debris, and nutrient rich cellular fluid, washing permits the reduction of the initial microbial load. The efficiency of this operation is often improved by the inclusion of antimicrobials in the wash water

Reduction of aerobic micro flora of 1.6 to 2.4 log cycle was observed for chlorine concentrations between 50 and 200 ppm and washing times between 5 and 20 minutes during washing of green salad leaves (Mazollier, 1998). Many antimicrobials are reported, but probably the most wildly used for vegetables is hypochlorite solution containing 50 to 100 ppm available chlorine (Adams, *et al.*,1989, Zhuvang,1995, Mermelstin, 1998, Izumi,1999)

Garg (1990) reported a reduction of approximately 2.7 log cycle when lettuce was dipped in ice water containing 300 ppm available chlorine in commercial fresh cut vegetable processing line.

The application of sanitizers linked to shelf life and safety of lightly processed fruits and vegetables were examined by Hurst (1995). He highlighted the role of processing, employee practices as an important area of watch; for maintaining safety standards during light processing.

Fresh cut processing of vegetables and fruits removes the natural protective barriers to microbial attack, making the moisture and nutrients of the interior tissues readily available as a medium conducive to growth of microorganisms (Brackett, 1999). Hong and Gross (2001) Gil, *et al.*, (1998) reported that surface sterilization with sodium hypochlorite is effective supplement in extending shelf life of fresh cut tomato.

According to Beuchat (2000a) peroxiacetic acid is the most commonly used sanitizer in fresh cut processing plants and is relatively tolerant of organic matter and exceptionally effective against biofilms. Other sanitizers used or proposed for the use in fresh cut plant include chlorine dioxide (ClO_2), bromine and iodine compounds, hydrogen peroxide (H_2O_2) and ozone (Beuchat 2000b).

To assure microbiological safety of minimally processed, refrigerated vegetables a disinfectant washing step was included in the process. Sodium hypochlorite was the active antimicrobial agent in the washing bath for processed cabbage, carrot, onion, and chinese cabbage (Dufkova, 2000).

Arnold, *et al.*, (2001) reported that electroplating stainless steels resisted biofilm formation better than stainless with other finishing treatments. Frank (2001) revealed that if processing equipment is not rigorously and continuously sanitized bio films can easily develop.

Rigorous sanitation of preparation areas would reduce the level of microbial contamination. Chlorine and other sanitizers are quite effective for inactivating microbes on inorganic surfaces and cutting equipments (Bacts and Tamplin, 2002). Extend of washing time did not affect the total count. However the appearance was affected by the extended contact time (Sanz, 2002). Fantuzzi and Pushman (2004) reported that the microbial population was reduced in minimally processed cabbage after sanitation for ten minutes with sodium hypochlorite at 200 mg/lit.

2.3.2.1.2. Preservatives

There are few antimicrobial chemicals that may be applied directly to fresh cut products. Chief among these are weak acids, sorbic acid or potassium sorbate (Sofa and Busta, 1993) and benzoic or sodium benzoate (Chipely, 1993). These compounds are most effective against yeast and molds but also act against many decay and human pathogenic bacteria. Other organic acids such as citric acid may also be considered as antimicrobial food additive but they act mainly to acidify the surface of fruit or vegetable tissue, thus making it inhospitable to microbial growth (Varoquax and Wiley 1994).

Dipersio, *et al.*, (2003) reported that by immersing apple slices in sodium metabisulphite (4%for ten minutes), the microbial population was reduced by 4cfu/gram. Shredded cabbage when treated with sodium metabisulphite (.1%)before storage at low temperature (5 ± 1°C) gave better storage results (Roshita, *et al.*, 2005).

2.3.2.2. Anti browning agents

Browning results from oxidation of phenolic compounds in fresh cut vegetables and fruits as a result of disruption of compartmention that occurs when cells are broken. Most chemical treatments that is applied to prevent browning contains an accidulant usually citric acid, as one component to lower the product pH and inhibit PPO activity. The methods now practiced to inhibit browning include low temperature storage, controlled atmosphere packaging and chemical treatments, which directly or indirectly reduce the activities of PPO (Laurila, *et al.,* 1998)

Browning on the cut surface when minimally processed was the most important cause of deterioration during storage and distribution (Albenzio, *et al.*, 1998 and Artes, *et al.*, 2000). Among detrimental effects, enzymatic browning most significantly impairs quality of the fresh cut produce due to the associated change in colour, flavour, aroma and texture (Hall, 1989: Huxsoll *et al.*, 1989). Cantose *et al.*, (2000) reported that increase in PPO enzyme activity cause browning.

Gonzales and Wang, (2000) reported that combination of several browning inhibitors were more effective than those applied individually. The combination 4-hexylresorcinol (0.001g/lit) + potassium sorbate (0.05g/lit) +and- acetyl cysteine (0.025g/lit) prevented browning and deterioration up to 14 days at 10°C (Gonzales and Wang 2001).

Cysteine is a thiol amino acid that also inhibits enzymatic browning. Ascorbic acid and erythrolic ascorbic acid also act as acidualnts (Beaulieu and Gorny, 2002).

Studies conducted by Romani (2004) revealed that cultivar and type of antibrowning agents play a fundamental role in avoiding browning during minimal processing and storage. They observe that a combination of 0.2% ascorbic acid + 0.2% citric acid + 0.2% $CaCl_2$ is better for preventing browning.

The fresh-cut industry currently uses antibrowning agents such as calcium ascorbate to prevent discoloration (Karaibrachimoglu, 2004)

2.3.2.2. **Firmness retention agents**

Textural changes in fresh cut vegetable and fruits are minimized at low temperature. Thus temperature management is the first step to maintain the initial fresh textural quality of these products .The postharvest application of aqueous solution of calcium salt as dips or spray have long been used to control postharvest disorders in storage and maintain tissue firmness of fresh fruits and vegetables.

Application of calcium salt to pears, strawberries, kiwifruit, peaches, and melons helps to maintain tissue firmness (Moris, *et al.*, 1985 Rosen and Kader, 1989.Agar.*et al.*, 1999; and Barrett, 2000)

Studies conducted by Gorny and Kader (2002) revealed that atmosphere alone would not effectively prevent cut surface browning or softening of fresh cut products. A post cutting dip in 2 % ascorbic acid, 1%calcium lactate and 0.5% cysteine adjusted to pH 7.0 significantly extended shelf life by inhibiting loss of slice flesh firmness and preventing cut surface browning.

Soliva, *et al.*, (2002) reported that the processing and the packaging treatments such as dipping in ascorbic acid and calcium chloride and storage under 100 percent N_2 could not effectively prevent the apple slices from softening and apple slices flesh underwent a progressive loss of firmness. Flesh firmness was maintained better by dip treatment in 1% citric acid solution and by 90.5 percent citric acid and one percent saline combined solution (Park and Lee, 2000).

2.3.2.3.4. . Edible coating

Edible coatings has been reported to prolong the shelf life and maintain quality of fresh cut vegetables and fruits (Baldwin, *et al.*, 1995). Edible coating acts as a barrier to water loss and gas exchange, thus creating internal modified atmosphere within tissue.

Incorporating the reducing agent ascorbic acid and the antimicrobials potassium sorbate and sodium benzoate into an edible coating in fresh cut apple and potato improved their effectiveness compared with aqueous dips (Baldwin, *et al.*, 1996).

Li and Barth (1998) reported that carotene retention was 15 per cent greater in edible-coated carrot. Edible coating may exert potential benefit in lightly processed onions by reducing moisture loss, lowering respiration rate, sealing in flavoring volatiles and carrying additives that retard structure degradation and microbial growth (Bladwin, *et al.*, 1999). They also opined that a combined process with modified atmosphere packaging could result in the development of new package atmosphere that may extend shelf life of salads.

2.4. PACKAGING AND STORAGE OF MINIMALLY PROCESSED PRODUCTS

The atmosphere surrounding minimally processed vegetables is extremely important to extend their shelf life and one of the most influential factors on its composition is the permeability of the film used in the packaging. Thus for a given product of known weight and storage temperature, proper film selection is essential for maintaining quality and restricting microbial growth.

Report on the use of permeable polymeric films to extend shelf life of minimally processed vegetables by means of the modification of the package atmosphere (Kader *et al.*, 1989, Carlin, 1990) have been published. The permeability of the package depend on the characteristic and temperature of the packaging material, the thickness of the material, type of permitting gas and the difference in gas concentration across it (Exama, *et al.*, 1993)

Kale and Kadavu, (2003) revealed that packages with micro perforation developed an internal atmosphere leading to a retention of product quality in respect of fresh weight and firmness, textural properties and sugar/acid ratio and thus a reduction of deterioration and prolonged shelf life.

Among all the packaging films used it was found that polypropylene (pp) could extend the shelf life of minimally processed shredded cabbage almost upto three weeks with minimum colour change, reduction in weight loss and deterioration in sensory properties and marginally low changes in other parameters. PVC cling film was the least effective packaging film (Roshita, *et al.*, 2005). They also revealed that samples in vaccum packaging showed no significant difference compared with those in non-vaccum packaging in almost all the parameters tested for all the different packaging films used.

2.4.1. Low temperature storage

Minimally processed fruits and vegetables are perishable and demonstrate fast degradation of quality when stored at inadequate temperatures as a consequence of damage caused to tissues during peeling, cutting, shredding and packaging.

Operations involved in conditioning fruits and vegetables as minimally fresh processed products generally increase its rate of deterioration and hence it is essential that all fresh cut items should be kept at the lowest temperature feasible through out the cold chain, and the range of 0°C to 5°C is strongly recommended for keeping quality and extending shelf life (Huxsoll and Bolin1989: Varaquax and Wiley 1994: Abvenainen 1996: Artes *et al.*, 1999)

Respiration rate of cut potato, carrot, sweet pepper (capsicum), radish, lettuce, celery, cabbage, chinese cabbage, button mushroom and cauliflower were determined at 10-30°C. It was observed that vegetables should be cut at temperatures of <15°C. The result of cold storage studies indicated that minimally processed vegetables transported and marketed at 5°C had low population of microorganisms for at least ten days when storage temperatures was maintained for three days but then increased rapidly (Wei, 1999)

Jaiwante and Sankat (1998) reported that minimally processed bread fruit stored at 8°C had a maximum shelf life of ten days and 13 days respectively, fruits stored at 0°C exhibited chilling injury and loss of sensory qualities. Minimally processed cactus pear fruit had longer shelf life at 4^0C (Carbo and Nobile, 2004)

2.4.2. Modified atmosphere storage

Consumer demand for fresh and convenient foods has led to the growth of modified atmosphere packaging (MAP) as a technique to improve product image. MAP has become a widely used food preservation technique in which the food is not kept under normal air but under a different gas mixture atmosphere (Handenburg, 1971).

Modified atmosphere help to maintain fresh cut quality and extend storage life by inhibiting metabolic activity, decay, browning (Gunes and Lee, 1997 Gil, *et al.*, 1998), chilling injury (Hong and Gross, 2001) and specially by inhibiting ethylene biosynthesis and action (Mathooko, 1996)

Fresh cut fruits and vegetables generally are packaged in film bags or containers, over wrapped with film, which create a modified atmosphere within the package (MAP). Gorny (2001) reported that MAP can extend shelf life of many intact and fresh cut horticultural products

Modified atmosphere packaging delays postharvest spoilage resulting in enhanced quality attributes .MAP relies on the integrity between the natural processes of respiration and gas exchange through the package (Fonseca *et al.*, 2000). The increase of CO_2 and depletion of O_2 due to respiration and regulation of the gas exchange through the polymeric film contribute to an adequate O_2 and CO_2 concentration at the equilibrium.

Artes *et al.*, (2000) reported that MAP strongly reduces water loss and chilling injuries without incidence of decay. Watkins (2000) observed that commodities vary widely in their response to elevated CO_2.

Gorny (2003) reported that MAP systems are used extensively for fresh cut fruit and vegetables products to extend shelflife by reducing water loss, respiration rate, cut surface browning and microbial growth.

Materials and Methods

3. MATERIALS AND METHODS

The present study on "Standardisation of minimal processing techniques for selected vegetables" was carried out in the Department of Processing Technology, College of Horticulture, and Radiotracer laboratory, Vellanikkara, during 2004-2006

Experimental details:

The investigation was comprised of four experiments,

1. Identification of sanitizing agent for minimally processed vegetables.
2. Standardisation of postharvest treatments for minimally processed vegetables
3. Irradiation of minimally processed vegetables
4. Standardisation of storage systems for minimally processed vegetables.

Materials:

The vegetables included in the study were collected from the local market. Fresh and wholesome vegetables of optimum maturity were used for the study. Vegetables were free from visual defects and relatively uniform size, weight and colour.

3.1. IDENTIFICATION OF A SANITIZING AGENT FOR MINIMALLY PROCESSED VEGETABLES

The effectiveness of the following sanitizing agents for surface decontaminating of whole vegetables were studied.

3.1.1. Treatments:

T0-washing with tap water

T1-washing with 5 ppm sodium hypochlorite solution

T2-washing with 10 ppm sodium hypochlorite solution

T3-washing with 20 ppm sodium hypochlorite solution

T4- washing with 30 ppm sodium hypochlorite solution

T5- washing with mild glacial acetic acid (2%)

Vegetables used for minimal processing were sanitized by immersion in different sanitizing solutions.Five hundred millilitres each of the above mentioned sanitizing solutions were taken in plastic containers. In each container 50 gram samples were placed in such a way that the whole produce were submerged in the solution for ten minutes. The samples were then transferred to a perforated vessel to drain water completely.

3.1.2. Slice preparation:

After surface sanitation vegetables were cut in to cubes or longitudinal pieces of uniform size. To avoid cross contamination during sample preparation and treatment, all knives, cutting boards and other equipments coming in contact with vegetables were sanitized by immersion for 10 minutes in 1000 ppm Sodium hypochlorite solution. Disposable gloves were worn during preparation and treatment of vegetables.

a. **Cowpea:** The blossom end and stem end were removed with a sharp knife and then cut into small pieces having 2-2.5 cm length.
b. **Brinjal:** Fruits were cut into 1 cm cube pieces after discarding proximal and distal ends.
c. **Okra:** Okra fruits were cut lengthwise into pieces having 1-2 mm thickness.
d. **Ash gourd and Pumpkin:** The sanitized vegetables were halved, peeled, cored, sliced and cut into 2 cm square cubes
e. **Elephant foot yam:** After sanitization the intact vegetables were halved, peeled, sliced and cut into 2 cm square cubes.
f. **Drumstick:** Drumstick fruits were peeled and cut longitudinally into pieces of 5 cm length.

The fresh cut vegetables were kept in paper plate and stored under ambient conditions.

3.1.3. Observations

The following observations were recorded

3.1.3.1.Shelf life

Vegetables were stored under ambient condition of temperature ($31^\circ \pm 2^\circ$ C) and relative humidity (70 – 80 %). The shelf life was calculated as number of days from treatment till the vegetables remained in marketable condition.

3.1.3.2. Visual parameters

Changes in colour, texture, and appearance of fresh cut vegetables during storage were recorded by visual method.

3.1.3.3. Physiological loss in weight (PLW %)

Weight of fresh cut vegetables were recorded before storage and subsequent reduction in weight was recorded daily as long as the vegetables remained in marketable stage. Vegetables were declared unmarketable when more than 25 percent of sample exhibited symptoms of decay, mould growth, shrinking or shriveling.

$$PLW\% = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.1.3. 4. Enumeration of total microorganisms

The quantitative assay of the microflora was carried out by serial dilution pour plate technique. Nutrient agar medium, Rose Bengal agar medium and Sabourd Dextrose agar medium were used for the enumeration of bacterial, fungal and yeast population of the fresh cut vegetables respectively (Appendix).

One gram of sample was suspended in 100ml of sterile distilled water taken in a conical flask and shaken thoroughly for 20 minutes in an orbital shaker. From this 1 ml of the supernatant was accurately pipetted out using a micropipette into a test tube containing 9 ml of sterile distilled water to get 10^{-3} dilution. This procedure was again repeated to get 10^{-6} dilution. One ml each of 10^{-6} and 10^{-3} dilution was used for enumeration of total bacterial fungal, yeast count of the sample respectively. The bacterial count was taken after two days whereas fungal and yeast count was taken four days after inoculation. The number of microorganisms per gram of sample was calculated by the formula

$$\text{No. of colony forming units (CFU) per gram of the sample} = \frac{\text{Mean number of cfu}}{\text{Quantity of the sample weight}} \times 100$$

3.2. STANDARDIZATION OF POSTHARVEST TREATMENTS FOR. MINIMALLY PROCESSED VEGETABLES.

Chemical treatments are used in minimally processed vegetables for controlling decay, reducing browning and retaining firmness. The comparative efficiency of the following treatments in extending shelf life of minimally processed products were studied.

3.2.1. Treatments

T0-Control

T1-Potassium metabisulphite (KMS) (0.1%)

T2-KMS + citric acid (0.1%)

T3-KMS + ascorbic acid (0.1%)

T4-Sodium benzoate (200ppm)

T5-Sodium benzoate + citric acid (0.1%)

T6-Sodium benzoate + ascorbic acid (0.1%)

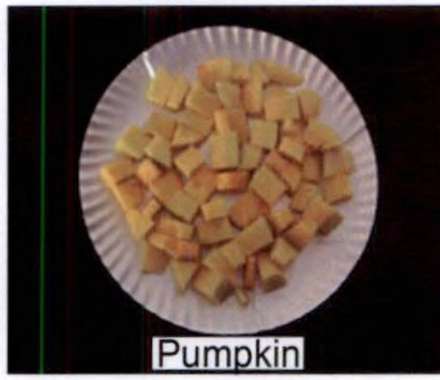
T7-Cysteine (0.2%)

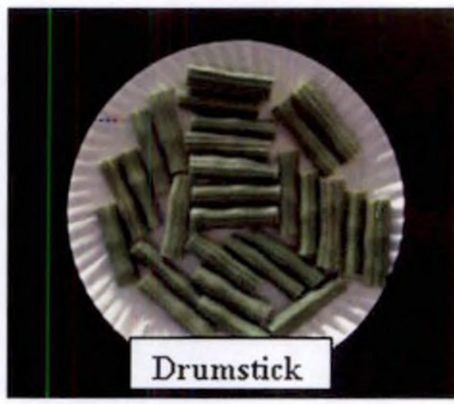
T8- Hot water treatment at 80°C for one minute

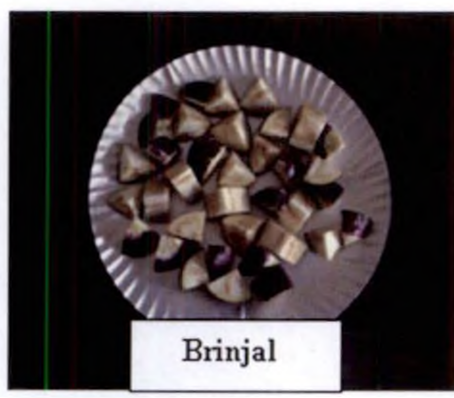
3.2.2. Materials and sample preparation

Vegetables collected from the local market were used for the study. Fresh and wholesome vegetables, uniform in size were selected for the experiment. Damaged ones were discarded. Slicing and cutting was done as in the experiment 1 with a sharp stainless steel knife. Immediately after cutting the vegetables were subjected to the above treatments. Samples were successively placed in nylon nets and dipped in the solutions taken in plastic containers in such a way that all the produce were submerged completely. After ten minutes the fresh cut vegetables were taken out and allowed to air dry for five minutes. Untreated samples were used as control. The cut vegetables were weighed, kept in paper plate and stored under ambient conditions (Plate 1).

Plate 1. Fresh cut vegetables used for the study







For hot water treatment, water was heated in a stainless steel container to a temperature of 80°C. The fresh vegetables were taken in a nylon bag and fully immersed in the water for one minute. After the treatment the samples were air dried, and kept in paper plates and stored at ambient conditions.

3.2.4. Observations:

Observations on the following parameters were recorded

3.2.4.1.Physiological loss in weight (PLW %)

PLW was calculated on the initial weight basis and expressed in percentage as in experiment 1.

3.2.4.2. Shelf life

Shelf life was calculated as in Expt 1

3.2.4.3. Microbial count

Microbial count was determined as in Expt1.

3.3. IRRADIATION OF MINIMALLY PROCESSED PRODUCTS

Feasibility of using ionizing radiation to control food borne pathogens in precut vegetables was investigated

The vegetables were cut into cubes or longitudinal pieces using a stainless steel knife.The materials used for cutting and handling was continuously sanitized using sodium hypochlorite solution to prevent cross contamination.

3.3.1. Treatments

Fifty gram each of the fresh cut vegetables were packed in PE cover hermatically sealed and subjected to gamma rays at the following doses.

T0-control (non irradiated)

T1- 25 Gy

T2-50 Gy

T3-100 Gy

T4-150 Gy

T5-200 Gy

3.3.2. Irradiation

Gamma irradiation was carried out using the gamma chamber (Model GC-900) (Plate 2) at Radio Tracer Laboratory, Vellanikkara. The materials mentioned in 3.3.1. were exposed to different doses, as per the treatments. The dose rate was 2.5 Gy min^{-1}. Non irradiated samples were used as control. After irradiation, the samples were stored at ambient temperature.

3.3.3. Observations

3.3.3.1.Shelf life

Shelf life was calculated as in experiment 1

3.3.3.2.Visual parameters

Visual attributes like colour, texture and overall appearance was observed daily during storage.

3.3.3.3.Microbial count

Microbial count was calculated as in Expt. 1

3.4. STANDARDIZATION OF STORAGE SYSTEMS FOR MINIMALLY PROCESSED PRODUCTS.

Fresh cut products were prepared under aseptic conditions. Fifty gram each of the samples were packed in different packaging materials as mentioned hereunder.

Storage study was conducted in three different conditions

3.4.1. Ambient condition

T0- Control

T1-packed in ventilated PE cover (150 gauge) (1% ventilation)

T2-packed in unventilated PE cover (150 gauge)

T3-packed in ventilated PP cover (100 gauge) (1% ventilation)

T4-packed in unventilated PP cover (100 gauge)

T5-vaccum packed in PE cover (150gauge)

T6- vacuum packed in PP cover (100gauge)

T7-packed in polystyrene tray with lid.

T8- packed in thermocol tray and wrapped with cling film.

Plate 2. Gamma Chamber

Plate 3. Vacuum Packaging Machine

T9- packed in areca sheath tray and wrapped with cling film

T10- packed in polystyrene tray and wrapped with cling film

3.4.1.1. Materials

Vegetables were washed thoroughly, peeled and cut into uniform size as in experiment 1. Vacuum packaging of cut vegetables packed in PP/PE was done in a multivac packaging machine. (Model: Quick seal 400 VSG) (Plate 3). The cut vegetables were packed in different packaging materials. For ventilated packages, the film was perforated with a puncher to get 2 mm size holes (Plate 4).

The packaged vegetables were stored under ambient conditions (31 ± 2°C).

3.4.2. Low temperature storage

Treatments T0-T9 were stored in a refrigerator maintained at a temperature of 4-8°C.

3.4.3. Low temperature + Irradiation

Minimally processed products packed in PP cover were irradiated at the following doses.

T0- Control (non irradiated)

T1- 25 Gy

T2- 50 Gy

T3-100 Gy

T4-150 Gy

T5-200 Gy

After irradiation the samples were stored in refrigerator maintained at a temperature of 8-10°C

3.4.4. Observations

Observations were recorded on the following parameters at alternative days interval

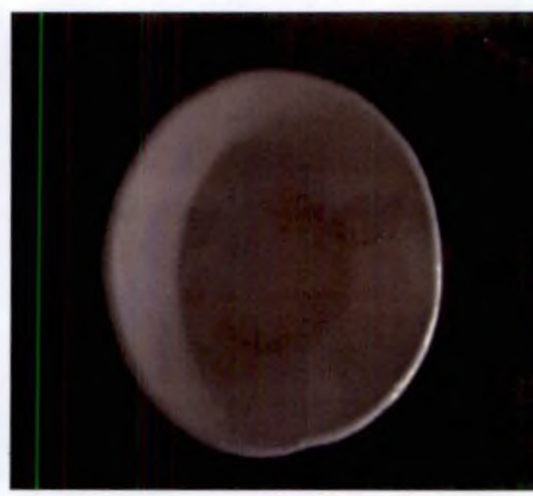
a) Shelf life
b) Change in colour firmness, flavour
c) Incidence of spoilage
d) Chilling injury
e) Microbial count

Plate 4. Different packaging materials used for the study

4a. Polystyrene tray with own lid

4b. Polystyrene tray with cling film Cover

4c.Areca sheath with cling film cover



4d.Thermocol cup with cling film Cover

4e. Polyethylene cover

4f. Polypropylene cover

f) PLW %

3.5. Development of protocol for minimal processing in fresh cut vegetables.

The best sanitizing agent, prestorage treatment, packaging material and storage system for each cut vegetable identified from the results obtained in the different experiments are as follows

3.5.1. *Sanitizing agent*:

Sodium hypochlorite 30 ppm for all vegetables

3.5.2. *Prestorage treatment*:

KMS 0.1 % + ascorbic acid 0.1% - cowpea, brinjal, and drumstick.

KMS0.1 % + citric acid 0.1% for ashgourd, EFY, pumpkin and okra.

3.5.3. *Packaging material*:

PP - cowpea, ashgourd, elephant foot yam, pumpkin and drumstick.

PE - okra and brinjal.

Protocol for minimal processing of each vegetable was developed based on this. The whole vegetables were immersed in sanitizing agents for ten minutes, then washed thoroughly and cut into pieces of uniform size as detailed in experiment 1. Prestorage dip in antimicrobial / antibrowning agents for ten minutes were given to the cut vegetables. Drained and air dried slices were then packed in PP / PE cover and kept under refrigeration. The whole operations were carried out under hygienic conditions.

3.5.4. *Observations:*

Visual attributes	:	Recorded as in experiment 1
Shelf life	:	Calculated as in experiment 1

3.6. Statistical analysis

The data was statistically analysed for difference in response to treatments by ANOVA and Duncan's Multiple Range Test to separate means. All statistical analysis was performed with STAT software.

Results

4. RESULT

4.1. IDENTIFICATION OF AN IDEAL SANITIZING AGENT FOR MINIMALLY PROCESSED VEGETABLES

The efficacy of seven treatments on surface decontamination of seven vegetables was studied under this experiment.

4.1.1 Cowpea

4.1.1.1 *Visual parameters*

After four days storage, colour was preserved best in slices dipped in sodium hypochlorite 30ppm (T4) whereas all other treatments exhibited colour change from green to light green by second day of storage. Control samples dried on the second day of storage itself. Shriveling was observed in all samples irrespective of the treatment. The intensity of shriveling was more in T0 and comparatively less in T3. Firmness of cut pieces was least in T5, followed by T6. After four days of storage overall appearance was better for samples treated with 30ppm sodium hypochlorite followed by 20 ppm sodium hypochlorite and least in T5 and T0 (samples dipped in tap water).

4.1.1.2 *Physiological loss in weight* (PLW%)

Maximum cumulative weight loss was recorded in T6 (57%) at the end of storage. The treatments, T3 and T2 showed least PLW (32.4% and 41.7% respectively). Throughout the period of storage PLW was comparatively less in T3 (Table 1).

4.1.1.3 *Shelf life*

The control treatment (washing with tap water) and T6 (washing with NaCl 1%) gave least shelf life of two days in ambient conditions. The treatment T4 gave comparatively longer shelf life of four days followed by T3 (three days).

Table.1 Effect of sanitizing agents on PLW (%) of fresh cut vegetables.

Vegetables	Days of storage	Treatments						
		T0	T1	T2	T3	T4	T5	T6
Cowpea	1st	39.2^{ab}	26.6^{de}	30.6^{cd}	23.4^{e}	36.1^{bc}	42.3^{ab}	44.2^{a}
	3rd	50.9^{a}	42.0^{b}	41.7^{b}	32.4^{c}	53.6^{a}	53.4^{a}	57.0^{a}
EFY	1st	9.9^{b}	7.4^{b}	8.4^{b}	3.2^{b}	4.4^{b}	8.0^{b}	3.7^{a}
	3rd	37.5^{bc}	32.6^{bc}	37.5^{b}	30.1^{c}	30.6^{bc}	31.9^{bc}	56.0^{a}
Ashgourd	1st	3.7^{a}	2.9^{a}	5.8^{a}	2.1^{a}	3.3^{a}	2.9^{a}	6.8^{a}
	3rd	38.1^{b}	41.5^{b}	36.8^{bc}	29.8^{c}	36.2^{bc}	51.6^{a}	57.2^{a}
Brinjal	1st	12.8^{ab}	14.0^{a}	14.8^{a}	6.0^{b}	7.7^{ab}	11.6^{ab}	13.4^{ab}
	3rd	43.6^{ab}	42.6^{b}	41.4^{b}	34.4^{c}	43.9^{ab}	47.4^{ab}	49.4^{a}
Okra	1st	53.4^{ab}	54.4^{ab}	49.8^{b}	41.4^{c}	53.0^{ab}	54.5^{ab}	58.1^{a}
	3rd	75.2^{a}	64.0^{b}	62.6^{b}	57.5^{b}	61.0^{b}	73.1^{a}	71.3^{a}
Pumpkin	1st	23.5^{b}	25.8^{ab}	32.9^{a}	22.7^{b}	29.0^{ab}	26.8^{ab}	29.9^{ab}
	3rd	73.0^{ab}	72.2^{ab}	78.9^{a}	66.6^{b}	72.5^{ab}	77.8^{a}	79.7^{a}
Drumstick	1st	13.4^{b}	10.8^{bc}	12.1^{b}	3.4^{d}	4.0^{cd}	9.8^{bcd}	31.0^{a}
	3rd	36.6^{ab}	26.9^{c}	30.0^{bc}	24.2^{c}	30.5^{bc}	29.2^{c}	43.2^{a}

* The treatments with same letter as superscript are on par.

4.1.1.4 ***Microbial count***

Significant variation was observed among treatments in reducing microbial population on fresh cut cowpea. Bacterial and fungal population were reduced to 1.8 x 10^6 $cfug^{-1}$ and 1.5 x 10^3 $cfug^{-1}$ respectively by immersion in sodium hypochlorite 30 ppm (Table 2). Immersion in NaCl (1%) reduced yeast population to 1.7 x 10^3 $cfug^{-1}$. Counts of bacteria, fungi and yeast in control samples were 5.1 x 10^6, 5.5 x 10^3 and 4.8 x 10^3 $cfug^{-1}$ respectively at the end of storage in ambient conditions.

4.1.2 Elephant foot yam

4.1.2.1 ***Visual parameters***

After five days of storage at ambient conditions, T4 gave best result with respect to colour, appearance and flavour. Colour change was minimum in T4 followed by T3. Irrespective of treatment, a decrease in flesh firmness with storage was reported in all samples. Suberization was observed in T0 on the second day of storage (Plate 5). No decay or off odour was observed upto five days of storage.

4.1.2.2. ***Physiological loss in weight*** **(PLW%)**

The physiological loss in weight was maximum in T6 (washing with NaCl 1%) followed by T0 (56.0% and 37.9% respectively)(Table1). Loss of weight was minimum in T3 and T4 (30.1% and 30.6% respectively).

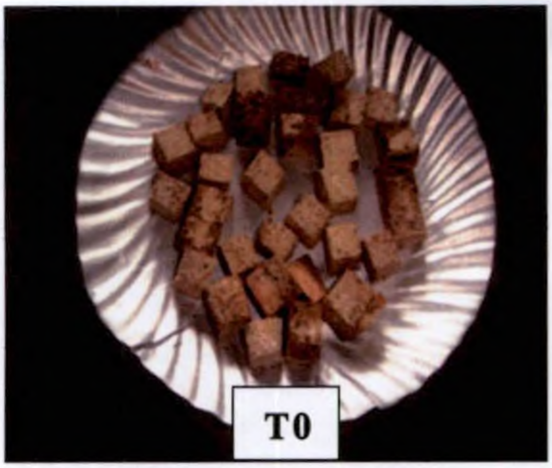
4.1.2.3 ***Shelf life***

Treatment with sodium hypochlorite 30 ppm (T4) recorded maximum shelf life (five days) in ambient condition. Samples washed with tap water (T0) recorded a shelf life of one day whereas T1 recorded two days shelf life.

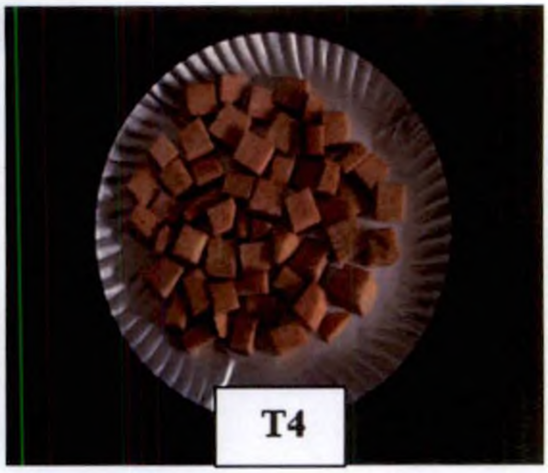
4.1.2.4. ***Microbial count***

After five days of storage, samples washed with 30 ppm sodium hypochlorite (T4) showed least microbial count. Bacterial count was 1.9 x 10^6 $cfug^{-1}$ and fungal count 1.5 x 10^3 $cfug^{-1}$ as compared to 5.9.x 10^6 $cfug^{-1}$ and 4.7 x 10^3 $cfug^{-1}$ respectively

Plate 5. Effect of sanitising agents on visual quality of EFY (3 DAS)



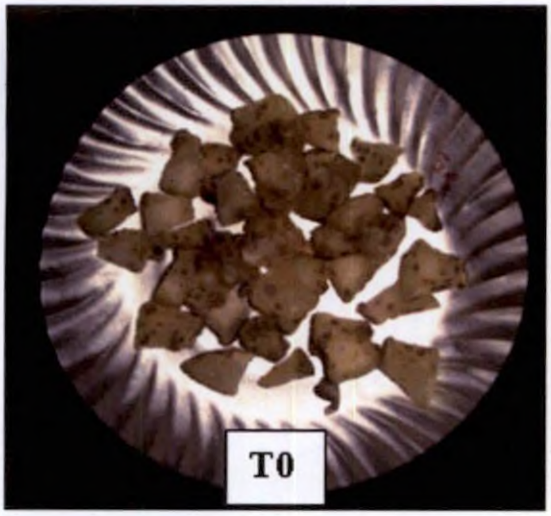
5 a



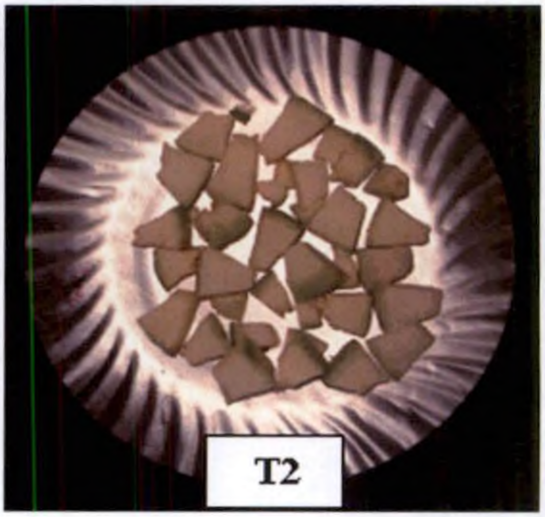
5 b

5a. -- Control
5b.-- Sodium hypochlorite (30 ppm)

Plate 6. Effect of prestorage treatments on visual quality (3 DAS)



6a



6b

6a -- Control
6b – KMS + citric acid (0.1%)

Table. 2. Effect of sanitizing agents on microbial count (cfug^{-1}) of fresh cut vegetables

Vegetables	Microbes	Treatments						
		T0	T1	T2	T3	T4	T5	T6
Cowpea	Bacteria	5.1^{c}	4.7^{c}	3.7^{b}	3.8^{b}	1.8^{a}	5.1^{c}	3.7^{b}
	Fungi	5.5^{e}	4.2^{d}	3.4^{c}	2.7^{b}	1.5^{a}	4.7^{d}	2.9^{c}
	Yeast	4.8^{e}	4.1^{d}	3.3^{c}	2.4^{b}	2.9^{bc}	4.3^{d}	1.7^{a}
EFY	Bacteria	5.9^{e}	4.7^{d}	4.2^{d}	3.6^{c}	1.9^{a}	3.4^{c}	2.8^{b}
	Fungi	4.7^{c}	3.5^{b}	2.8^{b}	2.0^{a}	1.5^{a}	3.3^{b}	3.1^{c}
	Yeast	5.7d	5.1^{cd}	4.8^{bc}	4.1^{b}	3.2^{a}	4.7^{bc}	3.1^{a}
Ashgourd	Bacteria	5.0^{e}	4.4^{d}	3.7^{c}	2.9^{b}	1.8^{a}	4.9^{e}	3.5^{c}
	Fungi	4.9^{c}	4.2^{d}	3.1^{c}	2.3^{b}	1.1^{a}	3.7^{d}	3.1^{c}
	Yeast	6.4^{e}	5.4^{d}	4.6^{c}	3.4^{b}	2.9^{b}	4.7^{b}	2.7^{a}
Brinjal	Bacteria	6.8^{f}	5.6^{e}	4.1^{c}	3.5^{b}	2.1^{a}	5.1^{d}	4.2^{e}
	Fungi	5.9^{f}	4.4^{e}	3.1^{d}	2.0^{b}	1.6^{a}	3.0^{d}	2.4^{c}
	Yeast	5.1^{f}	4.2^{e}	3.6^{d}	1.8^{b}	1.5^{b}	2.6^{c}	0.7^{a}
Okra	Bacteria	5.8^{f}	4.2^{e}	3.5^{cd}	2.6^{b}	1.8^{a}	3.6^{d}	3.2^{c}
	Fungi	4.6^{f}	3.9^{e}	3.0^{c}	2.2^{b}	0.8^{a}	3.6^{d}	2.9^{c}
	Yeast	5.1^{d}	4.4^{c}	3.3^{b}	2.9^{ab}	3.0^{ab}	4.5^{c}	2.7^{a}
Pumpkin	Bacteria	6.3^{e}	5.5^{d}	4.1^{c}	3.0^{b}	2.5^{a}	4.1^{c}	3.4^{b}
	Fungi	4.4^{g}	3.9^{f}	3.5^{e}	2.5^{c}	1.8^{a}	2.8^{d}	2.1^{b}
	Yeast	7.1^{f}	5.8^{e}	5.1^{e}	4.0^{c}	3.6^{b}	4.5^{d}	3.5^{a}
Drumstick	Bacteria	6.5^{g}	5.3^{e}	4.5^{d}	3.4^{b}	2.7^{a}	3.9^{c}	3.7^{bc}
	Fungi	5.2^{f}	4.8^{e}	3.5^{d}	2.8^{c}	1.8^{a}	2.4^{b}	2.0^{a}
	Yeast	6.2^{b}	5.6^{e}	5.6^{d}	5.0^{c}	2.1^{a}	4.5^{b}	1.8^{a}

* The treatments with same letter as superscript are on par.

in control samples(Table 2). But yeast count was minimum in T6 (3.1×10^3 cfug^{-1}) and maximum in T0 (5.7×10^3 cfug^{-1}).

4.1.3. Ash gourd

4.1.3.1. *Visual parameters*

In samples washed in tap water (T0), colour changed from light green to pale yellow on second day itself. Fungal growth was also observed on fresh cut ash gourd. The colour and freshness was retained only in T4. Upto end of storage period shrinking was observed in almost all the samples, but it was less in T4.

4.1.3.2. *Physiological loss in weight* (PLW%)

Significant difference in PLW % was noticed in all the treatments. Minimum loss in weight (29.8%) was observed in T3 (sodium hypochlorite 20 ppm), followed by T4 (36.2%). Weight loss was maximum (57.2%) in T6 (NaCl 1%) followed by T5 (51.6 %), at the end of storage period.

4.1.3.3 *Shelf life*

Maximum shelf life of four days was observed in T4 and T3. T5 and T6 recorded a shelf life of two days. Shelf life of all other treatments was one day only.

4.1.3.4 *Microbial count*

The bacterial and fungal count was least after treatment with 30 ppm sodium hypochlorite (1.8x106 and 1.1×10^3 cfug^{-1} respectively) followed by T3 (2.9×10^6 and 2.3×10^3 cfug^{-1}). Yeast count was least in T6 (2.7×10^3 cfug^{-1}) (Table 2). Maximum microbial count was observed in control (T0), the counts of bacteria, fungi and yeast were 5.0×10^6, 4.9×10^3 and 6.4×10^3 cfug^{-1} respectively.

4.1.4 Brinjal

4.1.4.1 *Visual parameters*

Black fungal growth was noticed in T6 (NaCl 1%) and also in T5 (glacial acetic acid 2%) at the end of storage. Rotting and colour change was observed in all other treatments. Colour and firmness was retained better in T4 and T3.

4.1.4.2 *Physiological loss in weight* (PLW%)

Significant loss in weight and shriveling was noticed in all the treatments. As compared to other treatments, loss in weight was minimum in T3 (34.7%) followed by T2 (41.45%) which was on par with T1. Maximum loss in weight was observed in T6 and T5 (49.4% and 47.4% respectively) (Table 1).

4.1.4.3 *Shelf life*

Shelf life of fresh cut brinjal was not significantly extended by sanitation treatment. Maximum storage life was obtained in T4 (three days) and minimum in T0 (one day) at ambient conditions. All other treatments had a shelf life of two days.

4.1.4.4 *Microbial count*

Microbiological analysis detected the presence of bacteria, fungus and yeast in all the treated samples but the count was significantly different in each samples. Compared to other treatments, T4 showed least bacterial and fungal count (2.1×10^6 and 1.6×10^3 cfug^{-1} respectively) while maximum count was in control treatment (6.8×10^6 and $5{,}9 \times 10^3$ cfug^{-1} respectively). Yeast count was minimum in T6 (0.7×10^3 cfug^{-1}).

4.1.5 Okra

4.1.5.1 *Visual parameters*

Colour and texture were preserved best in treated samples as compared to untreated samples. Sliminess and rotting were observed in T0 and T6 on the second day of storage. Colour and overall appearance were better in samples treated with sodium hypochlorite 30 ppm (T3). Control samples exhibited shriveling on the second day of storage itself.

4.1.5.2 *Physiological loss in weight* (PLW%)

Physiological loss in weight was observed in all the treatments. Loss in weight was maximum in T0 (75.2%), followed by T5 (73.1%). Least reduction in weight was in samples treated with sodium hypochlorite 20 ppm (57.5%), at the end of storage.

4.1.5.3 ***Shelf life***

Okra treated with sodium hypochlorite 30 ppm gave a shelf life of four days. Shelf life was minimum in samples treated with NaCl (1 %) and control treatment (two days).

4.1.5.4 ***Microbial count***

Significant reduction in microbial count was detected in all the treated samples. Bacterial and fungal count was minimum in T4 (1.8×10^6 and 0.8×10^3 $cfug^{-1}$ respectively)(Table2). Compared to all other treatments, T0 showed maximum number of microbes, bacteria (5.8×10^6 $cfug^{-1}$), fungi (4.6×10^3 $cfug^{-1}$) and yeast (5.1×10^3 $cfug^{-1}$). Yeast count was minimum in T8 (2.7×10^3 $cfug^{-1}$) and maximum in T0 (5.1×10^3 $cfug^{-1}$)

4.1.6 Pumpkin

4.1.6.1 ***Visual parameters***

Colour and overall appearance were best in samples treated with sodium hypochlorite 30ppm (T4) and poor in control samples. Shriveling and colour change from yellow to orange was observed in control samples. Firmness was retained in T4 till the end of storage.

4.1.6.2 ***Physiological loss in weight (PLW%)***

Significant reduction in weight was observed in minimally processed pumpkin throughout the storage period. Highest reduction in weight was observed in T5 (77.8%), which was on par with T2 and T6 (78.9% and 79.7%). Weight loss was minimum in T3 (66.6%) at the end of storage.

4.1.6.3 ***Shelf life***

A post cutting dip in sodium hypochlorite solution (30ppm) extended shelf life of minimally processed pumpkin to four days. The samples washed with tap water (T0) recorded a shelf life of two days only.

4.1.6.4 ***Microbial count***

The microbial population was significantly reduced in treated samples. Sanitation with sodium hypochlorite 30ppm reduced bacterial and fungal population to 2.5x10^6, and 1.8x10^3 $cfug^{-1}$ as compared to 6.3x10^6 and 4.4x10^3 $cfug^{-1}$ respectively in control treatment. The yeast count was minimum in T6 (3.5 x10^3 $cfug^{-1}$) and maximum in T0 (7.1 x10^3 $cfug^{-1}$).

4.1.7 Drumstick

4.1.7.1 ***Visual parameters***

The colour and appearance were superior in fresh cut drumstick washed with sodium hypochlorite 30 ppm (T3) solution as compared to other treatments. Green colour was maintained in T4 till the end of storage. Shriveling was observed in all the samples but there was no rotting.

4.1.7.2 ***Physiological loss in weight*** **(PLW%)**

Throughout the period of storage, significant reduction was observed in weight of samples. Weight loss was highest in T6 (NaCl 1%) followed by T0 (43.2 and 36.6% respectively). Weight loss was minimum in T3 (24.2%)(Table 1).

4.1.7.3 ***Shelf life***

Minimally processed drumstick recorded a shelf life of four days in T4 and T3 under ambient conditions.

4.1.7.4 ***Microbial count***

Total microbial count per gram of sample was significantly lowered after sanitation with 30 ppm sodium hypochlorite (T3)(Table 2). The bacterial and fungal count was 2.7x10^6 and 1.8x10^3 $cfug^{-1}$ respectively. A population of 6.5x10^6 bacteria and 5.2x10^3 $cfug^{-1}$ fungi was noted in control. Yeast count was least in T6 (1.8x10^3 $cfug^{-1}$) and highest in control (6.2x10^3 $cfug^{-1}$).

4.2 STANDARDISATION OF POSTHARVEST TREATMENTS FOR MINIMALLY PROCESSD VEGETABLES

The impact of nine prestorage treatments on quality and shelf life of seven vegetables were studied under this experiment.

4.2.1 Cowpea

4.2.1.1 *Visual parameters*

Colour change was least in T3 [samples treated with KMS (0.1%) + ascorbic acid (0.1%)] and T6 [Sodium benzoate + ascorbic acid (0.1%)]. Control samples showed colour change from green to light green on second day of storage. Blanching in hot water at 80°C for one minute (T8) resulted in complete loss of green colour and softening of fresh cut cowpea. Fresh appearance was retained in T3 till the end of storage.

4.2.1.2 *Physiological loss in weight* (PLW%)

All the treatments showed considerable loss in weight throughout the storage. Weight loss was maximum in T8 (62.9%) followed by T0 (61.2%). At the end of storage, minimum weight loss (40.9%) was observed in T5 (sodium benzoate + citric acid 0.1%) followed by T6 (45.8%) (Table 3).

4.2.1.3 *Shelf life*

Cowpea samples immersed in KMS 0.1%+ ascorbic acid 0.1% (T3) before storage had a maximum shelf life of four days at ambient conditions. Samples treated with hot water (T8) and tap water (T0) had a shelf life of one day only. All other treatments recorded a shelf life of two days.

4.2.1.4. *Microbial count*

After four days of storage, highest bacterial count was recorded in samples treated with hot water ($5.6x10^6 cfug^{-1}$) which was on par with T0 ($5.3x10^6$ $cfug^{-1}$) Bacterial count was minimum in T3 and T6. The counts were $2.1x10^6$and $2.4x10^6$ cfug-1 respectively. Fungal growth was maximum in T0 ($6.6x10^3$ $cfug^{-1}$) followed by

Table.3. Effect of prestorage treatments on PLW (%) of fresh cut vegetables.

Vegetables	Days	Treatments								
		T0	T1	T2	T3	T4	T5	T6	T7	T8
Cowpea	1st	38.2^{ab}	33.2^{ab}	22.5^{de}	37.1^{ab}	32.2^{bc}	14.8^{f}	18.7^{ef}	29.0^{cd}	39.6^{a}
	3rd	61.2^{a}	53.6^{bc}	51.4^{cd}	58.6^{ab}	50.0^{cd}	40.9^{e}	45.8^{de}	53.4^{bc}	62.9^{a}
EFY	1st	26.0^{b}	25.6^{b}	23.8^{b}	21.7^{b}	20.3^{b}	34.6^{a}	21.4^{b}	35.3^{a}	38.3^{a}
	3rd	53.2^{ab}	49.0^{b}	46.7^{b}	46.9^{b}	46.2^{b}	56.3^{a}	46.8^{b}	56.4^{a}	58.0^{a}
Ashgourd	1st	26.9^{abc}	29.2^{ab}	20.2^{cd}	23.1^{bcd}	28.6^{ab}	16.4^{e}	22.7^{bcd}	28.2^{ab}	33.4^{a}
	3rd	48.2^{bc}	52.4^{ab}	36.9^{de}	41.4^{cd}	53.0^{ab}	33.1^{e}	46.6^{bc}	43.6^{cd}	55.6^{a}
Brinjal	1st	42.2^{b}	36.2^{bc}	23.0^{ef}	17.2^{f}	32.2^{cd}	27.8^{de}	30.6^{cd}	39.5^{b}	50.6^{a}
	3rd	67.9^{b}	66.7^{b}	56.2^{cd}	50.8^{d}	62.8^{bc}	61.0^{bc}	61.7^{bc}	68.1^{b}	75.6^{a}
Okra	1st	36.6^{b}	36.0^{b}	38.2^{b}	36.8^{b}	35.8^{b}	39.1^{b}	40.2^{b}	47.7^{a}	37.6^{b}
	3rd	86.2^{a}	76.9^{bc}	75.2^{bc}	82.0^{ab}	77.0^{bc}	73.1^{c}	75.2^{bc}	74.1^{c}	80.4^{abc}
Pumpkin	1st	35.8^{bc}	43.2^{a}	31.8^{bcd}	30.8^{bcd}	27.7^{d}	25.3^{d}	30.4^{cd}	35.7^{bd}	38.0^{ab}
	3rd	61.2^{ab}	65.2^{a}	62.4^{ab}	66.4^{a}	56.9^{b}	57.5^{b}	61.7^{ab}	66.3^{a}	63.0^{ab}
Drumstick	1st	8.4^{ab}	3.6^{abc}	2.4^{bc}	4.7^{abc}	8.6^{ac}	0.7^{c}	5.0^{abc}	6.4^{abc}	10.6^{a}
	3rd	21.4^{bc}	17.4^{c}	16.8^{c}	21.2^{bc}	25.4^{ab}	16.4^{c}	21.0^{bc}	26.7^{ab}	30.0^{a}

* The treatments with same letter as superscript are on par.

T8 ($5.7x10^3$ $cfug^{-1}$) as compared to $1.7x10^3$ in T3 and $2.0x10^3$ $cfug^{-1}$ in T6. Highest yeast count was also in T0 ($4.7x10^3$ $cfug^{-1}$) and lowest in T3 ($2.3x10^3$ $cfug^{-1}$)(Table 4). Microbial count was effectively reduced by prestorage treatment with ascorbic acid.

4.2.2. Elephant foot yam

4.2.2.1 ***Visual parameters***

Treatments T2 (KMS 0.1 % + citric acid 0.1%) and T6 (sodium benzoate 0.1% + ascorbic acid 0.1%) registered less browning than all other treatments. Control samples exhibited shriveling on the second day of storage itself. Flesh firmness was maintained better by dip treatment in a solution containing KMS (0.1%) + citric acid (0.1%) (T2).

4. 2.2.2. Physiological loss in weight

Significant physiological loss in weight was recorded in all treatments during storage. Maximum weight loss was observed in T8 (hot water treatment) and T7 (58.0% and 56.4% respectively) (Table3). At the end of storage, minimum PLW was shown by T4 and T3. They were on par with a mean value of 46.2% and 46.9% percent respectively.

4.2.2.3 ***Shelf life***

Significant difference was noticed between different treatments with respect to shelf life. Longest shelf life (five days) was recorded for samples treated with a combination of KMS 0.1%+ ascorbic acid 0.1% (five days) and shortest for control and hot water treated samples (two days).

4.2.2.4 ***Microbial count***

Compared to control samples, microbial load was lower in all other treatments. Treatment T3 (KMS 0.1% + ascorbic acid 0.1% registered lower microbial count, $2.4x10^6$, $1.7x10^3$ and $2.3x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast

Table.4.Effect of prestorage treatments on microbial count ($cfug^{-1}$) of fresh cut vegetables.

Vegetables	Microbes	Treatments								
		T0	T1	T2	T3	T4	T5	T6	T7	T8
Cowpea	Bacteria	5.3^{e}	4.6^{d}	3.8^{b}	2.1^{a}	4.3^{c}	3.6^{b}	2.4^{a}	4.8^{d}	5.6^{e}
	Fungi	6.6^{g}	3.9^{d}	2.7^{c}	1.7^{a}	4.4^{e}	2.6^{c}	2.0^{b}	4.3^{e}	5.7^{f}
	Yeast	4.7^{f}	4.2^{e}	3.9^{d}	2.3^{a}	4.2^{de}	3.8^{cd}	2.7^{b}	3.7^{c}	4.1^{e}
EFY	Bacteria	5.7^{g}	3.3^{c}	2.8^{bc}	2.4^{a}	3.8^{d}	3.0^{c}	2.5^{ab}	4.6^{e}	4.9^{f}
	Fungi	4.4^{g}	2.6^{c}	3.1^{d}	1.7^{a}	2.9^{cd}	3.1^{d}	2.3^{b}	3.6^{e}	3.9^{f}
	Yeast	5.6^{g}	3.3^{c}	2.8^{b}	2.3^{a}	4.0^{d}	2.9^{b}	3.0^{b}	4.5^{e}	5.1^{f}
Ashgourd	Bacteria	4.6^{g}	1.8^{b}	2.2^{c}	1.3^{a}	2.1^{c}	2.7^{d}	1.7^{b}	3.3^{e}	4.0^{f}
	Fungi	4.8^{e}	2.6^{b}	2.3^{ab}	1.9^{a}	2.4^{b}	2.7^{b}	2.3^{ab}	3.7^{c}	4.3^{d}
	Yeast	6.7^{g}	2.8^{b}	3.4^{d}	2.4^{a}	3.1^{c}	3.6^{d}	2.7^{b}	4.7^{e}	5.1^{f}
Brinjal	Bacteria	6.8^{f}	3.3^{b}	4.0^{d}	1.9^{a}	3.7^{c}	3.9^{cd}	2.0^{a}	5.8^{e}	5.8^{e}
	Fungi	5.6^{h}	3.1^{e}	2.7^{c}	1.1^{a}	2.4^{de}	2.9^{d}	1.5^{b}	3.8^{f}	4.2^{g}
	Yeast	5.3^{f}	2.6^{b}	2.6^{b}	2.1^{a}	2.8^{c}	2.9^{c}	2.3^{a}	3.8^{d}	4.1^{e}
Okra	Bacteria	3.9^{ab}	4.1^{b}	4.1^{b}	3.3^{a}	3.3^{a}	3.2^{a}	4.3^{b}	3.9^{ab}	4.9^{c}
	Fungi	2.9^{a}	3.0^{a}	2.9^{a}	2.7^{a}	2.8^{a}	3.0^{a}	3.6^{ab}	3.6^{ab}	3.7^{ab}
	Yeast	4.1^{b}	4.0^{b}	3.9^{ab}	3.2^{a}	3.2^{a}	3.4^{a}	4.3^{b}	4.1^{b}	4.1^{b}
Pumpkin	Bacteria	6.1^{g}	2.6^{bc}	2.8^{c}	2.0^{ab}	3.6^{dc}	3.1^{cd}	1.6^{a}	4.3^{ef}	4.7^{f}
	Fungi	6.0^{g}	2.4^{b}	2.9^{d}	2.1^{a}	2.9^{d}	3.1^{e}	2.6^{c}	5.6^{f}	6.1^{g}
	Yeast	5.4^{f}	1.5^{b}	2.1^{c}	0.9^{a}	1.9^{c}	2.5^{d}	1.1^{a}	2.7^{d}	3.3^{e}
Drumstick	Bacteria	6.6^{g}	2.8^{b}	3.4^{c}	2.3^{a}	3.3^{c}	3.7^{d}	2.7^{b}	4.7^{c}	5.9^{f}
	Fungi	5.0^{g}	1.9^{bc}	2.6^{d}	1.1^{a}	2.1^{c}	2.8^{de}	1.6^{b}	3.2^{fe}	3.7^{f}
	Yeast	5.6^{f}	2.3^{a}	2.5^{ab}	2.3^{a}	2.6^{ab}	2.8^{b}	2.6^{ab}	4.6^{c}	5.1^{d}

* The treatments with same letter as superscript are on par.

respectively. The corresponding values for control were $5.7x10^6$, $4.4x10^3$ and $5.6x10^3$ $cfug^{-1}$ (Table 4).

4.2.3 Ash gourd

4.2.3.1. *Visual parameters*

Slices treated with a solution containing KMS (0.1%) + citric acid (0.1%) (T2) retained colour and freshness better during storage. Black fungal growth was observed in T0 and T8 on the second day of storage itself. Flesh firmness was maintained better by dip treatment in solution containing 0.1% KMS and 0.1% citric acid .

4.2.3.2 *Physiological loss in weight* (PLW %)

The average value for PLW differed significantly among the treatments. Highest value was recorded by T8 (55.6%) and the lowest value by T5 (33.1%) on the third day of storage.

4.2.3.3 *Shelf life*

Treatments T2 and T6 remained in a marketable condition upto four days of storage under ambient conditions (Plate 6). T0 and T8 become unmarketable by the third day and all other treatments by the second day of storage

4.2.3.4 *Microbial count*

Dipping minimally processed ash gourd in a solution of KMS 0.1% + ascorbic acid0.1% (T3) before storage reduced the bacterial count to $1.3x10^6$ $cfug^{-1}$ as compared to $4.6x10^6$ $cfug^{-1}$ in control. Lowest fungal and yeast count was also in T3 (1.9 $x10^3$ $cfug^{-1}$ and $2.4x10^3$ $cfug^{-1}$ respectively) In control the fungal count was 4.8 $x10^3$ $cfug^{-1}$ and yeast count was $6.7x10^3$ $cfug^{-1.}$

4.2.4 Brinjal

4.2.4.1 *Visual parameters*

Firmness and colour of minimally processed brinjal dipped in different solutions for ten minutes before storage at ambient conditions were observed. Colour and firmness were retained best in T3 (KMS 0.1%+ ascorbic acid 0.1%). Superficial growth of fungi was observed in T0 (control) and T7 (Cystiene 0.2%) after two days of storage.

4.2.4.2 ***Physiological loss in weight*** **(PLW %)**

Significant weight loss was recorded in the entire samples throughout the storage time. However least PLW was registered in T3 (50.8%) and the highest in T8 (75.6%) (Table 3).

4.2.4.3 ***Shelf life***

Treatments T2, T3, T4, T5 and T6 recorded maximum shelf life (three days) under ambient conditions. T1 and T8 remained in an acceptable condition only for one day. Compared to other vegetables, samples treated with cysteine showed two days shelf life. Control samples showed undesirable changes few hours after storage.

4.2.4.4 ***Microbial count***

Microbial population was not significantly reduced by cysteine (0.2%) and hot water treatments. Treatment with KMS 0.1% + ascorbic acid 0.1%(T3) gave best results. Counts of bacteria, fungi and yeast in T3 were $1.9x10^6$, $1.1x10^3$ and $2.1x10^3$ $cfug^{-1}$ respectively. T0 showed maximum microbial load. It was $6.8x10^6$, $5.6x10^3$ and $5.3x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively.

.4.2.5 Okra

4.2.5.1 ***Visual parameters***

Fresh cut okra fruits dipped in solution of KMS (0.1%) + citric acid (0.1%) preserved colour better. Progressive loss of firmness during storage was noticed in okra slices treated with hot water as well as with cystiene 0.2%. Irrespective of the treatments, all samples showed slight shriveling but it was comparatively more in T0.

4.2.5.2 *Physiological loss in weight* (PLW %)

At the end of storage, maximum cumulative weight loss was recorded in T0 (86.2%) and minimum in T5 and T7. They were on par with mean values of 73.1% and 74.1%.

4.2.5.3. *Shelf life*

Shelf life of fresh cut okra was reduced to one day by blanching in hot water. Maximum shelf life of four days was in T5 (samples treated with sodium benzoate + citric acid (0.1%)) while all other treatments became unmarketable after three days storage.

4.2.5.4 *Microbial count*

Bacterial count was least in T5, which was on par with T3 and T4. In samples treated with sodium benzoate + ascorbic acid (T6) the count was 4.3×10^6 $cfug^{-1}$. Maximum count was in T8 (4.9×10^6 $cfug^{-1}$) (Table 4) . Fungal and yeast count was minimum in T3, both recorded a count of 2.7×10^3 for fungi and 3.2×10^3 $cfug^{-1}$ for yeast. Fungal count was maximum in T8 (3.7×10^3 $cfug^{-1}$) and yeast count in T0, T7 and T8 at the end of storage.

4.2.6 Pumpkin

4.2.6.1 *Visual parameters*

Treatment with a combination of KMS (0.1%) + citric acid (0.1%) (T2) gave best results. Colour change was least and overall appearance was better till the end of the storage. Black fungal growth was observed in T0, T4 and T8.

4.2.6.2 *Physiological loss in weight* (PLW %)

Throughout the storage, gradual increase in PLW was observed in all the treatments. Maximum weight loss was in T7 (66.3%). T5 (Sodium benzoate (0.1%)) + ascorbic acid (0.1%) showed minimum PLW (33.1 %) (Table 3).

4.2.6.3 *Shelf life*

Shelf life was not significantly extended by any of the treatments. Treatment T2 recorded longest shelf life of four days whereas T0, T4, T7 and T8 recorded two days shelf life.

4.2.6.4 *Microbial count*

Postharvest treatments significantly lowered the microbial population in fresh cut pumpkin. Bacterial count was least in T6 ($1.6x10^6$ $cfug^{-1}$) and highest in control ($6.1x10^6$ $cfug^{-1}$). But fungal and yeast count was minimum in T3 ($2.1x10^3$ and 0.9 $x10^3$ $cfug^{-1}$ respectively). Maximum count of fungi ($6.4x10^3$ $cfug^{-1}$) and yeast (5.4 $x10^3$ $cfug^{-1}$) was observed in T0.

4.2.7 Drumstick

4.2.7.1 *Visual parameters*

Colour change was not observed in any of the treatments. Fungal growth was observed in T0. Softening was noticed in samples treated with hot water on second day of storage. Overall appearance was preserved best in T3 (KMS+ ascorbic acid 0.1%) throughout the storage period.

4.2.7.2 *Physiological loss in weight* (PLW %)

Compared to the other vegetables used for the study, cumulative weight was least in drumstick. Results revealed that maximum PLW was in T8 during the entire period of storage. Cumulative loss weight in T8 at the end of storage was 30.0 percentage. PLW was relatively less in T5 (16.4%) and T2 (16.8%).

4.2.7.3 *Shelf life*

Longest shelf life (five days) was observed in drumstick dipped in a solution of KMS (0.1%) + citric acid (0.1%). Shelf life was minimum in T0 (three days). Rotting was observed in T0 after three days of storage.

4.2.7.4 *Microbial count*

In all the treatments, microbial development was delayed compared to control. Bacteria, fungi and yeast count were minimum in T3 ($2.3x10^6$, $1.1x10^3$ and $2.9x10^3$

$cfug^{-1}$ respectively) (Table 4). Treatment T0 recorded maximum count, it was $6.6x10^6$, $5.0x10^3$ and $5.6x10^3$ $cfug^{-1}$ respectively for bacteria, fungi and yeast.

4.3 IRRADIATION OF MINIMALLY PROCESSED PRODUCTS

Feasibility of using ionizing radiation to control food pathogens in precut vegetables was studied under this experiment.

4.3.1 Cowpea

4.3.1.1 *Visual parameters*

Irradiation caused moderate changes in appearance and flesh firmness. Colour was retained best in T5 (200Gy) Extended dose rate negatively affected the flesh firmness. Treatment with gamma radiation resulted in deterioration of visual quality after three days of storage.

4.3.1.2 *Shelf life*

Fresh cut cowpea that received gamma radiation dose of 200 Gy (T5) could be stored at ambient condition for three days whereas control sample lost marketability within one day of storage.

4.3.1.3 *Microbial count*

A gradual decrease in microbial population was observed with increasing dose of irradiation. In samples irradiated at a dose of 200 Gy, microbial population was significantly lower than the control throughout the storage period. Bacterial count was least in T5 ($5.2x10^6$ $cfug^{-1}$) and highest in T0 ($12.2x10^6$ $cfug^{-1}$)(Table 5). Fungal and yeast count was $3.1x10^3$ and $3.0x10^3$ $cfug^{-1}$ respectively in T5 as compared to $10.4x10^3$ and $9.5x\ 10^3$ $cfug^{-1}$ in the control treatment.

4.3.2 Brinjal

4.3.2.1. *Visual parameters*

Overall appearance was superior for brinjal slices irradiated at a dose of 100 Gy (T3). The treatment 200 Gy (T5) resulted in loss of flesh firmness and

Table.5.Effect of irradiation on microbial count (cfug^{-1}) of fresh cut vegetables

Vegetables	Microbes	Irradiation (Gy)					
		T0	T1	T2	T3	T4	T5
Cowpea	Bacteria	12.2^{d}	11.2^{cd}	10.4^{c}	10.9^{cd}	8.0^{b}	5.2^{a}
	Fungi	10.4^{e}	10.5^{e}	8.6^{d}	7.7^{c}	5.5^{b}	3.1^{a}
	Yeast	9.5^{c}	9.3^{c}	9.6^{c}	9.4^{c}	8.2^{b}	7.0^{a}
Brinjal	Bacteria	13.0^{e}	13.0^{e}	11.9^{d}	5.9^{c}	8.7^{b}	9.3^{a}
	Fungi	10.0^{d}	9.2^{c}	8.4^{c}	4.3^{b}	4.6^{b}	5.0^{a}
	Yeast	9.4^{d}	9.6^{c}	9.3^{c}	3.2^{b}	7.6^{b}	8.2^{a}
EFY	Bacteria	14.0^{d}	13.6^{d}	12.4^{c}	11.0^{b}	10.0^{a}	9.2^{a}
	Fungi	12.6^{c}	12.2^{c}	10.1^{b}	8.7^{b}	7.0^{a}	5.8^{a}
	Yeast	10.0^{b}	9.9^{b}	10.6^{b}	9.4^{a}	10.5^{b}	8.3^{a}
Ashgourd	Bacteria	12.6^{d}	10.8^{c}	9.9^{c}	9.9^{c}	6.8^{b}	8.0^{a}
	Fungi	8.0^{f}	6.6^{e}	5.9^{d}	5.2^{c}	2.0^{b}	4.8^{a}
	Yeast	7.7^{de}	7.9^{e}	6.8^{cd}	5.9^{bc}	5.5^{b}	6.3^{a}
Okra	Bacteria	12.3^{e}	9.9^{d}	8.3^{c}	6.5^{b}	5.7^{ab}	4.9^{a}
	Fungi	8.7^{e}	7.1^{d}	6.7^{d}	5.9^{c}	5.3^{b}	4.3^{a}
	Yeast	7.1^{c}	6.8^{c}	6.0^{b}	4.7^{a}	4.2^{a}	3.9^{a}
Pumpkin	Bacteria	9.4^{e}	9.2^{e}	8.1^{d}	6.8^{c}	5.1^{b}	3.4^{a}
	Fungi	5.3^{d}	4.9^{d}	3.8^{c}	3.0^{b}	1.0^{b}	3.8^{a}
	Yeast	4.4^{d}	4.3^{cd}	3.9^{c}	3.3^{b}	2.9^{b}	3.1^{a}
Drumstick	Bacteria	14.7^{f}	9.7^{e}	8.7^{d}	7.3^{c}	5.6^{b}	5.0^{a}
	Fungi	12.6^{e}	8.1^{de}	7.6^{d}	5.2^{c}	4.2^{b}	2.4^{a}
	Yeast	7.2^{d}	6.5^{d}	5.1^{c}	4.4^{c}	3.4^{b}	2.4^{a}

* The treatments with same letter as superscript are on par.

deterioration of visual quality. In addition, radiation caused softening and cellular damage after two days of storage.

4.3.2.2 ***Shelf life***

Samples subjected to radiation dose of 100 Gy remained in marketable condition upto four days of storage. Irradiation dose beyond 100 Gy adversely affected visual parameters as evident by browning and softening of brinjal slices.

4.3.2.3 ***Microbial count***

Gamma irradiation was found to decrease the microbial count in fresh cut brinjal. The non irradiated samples recoded a microbial population of $13x10^6$ $cfug^{-1}$ (bacteria), $10x10^3$ $cfug^{-1}$ (fungi) and $9.4x10^3$ $cfug^{-1}$ (yeast). Microbial population was least in T3 ,bacteria ($5.9x10^6$ $cfug^{-1}$), fungi ($4.3x10^3$ $cfug^{-1}$) and yeast ($3.2x10^3$ $cfug^{-1}$) (Table 5).

4.3.3. Elephant foot yam

4.3.3.1 ***Visual parameters***

Irradiation at doses of 25 to 200 Gy had minimal effects on all parameters studied. Irradiation caused moderate changes in texture and appearance. Ballooning effect was noticed in all samples, but it was comparatively less in samples irradiated at 200 Gy (T5). Visual quality was also maintained in T5 (Plate 7).

4.3.3.2 ***Shelf life***

Shelf life was not significantly extended by radiation. Maximum shelf life of four days was observed in T5 (200 Gy). Non irradiated samples registered only one day shelf life.

4.3.3.3 ***Microbial count***

Microbial count in minimally processed elephant foot yam three days after irradiation at a dose of 200 Gy were $9.2x10^6$, $5.8x10^3$ and $8.3x10^3$ cfug-1 for bacteria, fungi and yeast respectively. The corresponding values for the non irradiated samples were $14.0x10^6$, $12.6x10^3$ and $10.0x10^3$ $cfug^{-1}$

Plate 7. Changes in visual attributes during storage of irradiated elephant foot yam (3 DAS)

4.3.4 Ash gourd

4.3.4.1 *Visual parameters*

Both T0 (control) and T5 (200 Gy) showed slipperiness and browning from the second day of storage. Fresh like appearance and flesh firmness was preserved better in ash gourd slices irradiated at a dose of 150Gy (T4)

4.3.4.2 *Shelf life*

Shelf life was minimum in T0 and T5 (one day). Longest shelf life (three days) was recorded in samples subjected to 150 Gy gamma irradiation.

4.3.4.3 *Microbial count*

Least count of microbes was observed in T4 (150 Gy). It was 6.8×10^6, 2.0×10^3 and 5.5×10^3 $cfug^{-1}$ for bacteria, fungi and yeast respectively (Table5). The corresponding values for control (T0) were 12.6×10^6, 8.0×10^3 and 7.7×10^3 $cfug^{-1}$ respectively.

4.3.5 Okra

4.3.5.1 *Visual parameters*

Overall acceptability of fresh cut okra was better in T5. The appearance and texture was adversely affected with increasing dose of radiation. Samples irradiated at a dose lower than 200 Gy showed browning and slipperiness, the intensity of which was the highest in T0.

4.3.5.2 *Shelf life*

Longest shelf life was in T5 (3 days) followed by T4 (150 Gy). T0 recorded a shelf life of one day.

4.3.5.3 ***Microbial count***

A significant increase in the microbial count per gram of fresh cut okra in T0 (12.3×10^6, 8.7×10^3 and 7.1x1203 $cfug^{-1}$) as compared to T5 (4.9×10^6 4.3×10^3 and $3.9 \times 10^3 cfug^{-1}$respectively for bacteria, fungi and yeast) was observed on the third day of storage.

4.3.6 Pumpkin

4.3.6.1 ***Visual parameters***

Visual parameters were preserved best in samples irradiated at 200 Gy. Softening and browning was noted in T0 as well as samples subjected to lower dose of irradiation.

4.3.6.2 ***Shelf life***

Shelf life was maximum (four days) in T5 (200Gy) and minimum in T0, T1 and T2 (two days). T3 and T4 recorded a shelf life of three days.

4.3.6.3 ***Microbial count***

Bacterial count was least in T5 ($3.4 \times 10^6 cfug^{-1}$) and highest in control ($9.4 \times 10^6 cfug^{-1}$). Fungi and yeast was least in T4 (1.0×10^3 $cfug^{-1}$ and 2.9×10^3 $cfug^{-1}$). T0 recorded a higher count of fungi (5.3×10^3 $cfug^{-1}$) and yeast (4.4 $cfug^{-1}$) (Table 5).

4.3.7 Drumstick

4.3.7.1 ***Visual parameters***

There was no marked change in appearance in irradiated samples upto two days of storage. Fungal growth was observed in control samples after one day storage. Firmness was less in samples subjected to higher dose of radiation (200 Gy).

4.3.7.2 ***Shelf life***

Shelf life was longest in T5 (four days) and shortest in control (one day). All other treatments recorded a shelf life of two days.

4.3.7.3 *Microbial count*

Total microbial count in samples was least in T5 ($5.0x10^6$, $2.4x10^3$ and $2.9x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively). T0 recorded the highest population of microbes $14.7x10^6$ $cfug^{-1}$ (bacteria), 12.6x103 $cfug^{-1}$ (fungi) and $7.2x10^3$ $cfug^{-1}$ (yeast).

4.4 STANDARDISATION OF STORAGE SYSTEMS FOR MINIMALLY PROCESSED PRODUCTS

4.4.1 Cowpea

4.4.1.1 *Visual parameters*

Colour and firmness retention were best in samples packed in T4 (unventilated PP cover). Vacuum packaging was not found ideal for minimally processed cowpea, since it enhanced rotting. Fungal growth was observed in samples packed in areca sheath tray (T9) on second day of storage. Samples packed in thermocal tray wrapped with cling film (T8) showed shriveling from first day of storage itself.

Colour change was least under low temperature storage compared to other storage systems. Packaging in unventilated PP (T4) proved best for visual quality under refrigeration also. Excessive rotting was observed in vaccum packaged cowpea from fifth day of storage. Fungal growth was the limiting factor for samples packed in areca sheath tray (T9). Slight browning was observed in samples packed in perforated film bags from third day onwards.

Irradiation in combination with low temperature did not have any marked effect on visual quality. Samples exposed to high dose (200 Gy) of irradiation showed slight yellow discoloration from second day onwards.

4.4.1.2. ***Shelf life***

Under ambient conditions, comparatively longer storage life of five days was recorded for fresh cut cow pea packed in unventilated PP cover (T4). The control treatment recorded a shelf life of one day only.

Under low temperature storage also, longer shelf life (ten days) was for samples packed in perforated PP cover. Vaccum packaged, as well as those packed in perforated PP and PE cover registered a shelf life of six days under refrigeration. Packing cowpea in polystyrene trays and wrapping with cling film renderd a shelf life of eight days, whereas wrapping with polystyrene lid reduced shelf life to six days. Thermocol and areca sheath tray packed cowpea as well as control treatment recorded a shelf life of three days only. While a shelf life of nine days under low temperature was observed for cowpea packed in PP cover, it was reduced to eight days when the samples packed in the same material were subjected to irradiation at a dose of 200 Gy.

All treatments registered significant weight loss throughout the storage period. PLW was comparatively less in samples packed in T2 (32.9%) and highest (59.0%) in T3 after five days of storage in ambient conditions (Table 6). Under refrigeration, maximum weight loss was in T10 (24.4%) after nine days storage and minimum in T4 (20.8%)(Table 7). Irradiation did not have any significant impact on PLW and shelf life (Table 8).

4.4.1.3 ***Microbial count***

Significant difference in microbial population was observed between different treatments under ambient conditions. Highest bacterial count was in control (9.4×10^6 cfu g^{-1}) and least in T4 (2.4×10^6 cfug^{-1}). Fungal population was highest (7.8×10^3 cfug^{-1}) in T9 (areca sheath tray covered with cling film). Least count (2.0×10^3 cfug^{-1}) was in T6 (vaccum packed PP) . Yeast count was significantly low in T2 (2.1×10^3 cfug^{-1}), which was on par with T4 (2.3×10^3 cfug^{-1}) (Table 9).

Table 6. Effect of packaging and storage on PLW (%) of fresh cut vegetables under ambient condition.

Vegetables	Days	Treatments										
		T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
EFY	1st	8.4^{a}	8.7^{a}	6.8^{a}	6.4^{a}	6.2^{a}	3.8^{a}	6.8^{a}	5.9^{a}	5.0^{a}	5.0^{a}	6.6^{a}
	3rd	29.8^{a}	28.4^{a}	21.6^{a}	29.2^{a}	32.4^{a}	15.6^{a}	17.0^{a}	22.4^{a}	21.9^{a}	25.5^{a}	22.4^{a}
	5th	D	D	36.8^{cd}	68.0^{cd}	38.0^{d}	49.9^{ab}	31.0^{d}	33.4^{d}	58.4^{bc}	65.6^{b}	41.2^{cd}
Okra	1st	14.0^{a}	14.6^{a}	4.6^{a}	11.0^{a}	7.7^{a}	12.4^{a}	10.0^{a}	6.9^{a}	15.5^{a}	12.6^{a}	6.4^{a}
	3rd	27.8^{ab}	29.4^{ab}	14.8^{b}	27.2^{ab}	17.5^{ab}	23.5^{ab}	28.3^{ab}	23.9^{ab}	28.5^{ab}	28.7^{ab}	31.3^{a}
	5th	D	40.33^{d}	28.8^{d}	41.7^{d}	31.1d	D	D	40.0^{d}	D	34.4^{d}	60.7^{c}
Brinjal	1st	17.5^{ab}	13.4^{ab}	5.2^{b}	29.1^{a}	7.2^{b}	6.1^{b}	8.7^{b}	4.2^{b}	13.2^{ab}	11.6^{ab}	9.0^{b}
	3rd	30.1^{a}	28.3^{a}	19.5^{a}	18.0^{a}	15.9^{a}	20.8a	23.8a	17.6^{a}	30.8$_{a}$	24.4^{a}	27.0^{a}
	5th	D	D	28.2^{c}	77.4^{b}	31.^{3c}	40.8^{c}	43.7^{c}	29.6^{c}	36.0^{b}	35.6^{c}	43.8^{c}
Cowpea	1st	16.8^{a}	12.2^{ab}	4.2^{b}	11.2^{ab}	5.2^{ab}	4.2^{b}	4.7^{b}	5.7^{ab}	12.4^{ab}	8.1^{ab}	8.9^{ab}
	3rd	32.6^{a}	29.8^{ab}	20.6^{bc}	27.7^{ab}	19.7^{bc}	22.6^{abc}	14.9^{ab}	23.2^{abc}	30.2^{ab}	23.0^{abc}	29.4^{ab}
	5th	D	42.7^{c}	32.9^{c}	59.0^{b}	38.8^{c}	34.8^{c}	36.7^{c}	39.2^{c}	D	D	43.0^{c}
Ashgourd	1st	15.2^{a}	15.9^{a}	8.3^{a}	14.4^{a}	8.2^{a}	11.0^{a}	3.0^{a}	4.6^{a}	13.7^{a}	7.8^{a}	8.8^{a}
	3rd	63.4^{a}	72.5^{b}	17.3^{a}	29.5^{a}	21.6^{a}	75.5^{a}	76.8^{a}	19.8^{a}	31.9^{a}	26.4^{a}	27.5^{a}
	5th	D	D	35.0^{a}	D	39.6^{a}	D	D	32.3^{a}	D	D	41.3^{a}
Pumpkin	1st	13.5^{a}	13.4^{a}	2.6^{a}	13.6^{a}	3.6^{a}	2.5^{a}	2.8^{a}	3.2^{a}	6.9^{a}	7.0^{a}	9.0^{a}
	3rd	33.4^{ab}	27.8^{abc}	17.2^{cd}	29.6^{abc}	41.2^{a}	10.8^{d}	12.4^{d}	16.4^{cd}	26.6^{bc}	23.2^{bcd}	21.2^{bcd}
	5th	D	42.4^{b}	32.0^{bc}	40.7^{b}	30.6^{bc}	22.4^{c}	26.0^{c}	28.2^{bc}	40.7^{b}	34.1^{bc}	31.3^{bc}
Drumstick	1st	9.0^{a}	8.6^{a}	1.2^{a}	8.4^{a}	2.6^{a}	3.1^{a}	2.4^{a}	2.4^{a}	6.4^{a}	4.8^{a}	1.9^{a}
	3rd	28.0^{b}	27.2^{b}	11.9^{b}	21.1^{b}	14.4^{b}	17.2^{b}	14.8^{b}	24.2^{b}	23.7^{b}	24.6^{b}	24.3^{b}
	5th	D	41.8^{b}	42.2^{b}	39.6^{b}	24.8^{b}	26.2^{b}	26.3^{b}	31.3^{b}	35.6^{b}	36.0^{b}	33.0^{b}

D- Damaged
* The treatments with same letter as superscript are on par.

Table.7. Effect of packaging and storage on PLW (%) of fresh cut vegetables under low temperature storage.

Vegetables	Days	Treatments										
		T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
	1st	3.6^{b}	0.8^{b}	2.1^{b}	0.8^{b}	1.3^{b}	1.0^{b}	0.9b	6.6^{b}	3.0^{b}	2.6^{b}	2.4^{b}
EFY	5th	28.7^{a}	10.6^{b}	16.0^{b}	9.6^{b}	3.1^{b}	5.7^{b}	9.8^{b}	19.0^{b}	21.0^{b}	15.9^{b}	10.0^{b}
	9th	D	16.8^{d}	D	21.0^{d}	14.8^{d}	16.4^{d}	16.5^{d}	40.4^{c}	76.6^{b}	54.0^{c}	20.3^{b}
Okra	1st	9.4^{a}	5.9^{a}	1.8^{a}	6.7^{b}	0.7^{a}	1.6^{c}	1.4^{c}	1.2^{c}	6.2^{b}	4.2^{a}	0.4^{c}
	5th	18.4^{a}	20.6^{a}	7.0^{a}	20.2^{a}	5.8^{a}	D	7.4^{a}	8.9^{a}	13.2^{a}	12.9^{a}	7.8a
	9th	D	D	22.6^{a}	D	20.1^{a}	D	21.0^{a}	D	D	D	23.2^{a}
Brinjal	1st	14.0^{ab}	9.6^{ab}	2.8^{a}	7.3^{b}	1.2^{a}	1.0^{b}	1.9^{a}	1.3^{b}	2.4^{b}	2.0^{b}	0.4^{b}
	5th	23.4^{a}	17.7^{a}	5.2^{a}	15.2^{a}	8.6^{a}	4.5^{a}	4.0^{a}	7.6^{a}	9.5^{a}	11.6^{a}	6.0^{a}
	9th	37.4a	D	21.0b	D	25.8b	20.7b	24.0b	22.5b	D	D	26.5b
Cowpea	1st	7.3^{a}	5.1^{bc}	1.0^{e}	5.8^{ab}	0.9^{e}	1.0^{e}	1.7^{de}	1.3^{de}	4.0^{bc}	3.2^{cd}	0.4^{e}
	5th	29.7^{a}	19.1^{b}	8.8^{d}	17.6^{b}	8.9^{d}	8.2^{d}	8.0^{d}	10.0^{d}	19.2^{b}	13.0^{c}	12.0^{c}
	9th	D	D	21.0^{c}	D	20.8^{c}	D	22.8^{bc}	D	D	D	24.4^{b}
	1st	7.3^{a}	5.1^{a}	1.0^{a}	5.8^{a}	0.9^{a}	1.0^{a}	1.7^{a}	1.3^{a}	4.0^{a}	3.2^{a}	0.4^{a}
Ashgourd	5th	29.7^{a}	19.1^{ab}	8.8^{b}	17.6^{ab}	8.9^{b}	8.2^{b}	8.0^{b}	10.0^{b}	19.2^{ab}	13.0^{b}	12.0^{b}
	9th	D	D	21.0^{b}	D	20.8^{b}	D	22.8^{b}	D	D	D	24.4^{b}
Pumpkin	1st	7.0^{a}	4.2^{a}	0.6^{a}	7.4^{a}	1.2^{a}	1.0^{a}	1.4^{a}	3.0^{a}	3.8^{a}	3.6^{a}	0.6^{a}
	5th	31.7^{a}	13.2^{a}	7.4^{a}	14.6^{a}	7.1^{a}	6.0^{a}	6.2^{a}	8.7^{a}	13.8^{a}	11.9^{a}	9.6^{a}
	9th	D	D	16.3^{b}	D	13.1^{b}	D	D	17.0^{b}	D	D	17.9^{b}
Drumstick	1st	3.0^{c}	4.8^{c}	0.5^{c}	1.9^{c}	3.0^{b}	6.0^{a}	0.7^{c}	6.0^{a}	1.6^{c}	2.8^{c}	0.4^{c}
	5th	10.4^{a}	10.9^{a}	8.8^{a}	9.6^{a}	6.7^{a}	7.0^{a}	8.0^{a}	4.5^{a}	11.1^{a}	11.6^{a}	7.9^{a}
	9th	D	D	21.2^{b}	18.8^{b}	20.0^{b}	D	D	D	D	D	23.4^{b}

* The treatments with same letter as superscript are on par.

Table.8. Effect of packaging and storage on PLW (%) of fresh cut vegetables under irradiation in combination with low temperature.

Vegtables	Days	Treatments					
		T0	T1	T2	T3	T4	T5
EFY	1st	0.33^{a}	1.0^{a}	1.2^{a}	1.7^{a}	1.0^{a}	3.0^{a}
	5th	14.8^{c}	15.2^{bc}	18.1^{ab}	20.4^{a}	20.6^{a}	19.2^{a}
	9th	29.3^{cd}	29.7^{cd}	31.4^{bc}	33.2^{ab}	35.0^{a}	27.4^{d}
Okra	1st	0.8^{a}	1.1^{a}	2.1^{a}	1.5^{a}	2.3^{a}	1.6^{a}
	5th	18.1^{a}	14.8^{b}	19.3^{a}	15.0^{b}	18.0^{a}	18.7^{a}
	9th	26.1^{b}	25.3^{b}	32.2^{a}	30.0^{a}	31.1^{a}	32.9^{a}
Brinjal	1st	0.9^{a}	0.5^{a}	2.1^{a}	2.0^{a}	0.7^{a}	1.1^{a}
	5th	14.8^{b}	16.2^{b}	11.0^{c}	19.2^{a}	8.8^{c}	15.6^{b}
	9th	27.2^{ab}	26.3^{ab}	27.8^{ab}	28.6^{a}	25.2^{b}	28.1^{a}
Pumpkin	1st	2.9^{a}	1.5^{a}	2.4^{a}	3.0^{a}	5.0^{a}	5.6^{a}
	5th	20.7^{ab}	16.6^{bc}	13.6^{c}	18.4^{abc}	20.6^{ab}	23.1^{a}
	9th	32.1^{a}	35.1^{a}	37.4^{a}	36.6^{a}	36.8^{a}	35.6^{a}
Cowpea	1st	2.0^{a}	2.1^{a}	4.6^{a}	2.4^{a}	1.9^{a}	1.7^{a}
	5th	8.8^{a}	11.8^{a}	10.2^{a}	8.5^{a}	11.6^{a}	11.2^{a}
	9th	24.4^{a}	23.1^{a}	25.4^{a}	22.5^{a}	22.3^{a}	21.6^{a}
Ashgourd	1st	1.3^{a}	2.9^{a}	3.5^{a}	1.9^{a}	2.1^{a}	1.5^{a}
	5th	15.8^{a}	14.7^{ab}	13.0^{bc}	11.2^{c}	10.7^{c}	14.6^{ab}
	9th	30.2^{a}	24.0^{bc}	26.0^{b}	21.8^{c}	23.8^{bc}	26.4^{b}
Drumstick	1st	4.4^{b}	0.9^{b}	3.1^{b}	3.8^{a}	3.0^{b}	1.4^{b}
	5th	21.6^{a}	8.4^{a}	10.0^{a}	21.2^{a}	12.2^{a}	9.0^{a}
	9th	33.6^{a}	23.6^{a}	24.4^{a}	31.0^{a}	23.4^{a}	24.8^{a}

* The treatments with same letter as superscript are on par.

Table.9. Effect of packaging and storage on microbial population of fresh cut vegetables under ambient condition.

Vegetables	Microbes	Treatments										
		T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Cowpea	Bacteria	9.4^{a}	8.5^{b}	3.2^{g}	4.0^{e}	2.4^{h}	5.7^{d}	3.9^{ef}	7.2^{c}	7.6^{c}	8.5^{b}	3.4^{fg}
	Fungi	7.2^{b}	6.4^{c}	2.3^{gh}	5.1^{d}	2.6^{g}	3.4^{f}	2.0^{h}	6.7^{c}	6.6^{c}	7.8^{a}	4.3^{e}
	Yeast	5.8^{a}	4.8^{b}	2.2^{e}	2.6^{e}	2.1^{e}	2.8^{d}	2.3^{e}	3.7^{c}	5.7^{a}	5.8^{a}	3.7^{c}
EFY	Bacteria	8.7^{b}	8.1^{bc}	5.2^{d}	7.7^{c}	3.0^{f}	3.0^{f}	2.9^{f}	4.1^{e}	8.6^{b}	11.6^{a}	8.8^{b}
	Fungi	9.7^{bc}	9.8^{bc}	2.6^{e}	10.2^{b}	2.0^{e}	3.2^{e}	2.8^{e}	9.2^{c}	9.5^{bc}	12.1^{a}	5.3^{d}
	Yeast	5.5^{b}	5.7^{b}	3.8^{c}	4.4^{c}	1.5^{e}	2.1^{e}	1.7^{e}	3.0^{d}	5.1^{b}	9.3^{a}	3.0^{d}
Okra	Bacteria	12.6^{c}	10.6^{e}	3.2^{g}	9.7^{d}	3.6^{g}	12.3^{ab}	12.6^{a}	6.8^{e}	10.0^{cd}	11.9^{b}	5.4^{f}
	Fungi	5.9^{f}	6.4^{ef}	2.7^{h}	6.8^{e}	3.6^{g}	8.02^{cd}	8.8^{b}	7.6^{d}	8.4^{bc}	9.9^{a}	8.2^{bcd}
	Yeast	6.6^{abc}	5.6^{abc}	2.1^{c}	5.5^{abc}	2.4^{c}	6.5^{abc}	8.5^{ab}	5.2^{abc}	8.2^{ab}	9.7^{a}	3.6^{bc}
Brinjal	Bacteria	9.7^{a}	7.2^{d}	3.0^{i}	5.1^{f}	4.4fg	7.8^{cd}	3.4^{hi}	4.1^{gh}	8.4^{bc}	9.1^{ab}	6.1^{e}
	Fungi	8.9^{b}	6.0^{c}	3.6^{f}	3.4^{fg}	4.6^{de}	4.9^{d}	4.2^{e}	3.1^{g}	5.7^{c}	9.5^{a}	5.9^{c}
	Yeast	5.4^{ab}	3.8^{c}	1.8^{e}	2.0^{e}	2.3^{de}	4.7^{b}	2.3^{de}	2.9^{d}	5.7^{a}	5.1^{ab}	5.0^{ab}
Ashgourd	Bacteria	13.1^{a}	12.7^{ab}	7.4^{de}	12.5^{ab}	6.6^{e}	7.7^{d}	7.7^{d}	10.5^{c}	11.9^{b}	9.8^{c}	3.9^{f}
	Fungi	9.7^{b}	9.1^{b}	5.8^{d}	9.2^{b}	5.6^{d}	5.2^{d}	3.8^{e}	11.9^{a}	8.0^{c}	11.2^{a}	5.5^{d}
	Yeast	8.4^{b}	5.6^{d}	4.5^{e}	6.4^{c}	4.0^{fg}	3.9^{g}	3.9^{g}	9.0^{a}	4.4^{ef}	6.7^{c}	4.5^{e}
Pumpkin	Bacteria	12.8^{a}	11.2b	2.4h	8.0^{d}	2.5^{h}	3.8^{g}	5.0^{e}	8.7^{c}	4.5^{f}	7.8^{d}	2.5^{h}
	Fungi	9.3^{a}	8.9^{a}	2.0^{f}	7.2^{b}	2.0^{f}	2.6^{e}	3.2^{d}	6.9^{b}	3.3^{d}	5.3^{c}	1.3^{g}
	Yeast	8.5^{a}	7.3^{b}	1.8^{fg}	6.5^{c}	2.1^{ef}	2.5^{e}	2.4^{e}	6.5^{c}	2.4^{e}	4.5^{d}	1.6^{g}
Drumstick	Bacteria	9.7^{a}	7.6^{c}	2.5^{g}	7.5^{c}	2.4^{g}	5.1^{d}	3.9^{e}	7.7^{c}	4.4^{e}	8.6^{b}	3.3^{f}
	Fungi	6.4^{b}	5.5^{d}	2.0^{h}	5.9^{c}	2.3^{gh}	3.4^{f}	2.7^{g}	5.3^{d}	4.3^{e}	6.9^{a}	2.5^{g}
	Yeast	7.6^{a}	6.1^{c}	1.3^{g}	4.6^{d}	1.9^{f}	2.5^{e}	2.5^{e}	4.4^{d}	2.8^{e}	6.9^{b}	2.6^{e}

* The treatments with same letter as superscript are on par.

Under low temperature storage highest number of microbes was in T0 (5.7×10^6, 4.4×10^3, and 4.6×10^3 $cfug^{-1}$ respectively for bacteria, fungi and yeast). T10 showed least bacterial count (1.9×10^6 $cfug^{-1}$) but fungi and yeast count was less in T4 (1.1×10^3 $cfug^{-1}$ and 1.5×10^3 $cfug^{-1}$ respectively) (Table 10).

Irradiation did not have any significant impact on shelf life, but it was effective in reducing microbial population in minimally processed cowpea. Increasing dose of irradiation was found to decrease microbial population. Highest count (5.5×10^6, 5.8×10^3 and6.5×10^3 $cfug^{-1}$respectively for bacteria, fungi and yeast) was in control samples (without irradiation). It was least (2.8×10^6, 2.8×10^3 and 2.4x103 $cfug^{-1}$) in T5 (200 Gy) (Table 11).

4.4.2 Elephant foot yam

4.4.2.1. *Visual parameters*

Colour and appearance were retained best in T4 under both ambient and low temperature storage. Under ambient condition, rotting was observed in T5 and T6 (Vaccum packaged PP and PE cover) within one day of storage. Black fungal growth was noticed in T7 and T9 after two days of storage. Periderm formation was observed in all samples of fresh cut elephant foot yam. Control treatments and thermocol packed samples showed shriveling on the next day of storage.

Under low temperature storage also better colour stability was observed in samples packed in unventilated PP cover. Shriveling was relatively more in control samples and those packed in perforated film bags.

Irradiation did not have any positive impact on visual attributes of fresh cut elephant foot yam stored under low temperature.

4.4.2.2. *Shelf life*

Under ambient conditions, all samples become unmarketable after five days of storage. The treatment T4 recorded longest shelf life of five days, followed by T2 (4 days). But control samples, as well as samples packed in thermocol tray became unmarketable after one day of storage. All other treatments registered two days shelf

Table.10. Effect of packaging and storage on microbial population of fresh cut vegetables under low temperature.

Vegetables	Microbes	Treatments										
		T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Cowpea	Bacteria	5.7^{a}	3.7^{c}	2.2^{d}	4.5^{b}	2.0^{d}	2.2^{d}	2.2^{d}	1.6^{d}	5.2^{a}	5.6^{a}	1.9^{d}
	Fungi	4.4^{a}	2.6^{cd}	1.8^{ef}	2.4^{d}	1.1^{g}	2.2^{de}	1.1^{g}	3.3^{b}	2.5^{cd}	3.0^{bc}	1.4^{fg}
	Yeast	4.6^{a}	2.1^{d}	1.9^{de}	3.8^{b}	1.5^{f}	1.7^{ef}	1.9^{def}	1.9^{def}	3.4^{c}	4.6^{a}	1.7^{ef}
EFY	Bacteria	4.5^{ab}	4.6^{a}	3.9^{abc}	4.6^{a}	1.7^{d}	3.4^{c}	2.1^{d}	2.2^{d}	4.5^{ab}	3.7^{bc}	2.2^{d}
	Fungi	4.4^{b}	3.1^{c}	1.5^{ef}	2.9^{cd}	1.9^{ef}	3.2^{c}	2.1^{de}	2.0^{def}	4.7^{ab}	5.6^{a}	1.1^{f}
	Yeast	3.4^{ab}	3.1^{bc}	3.6^{ab}	3.1^{bc}	2.2^{de}	3.7^{ab}	2.4^{cd}	1.5^{e}	4.0^{a}	4.2^{a}	2.1^{de}
Okra	Bacteria	5.3^{a}	2.5^{c}	1.2^{d}	2.5^{c}	1.5^{d}	1.4^{d}	2.7^{c}	2.4^{c}	3.3^{b}	5.1^{a}	3.4^{b}
	Fungi	2.6^{cd}	2.6^{cd}	3.5^{b}	2.1^{d}	2.5^{cd}	2.4^{cd}	2.4^{cd}	1.9^{d}	3.0^{bc}	5.3^{a}	1.9^{d}
	Yeast	4.4^{a}	1.6^{a}	0.9^{a}	2.0^{a}	1.3^{a}	1.1^{a}	1.5^{a}	1.9^{a}	2.0^{a}	4.4^{a}	2.4^{a}
Brinjal	Bacteria	6.0^{a}	6.8^{a}	1.3^{d}	3.7^{bc}	1.9^{d}	3.7^{bc}	1.6^{d}	1.8^{d}	3.2^{c}	4.5^{b}	3.6^{bc}
	Fungi	4.8^{a}	4.5^{a}	1.4^{de}	2.8^{c}	1.2^{e}	1.8^{d}	1.8^{d}	3.7^{b}	2.8^{c}	3.2^{c}	1.7^{d}
	Yeast	4.2^{a}	3.6^{ab}	1.1^{f}	3.3^{bc}	1.5^{ef}	2.5^{cd}	1.2^{f}	2.8^{bcd}	2.2^{de}	3.1^{bc}	2.1^{de}
Ashgourd	Bacteria	8.9^{a}	5.8^{b}	4.3^{c}	4.1^{c}	3.4^{cd}	2.1^{ef}	2.6^{def}	2.4^{ef}	3.1^{de}	2.3^{ef}	1.9^{e}
	Fungi	5.5^{a}	4.1^{b}	2.3^{def}	3.8^{b}	2.8^{cd}	1.7^{fg}	1.4^{g}	2.5^{de}	1.8^{efg}	3.4^{bc}	1.2^{g}
	Yeast	3.7^{a}	2.1^{c}	3.0^{b}	2.1^{c}	3.2^{b}	1.9^{cd}	2.1^{c}	2.0^{c}	1.4^{de}	1.7^{cde}	1.2^{e}
Pumpkin	Bacteria	5.7^{c}	5.8^{bc}	2.8^{f}	6.2^{b}	2.1^{g}	4.3^{d}	3.5^{e}	7.5^{a}	4.7^{d}	5.7^{bc}	3.6^{e}
	Fungi	4.7^{cd}	5.4^{b}	1.9^{f}	4.8^{c}	1.7^{f}	2.9^{e}	1.9^{f}	4.4^{cd}	4.3^{d}	6.5^{a}	1.3^{g}
	Yeast	2.4^{d}	3.8^{bc}	1.2^{e}	4.1^{b}	1.4^{e}	1.6^{e}	2.7^{d}	5.4^{a}	3.5^{c}	5.5^{a}	2.5^{d}
Drumstick	Bacteria	7.2^{a}	5.3^{c}	2.4^{ef}	6.3^{b}	1.8^{f}	4.1^{d}	2.7^{e}	6.0^{b}	5.7^{bc}	4.6^{d}	4.1^{d}
	Fungi	7.2^{a}	4.3^{c}	1.4^{e}	5.2^{b}	1.3^{e}	3.6^{d}	1.3^{e}	4.3^{c}	3.6^{d}	3.6^{d}	3.4^{d}
	Yeast	5.4^{a}	3.2^{b}	1.1^{f}	2.7^{c}	1.7^{e}	2.4^{cd}	2.1^{de}	2.7^{c}	2.3^{d}	2.7^{c}	2.2^{d}

* The treatments with same letter as superscript are on par.

Table.11. Effect of irradiation in combination with low temperature storage on microbial count(cfug^{-1})

Vegetables	Microbes	Irradiation (Gy) (cfug^{-1})					
		T0	T1	T2	T3	T4	T5
EFY	Bacteria	10.1^{d}	9.8^{d}	10.1^{d}	5.2^{c}	3.4^{b}	1.9^{a}
	Fungi	8.4^{d}	8.5^{d}	8.7^{d}	6.6^{c}	3.1^{b}	1.8^{a}
	Yeast	9.2^{d}	9.0^{d}	7.8^{d}	4.7^{c}	2.9^{b}	2.0^{c}
Okra	Bacteria	7.9^{c}	8.2^{cd}	8.7^{d}	4.9^{b}	3.3^{a}	2.7^{a}
	Fungi	1.0^{c}	7.2^{d}	8.3^{c}	4.9^{c}	2.6^{b}	1.7^{a}
	Yeast	6.2^{c}	5.8^{c}	6.2^{c}	4.2^{b}	2.6^{a}	2.3^{a}
Brinjal	Bacteria	9.0^{c}	7.3^{d}	4.6^{c}	3.2^{b}	2.5^{a}	8.8^{e}
	Fungi	6.8^{d}	5.5^{c}	4.9^{c}	3.7^{b}	1.9^{a}	7.5^{d}
	Yeast	6.2^{e}	5.4^{d}	4.2^{c}	2.6^{b}	1.6^{a}	7.6^{f}
Cowpea	Bacteria	5.5^{c}	6.1^{d}	5.6^{c}	4.4^{b}	3.0^{a}	2.8^{a}
	Fungi	5.8^{d}	5.6^{d}	4.7^{c}	4.3^{bc}	4.0^{b}	2.8^{a}
	Yeast	4.3^{c}	6.5^{d}	4.0^{c}	3.5^{b}	2.7^{a}	2.4^{a}
Ashgourd	Bacteria	4.7^{d}	4.4^{d}	3.6^{c}	3.0^{b}	2.7^{b}	2.0^{a}
	Fungi	3.9^{b}	2.7^{a}	2.1^{a}	1.9^{a}	1.5^{a}	1.2^{a}
	Yeast	3.3^{b}	2.3^{a}	2.0^{a}	2.3^{a}	2.4^{a}	2.5^{a}
Pumpkin	Bacteria	5.6^{e}	4.6^{d}	3.7^{c}	2.9^{b}	2.6^{b}	1.8^{a}
	Fungi	3.6^{d}	2.8^{c}	2.7^{c}	2.1^{b}	1.6^{ab}	1.2^{a}
	Yeast	4.0^{e}	3.2^{c}	2.5^{c}	1.5^{b}	1.3^{ab}	0.9^{a}
Drumstick	Bacteria	4.8^{d}	5.0^{d}	4.0^{c}	3.7^{c}	3.3^{b}	2.0^{a}
	Fungi	3.8^{e}	4.0^{e}	2.8^{d}	2.4^{c}	1.9^{b}	1.6^{a}
	Yeast	3.1^{d}	2.7^{d}	3.5^{d}	2.3^{c}	1.6^{b}	1.0^{a}

life. Significant physiological weight loss was observed under all storage conditions, but it was higher under ambient conditions. Samples packed in perforated PP cover (T3) showed maximum (68.2%) weight loss and vaccum packaged samples (T6) minimum weight loss (31.0%) (Table 6).

Minimally processed EFY packed in unventilated PP cover and stored under low temperature remained in marketable condition upto ten days when kept under refrigeration. Shelf life was the least in control samples (four days), followed by samples in areca sheath tray and thermocol tray (five days). Weight loss was minimum in samples stored under low temperature compared to ambient conditions (Table 7). Among treatments, weight loss was highest in T3 (21.0%) and lowest in T4 (14.8%).

Shelf life was not increased in irradiated samples as compared to samples stored under refrigertion. Shelf life was increased with increase in dose of irradiation. Samples irradiated at 200 Gy registered a shelf life of eight days as compared to six days for samples irradiated at 25 Gy.

4.4.2.3 ***Microbial count***

Packaging and storage significantly reduced microbial population as compared to control. Compared to other two storage systems, microbial count was highest in samples stored under ambient conditions. Microbial count was highest in samples packed in areca sheath tray (11.6 $x10^6$, 12.1 $x10^3$ and 9.3 $x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively) (Table 9).

Microbial population was significantly reduced in EFY under refrigeration. Highest bacterial count was in samples packed in perforated PP films (4.6 $x10^6$ $cfug^{-1}$) and least (2.0 $x10^6$ $cfug^{-1}$) in T10 (polystyrene tray wrapped with cling film). Fungal and yeast count was highest (5.6 $x10^3$ $cfug^{-1}$ and 4.2 $x10^3$ $cfug^{-1}$ respectively) in T9 and least in T10 (1.1 $x10^3$ $cfug^{-1}$ each for fungi and yeast), followed by T7.

Irradiation treatment could reduce the microbial count in fresh cut EFY significantly. Control (non irradiated samples) recorded highest microbial count (10.1

$\times 10^6$, 8.4 $\times 10^3$ and 9.2 $\times 10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively) (Table 10). Samples irradiated at dose of 200 Gy (T5) registered a count of 1.9 $\times 10^6$ bacteria, 1.8 $\times 10^3$ fungi and 2.0 $\times 10^3$ $cfug^{-1}$ yeast.

4.4.3 Okra

4.4.3.1 *Visual parameters*

Under ambient conditions rotting and softening was observed in vaccum packaged samples one day after storage itself. Slight browning and shriveling was observed in T0, T1 and T3 from the same day of storage. Samples packed in thermocol tray exhibited shriveling from second day onwards. Black fungal growth was observed in T9 after two days of storage.

Overall appearance was best in T2 (okra packed in unventilated PE cover) followed by T4 (unventilated PP cover) and T10 (polystyrene tray with cling film). Under refrigerated storage also overall appearance was better for cut okra packed in unventilated PE cover.

Visual appearance was not improved with irradiation treatment. Slight reduction in green colour was observed in fresh cut okra with increased doses of irradiation. Fresh colour was preserved best at lower dose of irradiation.

4.4.3.2. *Shelf life*

Minimally processed okra packed in unventilated PP cover recorded four days shelf life under refrigeration. Control samples became unmarketable after one day of storage. Physiological weight loss was highest in samples stored under ambient conditions. Significant difference in weight loss was observed between treatments. Control samples showed maximum PLW under all storage conditions (Table 6). Under ambient condition, maximum weight loss was in T3 (41.7%) and minimum ((28.2%) in T2.

Under low temperature storage longest shelf life (nine days) was in samples packed in T2 (unventilated PE cover) followed by T4 (eight days) and T10 (seven days). All other treatments had shelf life of five to six days. Shelf life was least (three days) in control samples. Under refrigeration also significant weight loss was observed but it was lower than at ambient condition (Table 7). Highest PLW was in T0 (23.2%) and lowest (20.1 %) in T4 (unventilated PP cover).

Shelf fife was not further extended by combination of irradiation and low temperature storage.. Non irradiated okra packed in PP cover registered a shelf life of nine days under refrigeration, whereas okra packed in PP cover and subjected to irradiation at a dose of 200 Gy had a shelf life of eight days only under the same conditions.

4.4.3.3 *Microbial count*

Significant reduction in microbial count was noticed in all the packed materials under ambient condition. Bacterial count was highest (12.6 $x10^6$ $cfug^{-1}$) in T6 (vaccum packaged PP cover). Fungi and yeast count was maximum in T9 (9.9 $x10^3$ $cfug^{-1}$ and 9.7 $x10^3$ $cfug^{-1}$ respectively). Least number of microbes was observed in T2 (3.2 $x10^6$, 2.7 $x10^3$ and 2.1 $x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively) (Table 9).

In low temperature storage highest bacterial and yeast count was in T0 (5.3 $x10^6$ $cfug^{-1}$ and 4.4 $x10^3$ $cfug^{-1}$) and least in T2 (1.2 $x10^6$ $cfug^{-1}$ and 0.9 $x10^3$ $cfug^{-1}$) (Table 10). Fungal growth was maximum in T9 (5.3 $x10^3$ $cfug^{-1}$) and minimum in T7 and T10 (1.9 $x10^3$ $cfug^{-1}$).

Fresh cut okra packed in PP cover irradiated at a dose of 200 Gy recorded a microbial count of 2.7 $x10^6$, 1.7 $x10^3$ and 2.3 $x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively, when kept under refrigeration(Table 11).

4.4.4 Brinjal

4.4.4.1. *Visual parameters*

Irrespective of the packaging materials, colour change was noticed in all samples under ambient conditions. Better colour stability was noticed in fresh cut brinjal packed in unventilated PE cover. Browning was severe in control samples, which was evident immediately after cutting. T1 and T3 registered browning from second day onwards. Shriveling was observed in samples packed in thermocol tray from second day of storage.

Compared to ambient conditions, over all appearance was best for samples under refrigeration. In low temperature storage, slight colour change was observed in T0, T1 and T3 after three days of storage. Colour was retained best in samples packed in unventilated PE cover and kept under refrigeration. Shriveling was very high in control and ventilated samples. Samples packed in thermocol tray exhibited shriveling from fourth day of storage. Samples packed in polystyrene tray with own lid exhibited colour change and sliminess after sixth day of storage. Black fungal growth was observed in samples packed in areca sheath tray. Rotting was very high in vaccum packaged brinjal both under ambient and low temperature storage.

Combination of irradiation and low temperature storage was not found to be very effective in maintaining visual qualities. Overall appearance and firmness was better in samples irradiated at a dose of 100 Gy. Irradiation at a dose above 100 Gy adversely affected visual quality as evidenced by rotting and softening of cut pieces. Textural quality was poor in samples exposed to irradiation dose of 200 Gy.

4.4.4.2. *Shelf life*

Under ambient conditions, shelf life was comparatively more (four days) for samples packed in unventilated PE (T2). All other treatments recorded a shelf life of two days. Control samples became unmarketable within few hours after storage. Significant weight loss was observed in all the treatments under ambient conditions (Table 6). Maximum weight loss (77.4%) was in T3 and minimum (28.2%) in T2 (unventilated PE).

Shelf life was longest in T2 (ten days), followed by T4 (nine days). Control samples exhibited unmarketable changes after four days of storage. Shelf life of vacuum packaged samples was relatively less (six days). After nine days of storage, maximum weight loss was in T0 (36.0%) and minimum in T2 (17.3 %), which was on par with T7 (18.5%) (Table 7).

Shelf life was reduced with increase in irradiation dose. Longest shelf life (nine dasys) was in samples irradiated at a dose of 100 Gy, whereas samples irradiated at 200 Gy become unmarketable four days after storage.

4.4.4.3. ***Microbial count***

Microbial count was highest in fresh cut brinjal samples stored under ambient conditions and least in samples under low temperature. Under ambient conditions, maximum count of bacteria (9.7 x10^6 cfug^{-1}) was in control (unpacked) samples, fungal count was highest in T9 (9.52x10^3 cfug^{-1}) and yeast count in T8 (5.7). Samples packed in unventilated PE cover showed least number of microbes (3.0 x10^6, 3.6 x10^3 and 1.8 x10^3 cfug^{-1} for bacteria, fungi and yeast respectively).

Microbial count was further reduced under low temperature storage. Significant difference in microbial count was noticed between different treatments. Maximum count was in control samples (6.6x10^6, 4.8x10^3 and 4.2x10^3 cfug^{-1} respectively for bacteria, fungi and yeast.) and minimum in samples packed in T2 (1.3 x10^6, 1.2 x$10^3$and 1.1 x10^3 cfug^{-1} respectively) (Table 10).

In irradiated samples minimum count was in T4 (2.5x$10^{6,}$ 1.9 x$10^3$and 1.6 x10^3 cfug^{-1}) and maximum count in T5 (8.8 x10^6, 7.5 x10^3 and 7.6 x10^3 cfug $^{-1}$ for bacteria, fungi and yeast respectively) (Table 11).

4.4.5. Ashgourd

4.4.5.1. ***Visual parameters***

There was no marked colour change during storage of fresh cut ashgourd. Shriveling was the major problem associated with storage of fresh cut ashgourd under ambient conditions. Control and samples packed in perforated PP and PE cover showed shriveling from second day of storage. Samples vacuum packaged in both PE and PP cover exhibited rotting from second day of storage. Overall appearance was better in samples packed in T4 (PP cover). Sliminess was observed in samples packed in polystyrene tray covered with own lid (T7). Black fungal growth was noticed in T9 from third day of storage.

Better appearance and colour stability was observed in samples stored under low temperature. But shriveling was observed in T0 from third day of storage. Treatments T1 and T3 also exhibited shriveling symptoms after fourth day of storage. Visual quality was better for samples packed in polystyrene tray and wrapped with cling film (T10) followed by samples packed in unventilated PP cover.High dose of irradiation (200 Gy) preserved visual qualities better.

4.4.5.2. ***Shelf life***

Under ambient condition, longest shelf life was observed in T4 (five days). Vaccum packed samples showed unmarketable changes within one day of storage. Maximum PLW was noticed in T10 (41.3%) and minimum in T7 (32.3 %)

Fresh cut ashgourd samples packaged in unventilated PP cover remained in marketable condition even after ten days of storage under refrigeration. Control sample recorded only three days shelf life. Shelf life was also short for vaccum packed samples. Among the storage systems, PLW was least under low temperature and highest in ambient conditions. Samples packed in unventilated PP cover (T4) and kept under refrigeration showed least PLW (20.8%). After nine days storage, maximum PLW was in T10 (24.4%) (Table 7).

Shelf life was high in samples irradiated at a dose 200 Gy than with lower doses. There was no significant difference between irradiated samples in physiological loss in weight.

4.4.5.3. ***Microbial count***

Highest microbial count was in samples stored under ambient condition. Control samples showed maximum bacterial count (13.1 x10^6 cfug^{-1}) where as least count (3.9 x10^6 cfug^{-1}) was in T10 (polystyrene tray with cling film). Significant difference in fungal count was also observed between treatments. Highest count (7.8 x10^3 cfug^{-1}) was in T9 and lowest (2.3 x10^3 cfug^{-1}) in T2. Maximum population of yeast was in T0 and T9 (5.8 x10^3 cfug^{-1}), which is on par with T8 (5.7 x10^3 cfug^{-1}).

Low temperature storage considerably reduced the microbial population. Among the different packing materials, T10 showed least number of microbes (1.9

$x10^6$, 1.2 $x10^3$ and 1.2 $x10^3$ $cfug^{-1}$). Highest microbial count was in control samples (8.9 $x10^6$, 5.5 $x10^3$ and 3.7 $x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively) (Table 10).

Microbial count was low in samples stored under low temperature after irradiation. Highest microbial population was in T0 (4.7 $x10^6$, 3.9 $x10^3$, 3.3 $x10^3$ $cfug^{-1}$ respectively for bacteria, fungi and yeast). Least count was noticed in samples irradiated at 200 Gy (1.2 $x10^6$, 2.0 $x10^3$ and 2.0 $x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively).

4.4.6. Pumpkin

4.4.6.1 *Visual appearance*

Visual quality was highly affected by elevated temperature. Under ambient conditions shriveling was observed in control as well as samples packed in ventilated packages after one day of storage. Control samples showed shriveling from the second day of storage. Fungal growth was associated with samples packed in areca sheath tray and wrapped with cling film. Overall appearance was best in samples packed in unventilated PP cover (T4) and unventilated PE cover (T2)

Better retention of colour and appearance was observed in samples stored under low temperature. Among the packaging materials used, T4 (unventilated PP) showed best results. Fungal growth was observed in T9 after sixth day of storage. Visual quality was reduced with increase in storage time. Shriveling was more in samples wrapped in thermocol tray with cling film. Visual quality was not improved by irradiation treatment.

4.4.6.2 *Shelf life*

All samples stored under ambient conditions became unmarketable within five days. Samples packed in unventilated PP cover showed longest shelf life (five days). Least shelf life was in control samples (one day) followed by samples in T1 and T3 (two days). Significant weight loss was observed in different packaging materials. Compared to other cut vegetables. PLW was less in pumpkin. Maximum weight loss was observed in T1 (42.4%) and minimum (22.4%) in T4.

Longer shelf life was registered in samples stored under refrigeration as compared to ambient condition. Maximum shelf life of eleven days was observed for samples packed in unventilated PP cover (T4) followed by unventilated PE cover (T2) and T10 (polystyrene wrapped with cling film. Significant weight loss was observed under all storage condition. Maximum weight loss was in ambient conditions as compared to low temperature. Under refrigeration maximum PLW was in T10 (17.9%) followed by T7 (17.0%) and minimum in T4 (13.4 %)after nine days of storage (Table 7).

Shelf life of minimally processed pumpkin was not extended by combination treatment of irradiation and low temperature. Radiation dose did not have any significant impact on weight loss. All the treatments showed same trend throughout the storage.

4.4.6.2. ***Microbial count***

Maximum microbial count was in samples stored under ambient condition. But significant difference was observed between different packing materials in reducing microbial count. Highest number of microbes was present in control samples. A count of (12.8 $x10^6$, 9.3 $x10^3$ and 8.5 $x10^3$ $cfug^{-1)}$ and least count were in T10 (2.4 $x10^6$, 1.3 $x10^3$ and 1.6 $x10^3$ $cfug^{-1}$ for bacteria, fungi and yeast respectively).

Compared to ambient condition lower microbial population was observed under low temperature storage. In cold storage, bacterial cont was highest (7.5 $x10^6$ $cfug^{-1}$) in T7 and least in T4 (2.1 $x10^6$ $cfug^{-1}$). Fungal and yeast population was maximum in T9 (6.5 $x10^3$ $cfug^{-1}$ and 5.5 $x10^3$ $cfug^{-1}$)and minimum in T2 (1.3 $x10^3$ $cfug^{-1}$and 1.2 $x10^3$ $cfug^{-1}$) (Table 10).

Increased dose of irradiation lowered the count of microbes. Highest count of microbes was in T0 (5.6 $x10^6$, 3.6 $x10^3$ and 4.0 $x10^3$ $cfug^{-1}$ respectively for bacteria, fungi and yeast) and lowest count of 2.0×10^3, 1.6×10^3 and 1.0×10^3 $cfug^{-1}$ for bacteria, fungi and yeast respectively in T5 (200 Gy) (Table 11).

4.4.7. Drumstick

4.4.7.1. *Visual parameters*

Control samples showed shriveling after three days of storage. Fungal growth was noticed in polystyrene tray with lid after two days storage. Softening in vaccum packaged materials was noted after third day of storage. Black fungal growth was bserved in samples packed in T7 and T9 after seventh day of storage. No marked difference in visual quality was noticed among samples irradiated at different doses.

4.4.7.2. *Shelf life*

Compared to other vegetables longer shelf life was recorded by drumstick under ambient and low temperature storage. Under ambient conditions, longest shelf was in T4 (six days) and least in control (two days). Weight loss was maximum in T1 (44.8%) and minimum in T4 (24.8%)

Under low temperature storage, longest shelf life was observed in drumstick (14 days). This was significantly high when compared to other cut vegetables. Control samples became unmarketable after five days storage. Highest PLW % was noticed in samples stored under ambient conditions. Least weight loss was in less at low temperature. Least PLW was in T4 (18.8%) and highest in T10 (23.4%) after nine days storage (Table 7).

4.4.7.3. *Microbial count*

Microbial count was highest in samples packed and stored under ambient condition. Highest bacterial and yeast count was in T0 (9.7×10^6 and 7.6×10^3 $cfug^{-1}$) and least bacterial (2.4×10^6 $cfug^{-1}$) count in T4 and yeast count in T2 (1.3×10^3 $cfug^{-1}$). Fungal count was highest in T9 (6.9×10^3 $cfug^{-1}$) and lowest in T2 (2.0×10^3 $cfug^{-1}$).

In refrigerated storage, control samples recorded highest count of microbes, bacteria (7.2 x10^6 $cfug^{-1}$), fungi (7.2 x10^3) and yeast (5.4 x10^3 $cfug^{-1}$). The lowest count of microbes was in T4 (1.8 x10^6, x$10^3$and 1.1 x10^3 $cfug^{-1}$ respectively for bacteria, fungi and yeast) (Table 10).

Radiation treatment was very effective in controlling microbial population. Highest count of microbes was observed in T0 (4.8 x10^6, 3.8 x10^3 and 3.1 x10^3 $cfug^{-1}$) and least in T5 (2.0 x10^6, 1.6 x10^3 and 1.0 x10^3 $cfug^{-1}$) respectively for bacteria fungi and yeast compared to other vegetables, least change in visual attributes was observed in drumstick under all storage conditions.

4.5. Protocol for minimal processing

The different steps in minimal processing (surface sanitation of whole vegetables, prestorage dip in antimicrobial and anti browning agents and packaging and storage) was followed in each vegetable based on the superior treatments identified from the previous experiments

Longest shelf life (14 days) was observed in drumstick, followed by elephant foot yam and pumpkin (12 days) whereas the shortest shelf life was in brinjal and cowpea (nine days). Okra and ashgourd recorded an average shelf life of ten days.

Discussion

5. DISCUSSION

The concept of minimal processing is getting momentum now a days. Freshcut fruits and vegetables offer consumers highly nutritious, convenient and healthful food while still maintaining the freshness that people desire from produce. However freshcut products are perishable and subjected to fast degradation of quality when stored at inadequate temperatures as a consequence of the damage caused to the tissues during peeling, cutting, shredding and packaging. The type of handling temperature, humidity, use of modified atmosphere and low doses of radiation can influence the microenvironment and consequently the safety and quality of these products. Decrease in the rate of deterioration would greatly expand the opportunities for the industry to supply high quality fresh cut vegetables to local and export market.

5.1. IDENTIFICATION OF SANITIZING AGENTS FOR MINIMALLY PROCESSED VEGETABLES

To ensure microbiological safety of minimally processed vegetables, a disinfectant sanitation step was included as the first step in minimal processing. Efficacy of several sanitizing agents for surface decontamination of seven vegetables were evaluated under this experiment. The influence of sanitizing agents on the visual as well as keeping qualities and microbial load was also investigated. The primary purpose of chemical sanitizers is to prevent contamination of food products by maintaining low levels of microorganisms in the processing environment.

5.1.1. Visual parameters

Important consideration in quality of fresh cut items includes a consistant and fresh appearance and acceptable texture and sufficient shelf life to survive the distribution system (Schlimme, 1995). The deterioration in physical attributes (colour and firmness) is the main factor that limits the shelf life of fresh cut vegetables. Irrespective of the treatments, deterioration in visual quality with increase in storage time was observed in all the precut vegetables included in this experiment (cowpea, brinjal, okra, ashgourd, pumpkin, elephant foot yam and drumstick.) All vegetables treated with 30 ppm sodium hypochlorite (T4) exhibited minimum colour change and retained fresh like appearance. The chlorine rinse could also remove cellular contents at cut surface that may promote browning and also directly inhibit browning reactions (Brecht, *et al.*, 1993)

During storage, colour change was least in ashgourd. Browning was observed in brinjal and okra during storage. Browning was severe in control samples (rinsed with tap water). Browning at cut surface is due to oxidation of polyphenols and other substrates. Enzyme polyphenol oxidase and peroxidase catalyze these reactions. (Hanzon and Havier, 1979). Stress from the physical action during processing like wounding may affect physical appearance and visual quality. In cowpea, reduction in intensity of green colour was observed from second day of storage. Loss of fresh colour may be due to degradation of chlorophyll. This degradation of chlorophyll in fresh cut products may be initiated by wound ethylene or by free radical products of membrane lipid peroxidation (Laurila *et al.*, 1998).

In brinjal rotting was also observed in samples rinsed in tap water and mild glacial acetic acid. But it was absent in samples treated with sodium hypochlorite solution. Rotting and softening was due to contamination by microorganisms.

Shriveling was another problem in storage of minimally processed vegetables. It was comparatively higher in ashgourd, okra and cowpea .All these vegetables exhibited shriveling from the second day of storage .Low humidity and higher temperature in the surrounding environment lead to drying or wilting of the product. Motilal and Sankat (1998) reported that compared to higher temperature, minimally processed pumpkins kept at 0° C had longer shelf life and overall acceptability in terms of flavour and fresh like appearance

Periderm formation was observed in elephant foot yam from second day of storage, which may have developed as a wound healing process. Development of wound periderm and suberization of tissues adjacent to the wound is commonly observed in tuber crops like potato (Burton, 1966). But in fresh cut vegetables these responses are detrimental to the overall quality of the product.

5.1.2. Physiological loss in weight

Accelerated weight loss is a major problem with fresh cut vegetables. Excessive water loss and increased respiration is the major reason for physiological loss in weight. It may be due to combined effect of peeling and slicing of vegetables and the direct effect of room temperature. Any reduction of water vapour pressure in the atmosphere below that in the tissues result in faster water loss ultimately result in weight loss (Gaffey *et al.*, 1985).

In the present study also marked physiological loss in weight was observed in all the fresh cut vegetables, the intensity of which increased with duration of storage. In whole organs the water in the intracellular space is not directly exposed to the outside atmosphere. However cutting or peeling the vegetables expose the hydrated interior tissues and drastically increase the rate of evaporation of water, which resulted in weight loss of the cut vegetables.

Surface sanitation with either NaCl 1 % or tap water accelerated the weight loss during storage in all the vegetables. Treatment with NaCl 1% may have affected the cell wall permeability thereby increasing the weight loss in fresh cut vegetables.

5.1.3 Microbiological contamination

Microbiological contamination and growth on fresh cut vegetables is a major concern for the industry (Fain, 1996). The growth of microorganisms in fresh cut product is facilitated by plant cell injury, senescence or stress. Cells injured during minimal processing release fluid containing compounds that microbes use for nutrition. With minimal processing the increase in cut damaged surface and availability of cell nutrients provide condition that increase the number and type of

Fig.1a. Effect of sanitising agents on bacterial count in cut vegetables

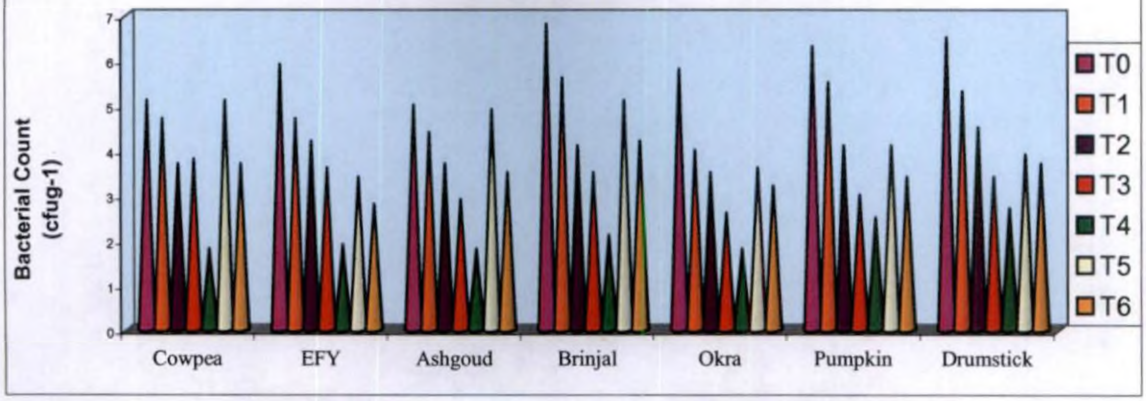


Fig.1b. Effect of sanitising agents on fungal count in cut vegetables

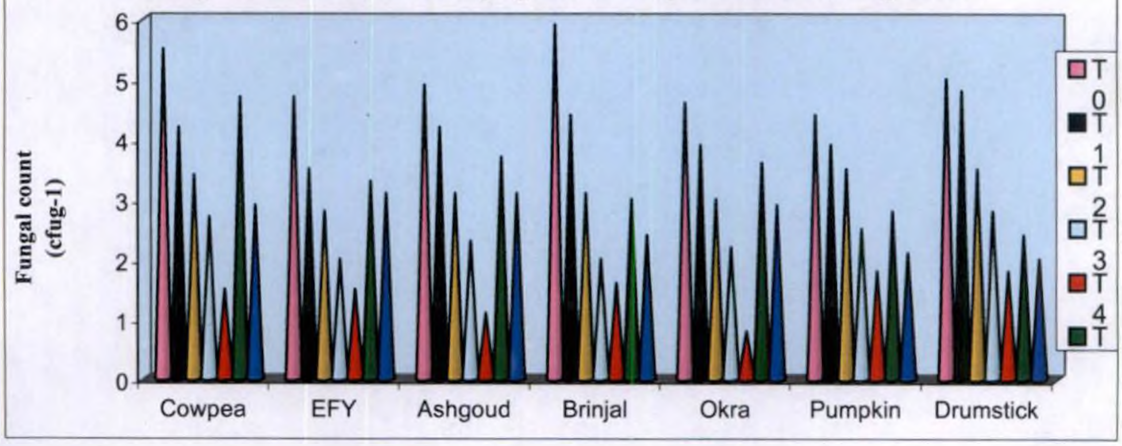
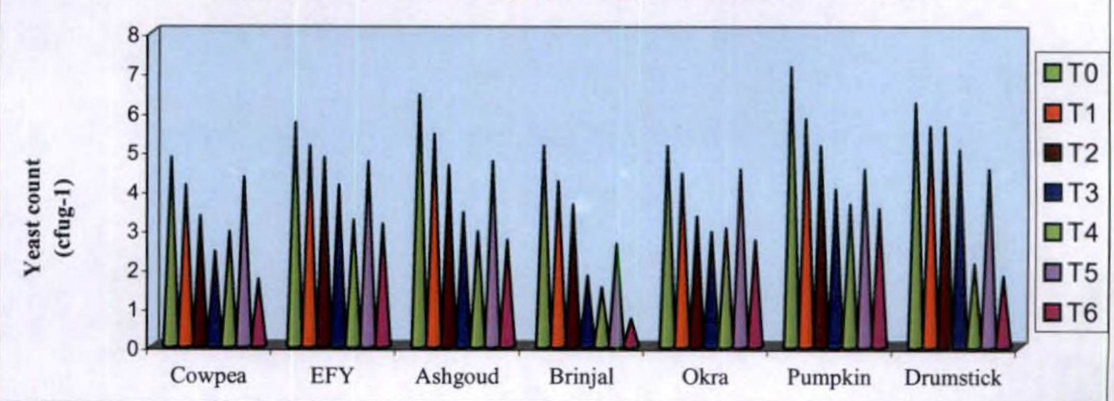


Fig. 1c. Effect of sanitising agents on yeast count in cut vegetables



microbes that develop. Further more the increased handling of the product provides greater opportunity for contamination by pathogenic organisms (Fig. 1a-1c).

In the present study washing with different sanitizing agents effectively reduced the microbial count in minimally processed vegetables compared to washing with tap water.Four fold reduction in bacterial and fungal count was registered by washing with sodium hypochlorite 30 ppm compared to control. Yeast count was reduced with NaCl 1%. Sodium chloride is a natural antimicrobial agent capable of inhibiting growth of microbes. Chloride ion in sodium hypochlorite is toxic to certain microorganisms. Adams, *et al.*, (1989) and Delaquis, *et al.*, (1999) observed a reduction upto 2 log $cfug^{-1}$ by washing lettuce leaves with water containing 100 mg/L free chlorine. Fantuzzi and Pushman (2004) observed that microbial population was reduced in minimally processed cabbage after sanitation for ten minutes with sodium hypochlorite at 200 mg/L. Reduction of aerobic micrflora of 1.6-2.4 log cycle was observed for chlorine concentration between 50 and 200 ppm (Mazollier, 1998) Sepulveda (2000) also reported low microbial count in MP pomegranate after washing with chlorinated water. Dufkova *et al.*, (2000) suggested use of sodium hypochlorite as an active antimicrobial agent in the washing bath for processed cabbage, carrot, onion and Chinese cabbage.

The results of the present study indicates that rinsing of vegetables in chlorine water (30ppm) before cutting/slicing was effective in lowering the microbial count, extending shelf life and preserving the colour of the cut products.

Surface sanitation with sodium hypochlorite was also effective in prolonging shelf life in all the precut vegetables as compared to control The shelf life attained was five days in EFY and drumstick, four days in cowpea, okra, pumpkin and three days in ashgourd and brinjal, whereas the untreated samples had only two days shelf lie under ambient condition. The cut vegetables after treatments were kept open under ambient condition. Though the treatments were effective, the storage condition must have favoured further contamination and proliferation of microbes, resulting in their faster deterioration.

The initial microbial load mainly determines product shelf life. Therefore to ensure highest microbial safety the use of low contaminated raw material is a prerequisite for subsequent reduction of the microbial load during processing. Because chlorinated water exhibits an efficient antimicrobial effect at low cost, its use in the washing process can be commonly applied in the fresh produce industry (Adams *et al.*, 1989).

5.2 STANDARDIZATION OF POSTHARVEST TREATMENTS FOR MINIMALLY PROCESSED VEGETABLES.

Fresh cut vegetables and fruits are intended to be "ready-to-eat" products and hence should be at the best of its freshness and quality when consumed .The influence of nine prestorage treatments for maintaining the quality of fresh cut products at an acceptable level through their shelf life was studied under this experiment.

5.2.1. Visual parameters

Visual quality loss is the main factor that limits the shelf life of fresh cut vegetables (Laurila *et al.,* 1998). Browning was observed in control treatments of brinjal, okra and cowpea. In brinjal, browning started a few hours after storage whereas in okra and cowpea it was observed from second day of storage. Original colour retention was better in samples dipped in a solution containing KMS 0.1% and ascorbic acid 0.1%. Browning was less severe in brinjal slices immersed in 0.2% cysteine. Dornantes and Chiratt (1998) have reported that colour was preserved best in avocado slices dipped in 0.2% L. cysteine.

Enzymatic browning represents the major challenge in fresh cut products. Poly phenol oxidase, the enzyme that catalyse the formation of o-quinone from o-diphenols, beginning the sequence of reactions leading to polymerization and formation of brown phenolic pigments in vegetable tissues is active at a pH 4.5 (Whitaker, 1994). Acidulants like ascorbic acid or citric acid are capable of lowering the product pH and inhibiting PPO activity. According to Kim *et al.*, (1993), another strategy for inhibiting browning is to add chemicals that act as reducing agents since browning involves oxidation reactions. Ascorbic acid being a reducing agent can reduce the o-quinones back to diphenols thereby preventing brown colour formation. Being consumed in the process, reducing agents have a finite capacity to inhibit browning. The present study also confirmed the anti browning effect of ascorbic acid in fresh cut vegetables.

Treatment combination of several browning inhibitors were more effective than those applied individually. Potassium meta bisulphite is a chemical preservative that can prevent both enzymatic and nonezyamtic browning. Potassium meta bisulphite was more effective when used along with acidulants like citric acid or ascorbic acid rather than used alone. Similar result was obtained by Wang and Buta (2000). Ascorbic acid was effective in preventing discolouration of fresh cut apples (Ponting, 1972; Drake and Spayed, 1983) and pears (Rosen and Kader, 1989).

In ashgourd the colour was preserved best in samples dipped in 0.1% citric acid solution. A similar result was obtained in fresh cut apples and tomatoes and other products (Son *et al.*, 2001) with citric acid treatment. Results confirmed that ascorbic acid and citric acid play a fundamental role in avoiding browning during minimal processing and storage. Whitaker (1972) had also reported the beneficial role of citric acid and ascorbic acid in colour retention. Sapers (1990) had also observed that dipping fresh cut vegetables in 0.2% citric acid solution for ten minutes preserved colour better than that rinsed with distilled water.

Appearance was adversely affected in all vegetables treated with hot water. Minimal processing operations like peeling might have increased the sensitiveness of tissues to hot water. Saltveit (2000) had reported that wound induced enzymes of phenyl propanoid metabolism can be prevented by giving a brief heat shock treatment (i.e. immersion in 45°C water for 90 s) after processing. However in the present investigation, hot water treatment had a negative effect on visual quality probably due to the elevated temperature of the water used for immersion of fresh cut vegetables.

Periderm formation and suberization was noticed in fresh cut elephant foot yam after one day of storage. The first visually observed change at the cut surface of the plant tissue is desiccation of the first layer of the broken cells and one to a few additional subtending layers of the cells. Suberization of the next layer of cells occurs in many tissues, including potato and yam tubers, sweet potatos and carrot roots, bean pods and tomato and cucumber pericarp (Kolattukudy, 1984; Walter *et al.*, 1990). The environment surrounding the tissue has been shown to influence both suberization and the formation of a wound periderm (Wigginton, 1974). Prestorage treatments with KMS 0.1% + 0.1% ascorbic acid however delayed periderm formation in EFY by two days.

5.2.2 *Physiological loss in weight*

Significant weight loss during storage was observed in all the cut vegetables, irrespective of treatments. Weight loss was due to evaporation of water from the surface of fresh cut vegetables. Removal of protective epidermal layer during minimal processing may have accelerated the rate of moisture loss.

Throughout the storage period, highest PLW% was recorded by okra followed by brinjal, whereas least PLW was in drumstick. Elephant foot yam also showed comparatively lesser weight loss. Suberization was observed one day after minimal processing in elephant foot yam. The protective periderm layer in cut elephant foot yam accounts for relatively less moisture loss from elephant foot yam.

The influence of nine prestorage treatments on PLW in cut vegetables was studied. Hot water treatment resulted in high water loss in all the cut vegetables. Hot water treatment might have increased the permeability of cell walls leading to enhanced moisture loss. Considerable weight loss was also noted for the control treatments. Weight loss was not considerably influenced by the other pre storage treatments.

5.2.3 Microbial count

One of the major reasons for spoilage of cut vegetables is the growth of microorganisms that render the fresh cut vegetables unmarketable or inedible .It is characterized by undesirable changes in the colour, texture and flavour or odour. Common microbes that directly reduce the shelf life include strains of bacteria, *Pseudomonas, Erwinia, Bacillus* and *Clostridium spp* (Bacts and Wei, 2002) fungi belonging to species of *Fusarium, Alternaria, Mucour, Rhizopus, Botrytis* etc. Certain microbes indirectly reduce the shelf life of fresh cut vegetables through the production of off flavour, sliminess, cloudy plant juice or discoloration. The increased susceptibility of fresh cut produce to microbial proliferation is usually by exposure of the inner tissues by removal of cuticle, which act as a barrier to entry, and growth of microorganisms.

Microbial population was reduced marginally following hot water treatment in all cut vegetables except okra. Okra was found to be highly sensitive to the high temperature (80°C) involved in the treatment, which led to its desiccation and increased spoilage. Li *et al.*, (2001) had observed that the there was no significant reduction in microbial population following hot water treatments Significant variation was observed among other treatments in reducing microbial population on fresh cut vegetables. In all the vegetables a four fold reduction in bacterial count and a three fold reduction in fungal and yeast count as compared to control was observed. Among the treatments, the combination of KMS 0.1% and ascorbic acid 0.1% was the most effective in reducing microbial population (Fig. 2a-2c).. The chemical preservative sodium benzoate was also effective in lowering the microbial count in precut vegetables as compared to control. Chipely (1993) had reported the effectiveness of weak acids like benzoic acid against yeast and moulds and also against human pathogenic bacteria.

Potassium meta bisulphite (KMS) is a chemical preservative having broad antimicrobial action. Microbial population was significantly reduced when KMS was used either alone or in combination with citric acid or ascorbic acid. Chemical preservatives have a synergistic action when used along with mild acidulants. These acids lower the pH of the product creating an unfavourable condition for the growth of microbes. Pao and Petrack (1997) had observed significant reduction in bacterial population in minimally processed oranges following citric acid treatment. Burhan *et al.*, (2001) has proved the usefulness of ascorbic acid in destroying the pathogenic microorganisms in apples, though the concentration was much higher than used in this study. The result in the present study is in line with that obtained by Pripeke *et al.*, (1976), they had reported that addition of ascorbic acid to wash water is helpful in reducing the microbial load of the vegetables. Antimicrobial activity of ascorbic acid has also been reported by Adams *et al.*, (1989).

The results of the study revealed that shelf life could be extended by prestorage treatment with chemical preservatives like KMS or sodium benzoate coupled with acidulants like ascorbic acid or citric acid. John and Narasimham (1998) had reported a shelf life of 30 and 120 days at 28° C and 0°C respectively for breadfruit slices dipped in 1000 ppm So_2 before storage. The maximum shelf life for pretreated cut vegetables was four to five days under ambient conditions. Potassium meta bisulphite in combination with citric acid proved to be the most effective in cowpea, elephant foot yam, brinjal and ascorbic acid in pumpkin and drumstick for prolonging shelf life under ambient conditions. In ashgourd and okra combination treatment of sodium benzoate with antioxidant ascorbic acid was more effective in extending shelf life. The antimicrobial and antibrowning effect of these chemicals has been mentioned else where in the test.

5.3 IRRADIATION OF MINIMALLY PROCESSED PRODUCTS

Irradiation is one of the novel methods of food preservation, which can be used to extend the shelf life of fresh and processed foods and to improve the microbiological safety by eliminating several pathogens from it. In this study the fresh cut vegetables were subjected to different doses of gamma irradiation.

5.3.1 Visual parameters

Irradiation caused significant changes in visual parameters and quality in some of the vegetables studied. In brinjal and ashgourd the loss of flesh firmness and deterioration of visual quality was observed in samples irradiated at dose above 100 Gy. Colour and other visual parameters were preserved best in brinjal and ashgourd slices irradiated at 100 Gy. Minimally processed cowpea, drumstick, elephant foot yam and pumpkin could withstand a radiation dose up to 200 Gy with minimum deterioration in visual quality. Several studies have been undertaken to evaluate the sensory quality of different vegetables subjected to gamma irradiation. Thomas (1988) had reported that exposure to above optimal dose cause undesirable changes in texture, taste, flavour, aroma and colour proportional to the radiation dose. Similar results were reported by Thomas *et al.*,(1986); Kader (1986); Brackett (1987); Khattak (2005).

The tissue softening is caused by partial depolimerizatrion of cell wall polysaccharides, mainly cellulose and pectin and damage to cell membranes. Radiation induced texture changes has been associated with pectic substances. This problem can be over come by the use of hurdle techniques.

5.2.2 Effect of radiation on microbial population

Fresh cut vegetables when subjected to irradiation at a dose 200 Gy (T5) showed six fold reduction in bacterial and fungal counts than the control samples. In all the vegetables, the trend was almost same with slight variation. Three fold reduction in population of yeast was observed. Similar results were observed in all the other vegetables (cowpea, elephant foot yam, brinjal, okra, pumpkin, ashgourd and drumstick). The results of the study revealed that radiation exposure resulted in significant reduction of microbial population. Hagenmier and Backer (1997) reported a reduction of microbial population in fresh cut lettuce following a mean dose of 0.19 K Gy as compared to nonirradiated control.

Kader, (1986) suggested that irradiation level of 1.5-2 K Gy is necessary to destroy yeast and molds that may exist as spores and these levels are damaging to plant tissue. Although irradiation is a very potent and useful antimicrobial process, it has been used in a limited extend so far. Irradiation dose required to eliminate some microorganisms may cause vitamin C losses, negative textural changes (Gunes *et.al* 2001) and enzymatic browning (Hanotel *et al.*, 1995) in some vegetables. Farkas and Saray (1997); Molins *et al.*, (2001) and Foley *et al.*, (2002) had suggested the feasibility of using irradiation for elimination of microbes in cut products. Shelf life of cut vegetables was extended following exposure to gamma radiation. The shelf life was extended to five days in drumstick, four days in brinjal and pumpkin and three days in EFY, okra, cowpea and ashgourd.

The optimum dose of radiation for preserving visual quality, prolonging shelf life and reducing microbial proliferation without adversely affecting the sensory qualities was found to be 100 Gy for fresh cut ashgourd and brinjal and 200 Gy for cowpea, EFY, okra, pumpkin and drumstick (Fig. 3). Higher dose of radiation can have adverse effect on sensory qualities in ashgourd and brinjal. Better microbial inhibition at dose above 200 Gy can be expected in all other precut vegetables. However with the facilities in our institute, a higher dose of irradiation could not be tried.

5.4. PACKAGING AND STORAGE STUDIES FOR FRESH CUT VEGETABLES

Precut packaged vegetables are subjected to many stresses including deterioration reactions of wounded or senescing tissues, decay caused by the growth

Plate 8. Deteriorative changes during storage of fresh cut vegetables

8a.

8b.

8c.

8d.

8e.

8f.

8a. Periderm formation in EFY
8b. Fungal growth in brinjal
8c. Sliminess in EFY
8d. Browning at cut ends of okra
8e. Shriveling in ashgourd
8f. Browning in brinjal

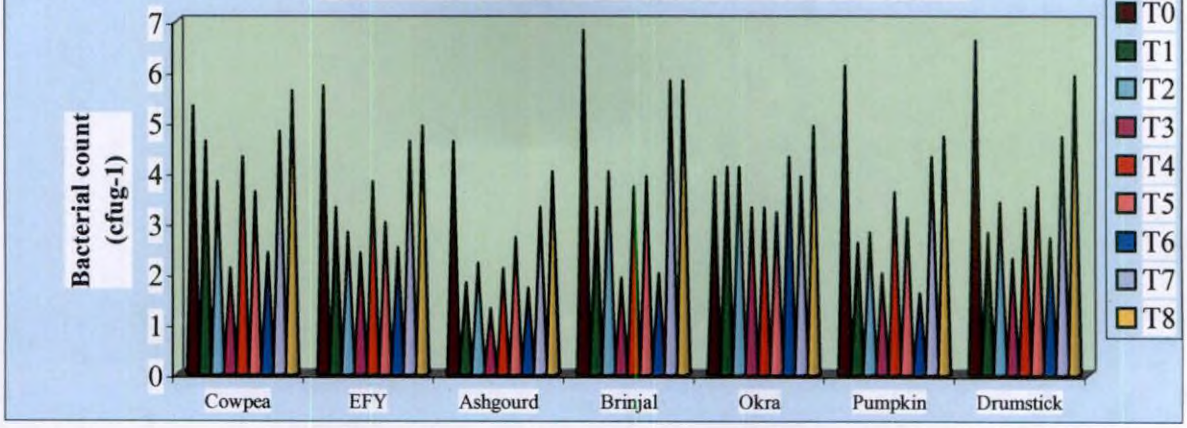


Fig.2a. Effect of pre storage treatmetns on bacteria

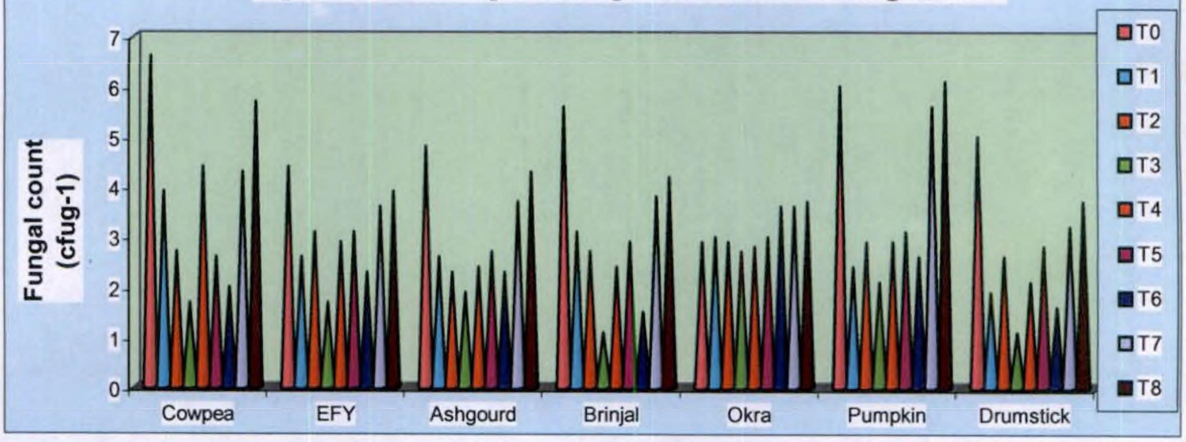


Fig. 2b. Effect of pre stoarge treatments on fungal count

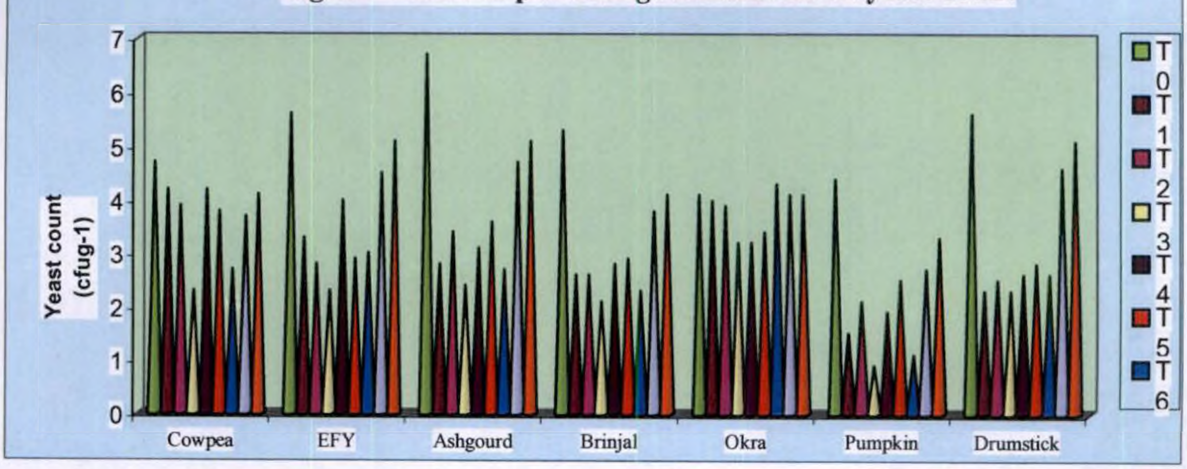


Fig. 2c. Effect of pre storage treatmetns on yeast count

of microorganisms and water loss from the tissue and increase in respiration and ethylene production (Plate 8). These injuries induce severe damage and stress, with considerable reduction in shelf life. Temperature management is a crucial factor determining the rate of metabolic reactions and activity of microorganisms. Hence in this experiment the impact of modified atmosphere packaging coupled with low temperature storage and /or irradiation on shelf life and quality of precut vegetables were investigated. Modified atmosphere (MA) help to maintain fresh quality and extend storage life by inhibiting metabolic activity, decay, browning (Gunes and Lee, 1997), and chilling injury (Hong and Gross, 2001) especially by inhibition of microorganisms, ethylene biosynthesis and action (Kader *et al.*, 1989), Modified atmosphere packaging (MAP) is widely used for fresh cut vegetables and fruits, semi permeable plastic films are chosen for MAP so that film permeability and product respiration can combine to produce a desirable steady state atmosphere within the package at an anticipated temperature.

5.4.1. Visual qualities

The unpacked samples of all the vegetables included in the experiment (cowpea, brinjal, okra, elephant foot yam, ashgourd, pumpkin, and drumstick) exhibited deterioration in visual quality from the second day of storage. Browning was severe in brinjal as compared to other cut vegetables. This may be due to high polyphenol content in brinjal, which gets oxidised to o-quinones by enzyme ploy phenyl oxidise (PPO). The browning process would have accelerated in unpacked samples under ambient conditions, because of free access to oxygen in the atmosphere. Fresh cut brinjal packed in unventilated polyethylene cover exhibited comparatively less browning. The permeability of packaging material to O_2 and CO_2 determines the degree of deterioration of cut samples (Escalona, 2003).

Discolouration at cut ends and shriveling observed in unpacked okra pieces during storage under ambient conditions rendered them unmarketable within two

Plate 9. Fresh cut pumpkin packed in different packaging material (4DAS)

9a.

9b.

9c

9d

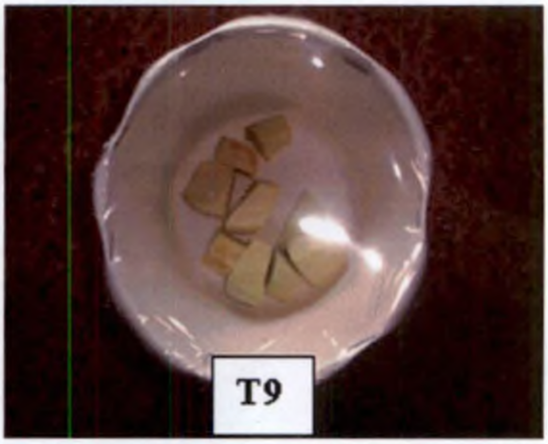
9e

9f

9g.

9h.

9i.



9j.

9k.

days. Discolouration at cut surface of okra could be due to disruption of compartmentation that occurs when cells are broken allowing substrate and enzyme to come into contact. Wounding also induce synthesis of some enzymes involved in browning reactions or substrate biosynthesis (Rolle and Chism, 1987). The rate of browning depends on factors like storage temperature, storage atmosphere, and barrier characteristics of the packaging material as well as packing conditions (Plate 9). It has been reported that vacuum packaging has a profound effect against browning. However in the present study rotting was relatively more in vacuum packaged samples probably due to the compressive effect during packaging. Visual quality was retained upto five days by packaging in unventilated PP cover. Minimally processed drumstick, ashgourd and pumpkin did not show much colour change during storage. However stored fresh cut cowpea exhibited a slight reduction in green colour.

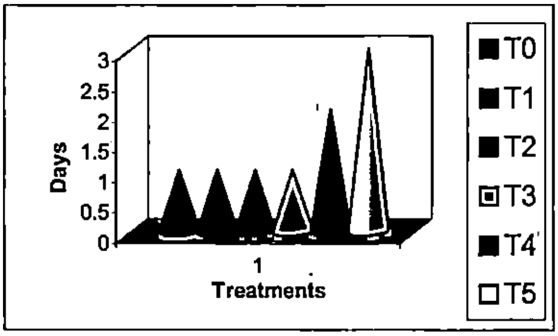
Shriveling was observed in all cut vegetables but the intensity was comparatively lower in elephant foot yam and drumstick. This can be attributed to less initial moisture content in these vegetables. Evaporation loss of water from stored material is the most obvious way in which freshness is lost and it affects the appearance, texture and stability under ambient conditions. Relatively high temperature experienced under ambient conditions could have accelerated the physiological processes like respiration and transpiration leading to weight loss and shriveled appearance. Shriveling was least in minimally processed drumstick, ashgourd, cowpea and pumpkin packed in unventilated PP cover. The good barrier properties of PE and PP reduced the chemical and microbial deterioration of fresh cut vegetables, therefore the products exhibited stability in visual qualities throughout the storage period.

Visual quality of fresh cut vegetables were preserved for comparatively longer period under cold storage. The intensity of shriveling, softening, browning or other deterioration was less severe. Furthermore manifestation of undesirable physical changes was delayed under refrigerated storage. Operations involved in minimal processing generally increase the rate of deterioration. However the rate of deterioration can be decreased with reduction in storage temperature. Periderm formation was the first visible change in fresh cut elephant foot yam, but this was delayed by two to three days in samples packed in PE under ambient conditions. Suberisation as a consequence of wounding is commonly observed in root and tuberous vegetables. However in fresh cut vegetables wound induced response is usually detrimental to overall quality of the product. The formation of protective periderm layer was delayed under low temperature storage. Similar results were reported by Wigginton (1974) in potato. He had observed that suberisation of potato tubers can take 3-6 weeks at 5°C, 1-2 weeks at 10°C and 3-6 days at 20°C.

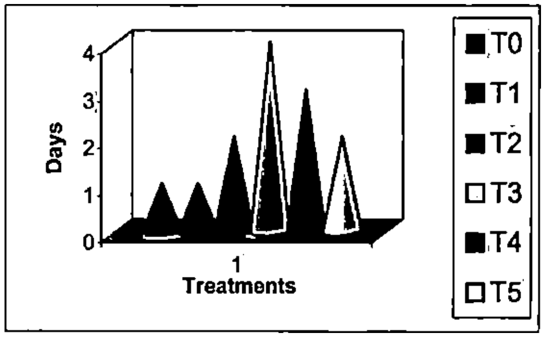
Lipetz (1970) reported that temperature management is important for minimising such undesirable reactions, the rate of which would be minimal at temperature below 5°C.Quality deterioration can be prevented by decreasing the temperature of the plant tissue and this can enhance the quality and shelf life by at least three to five fold or more. All pre cut vegetables showed less discolouration and shriveling under refrigerated storage compared to ambient conditions. Motilal *et al.*, (1998) had reported longer shelf life and overall acceptability in terms of flavour and fresh like appearance in pumpkin stored at 0°C, as compared to storage at higher temperature. MAP systems are used extensively for fresh cut fruit and vegetable products to extend shelf life by reducing water loss, respiration rates, cut surface browning, microbial growth, ethylene biosynthesis and ethylene action (Gorny, 2003). Jaiwante and Sankat (1998) had suggested that packaging was significant in maintaining colour and texture of breadfruit slices in cold storage.

The atmosphere surrounding minimally processed vegetables is extremely important to extend their shelf life and one of the most influential factors on its composition is the permeability of the films used in packaging. In the present study visual quality of the fresh cut brinjal and okra was better when packed in

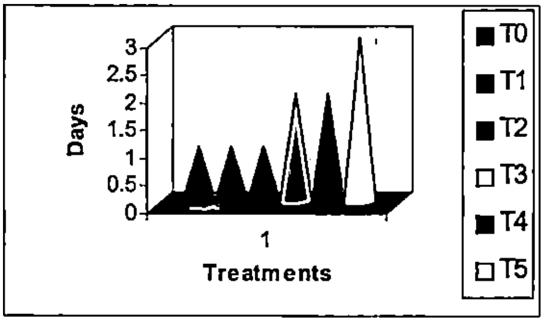
Fig. 3. Effect of irradiation on shelf life of cut vegetables under ambient condition



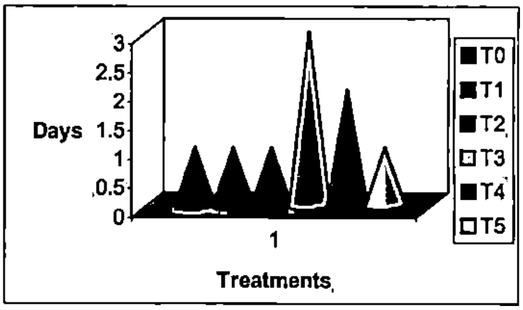
3a. Cowpea



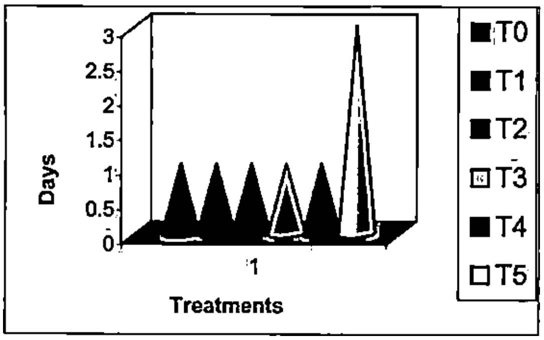
3b. Brinjal



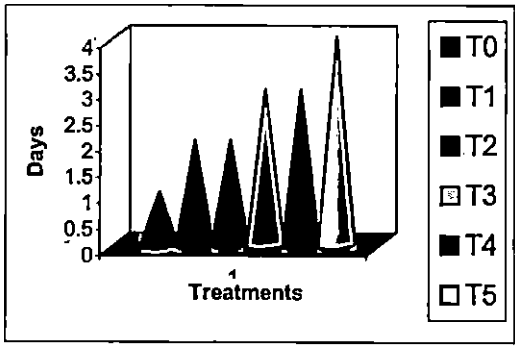
3c. Elephant Foot Yam



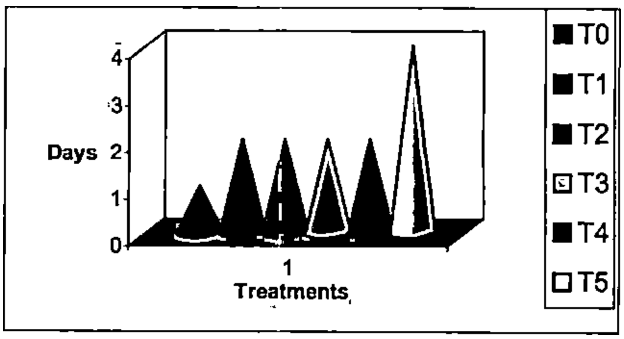
3d.Ashgourd



3e. Okra



3f. Pumpkin



3g. Drumstick

polyethylene (PE). Polypropylene (PP) proved to be the best packaging material for maintaining visual quality in precut cowpea, EFY, ashgourd, pumpkin and drumstick. Rapid deterioration in physical attributes (colour, texture, overall appearance) in minimally processed vegetables packed in perforated polymeric films was observed. Contrary to this Kale and Kadavu, (2003) had observed that packages with microperfortion developed an internal atmosphere leading to retention of product quality with respect to fresh weight, firmness, textural properties, sugar acid ratio and prolonged shelf life in minimally processed asparagus. Similar observations have been made by Hurne *et al.*, (1992). They had obtained a prolonged shelf life for fresh cut chinese cabbage packed in non perforated PP films. The disparity in the results reported above and that obtained in the present investigation could be due to difference in size of ventilation holes. Macroperforaions in the polymeric films used in the study would have accelerated the rate of transpiration and gaseous exchange, leading to faster degradation of the product. This is in agreement with findings of Tuncay and Kusakz (2003), they observed a decline in quality of fresh cut products of lettuce, carrot, cabbage and leek with increase in the size of perforations of PE bags

Unpacked, vacuum packaged, as well as samples packed in ventilated PE/PP cover lost firmness within a shorter time. Reduction of firmness was found to be less in refrigerated storage as compared to ambient storage. MP products wrapped with unventilated PE/PP bags recorded maximum firmness during refrigerated storage.

Storage under low temperature is suggested as a good method for restriction of deterioration in minimally processed products. Storing MP products under refrigerated conditions significantly reduced weight loss compared to ambient conditions (Fig. 4a-4b).

Colour and fresh like appearance was preserved better in fresh cut brinjal and ashgourd irradiated at a dose of 100 Gy. Irradiation dose above this resulted in softening and rotting of cut pieces. However in pumpkin, cowpea, okra, EFY and drumstick visual parameters were superior in samples irradiated at 200 Gy (Fig. 7).

Fig. 4a. Effect of packaging and sorage on PLW (%) under ambient condition

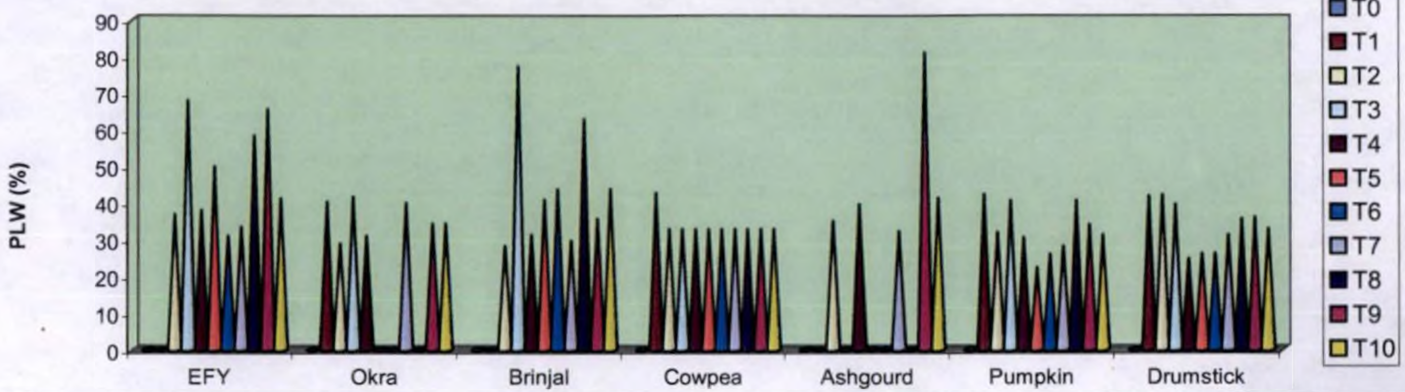


Fig. 4b. Effect of packaging and storage on PLW (%) under lowtemperature

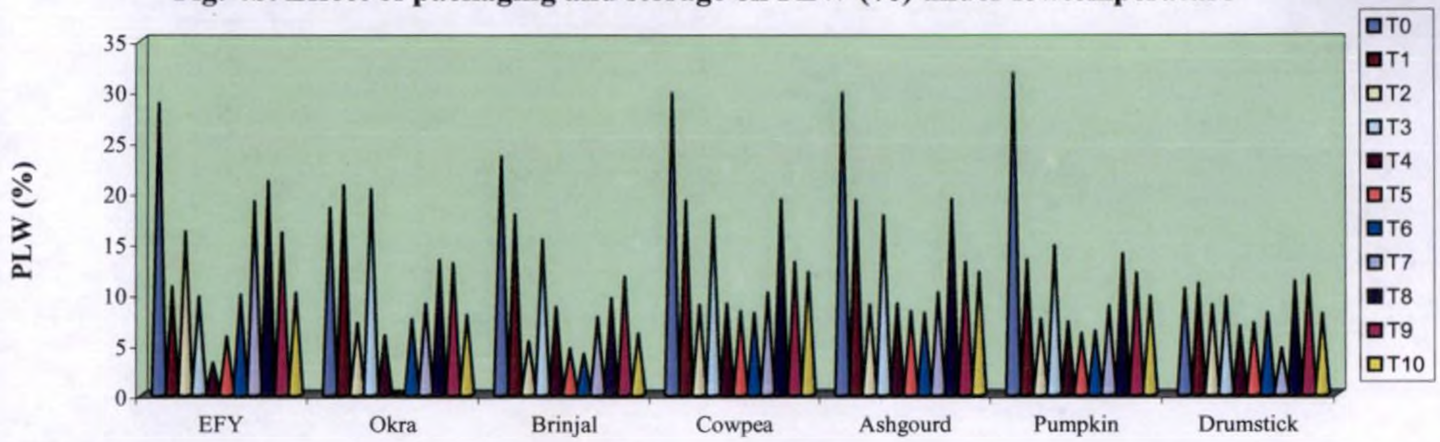
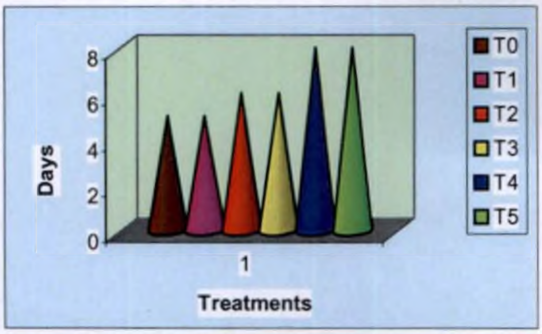
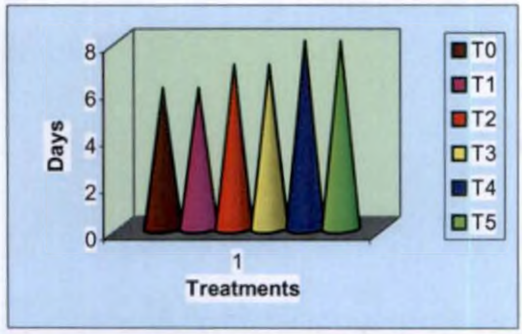


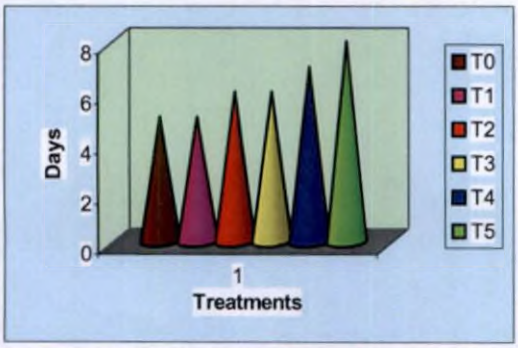
Fig.5. Effect of combination of low temperature and irradiation on shelf life



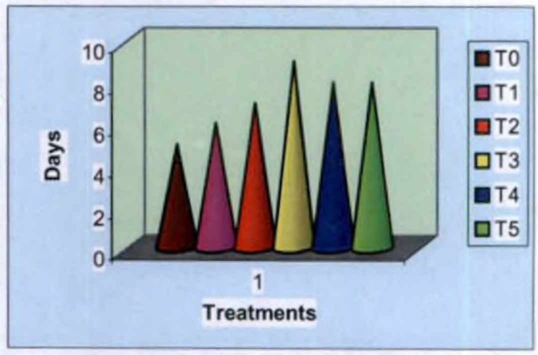
5a. Cowpea



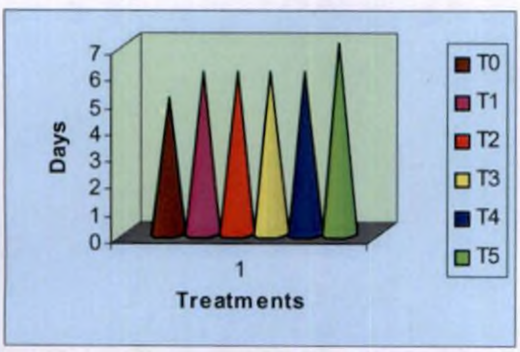
5b. Elephant Foot Yam



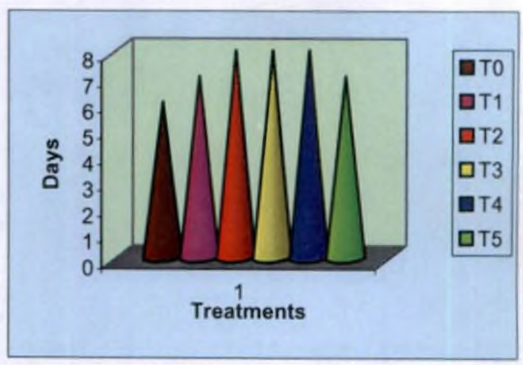
5c. Okra



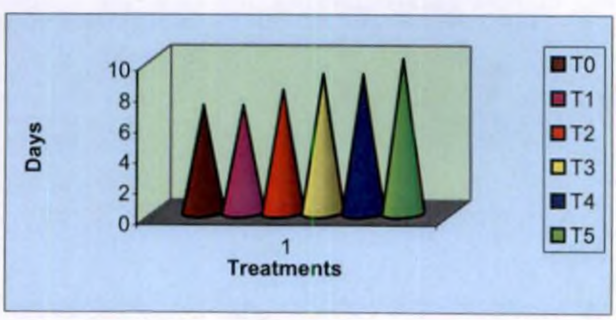
5d. Brinjal



5e. Pumpkin



5f. Ashgourd



5g. Drumstick

Fig. 6a. Effect of storage conditions on shelf life of fresh cut Cowpea

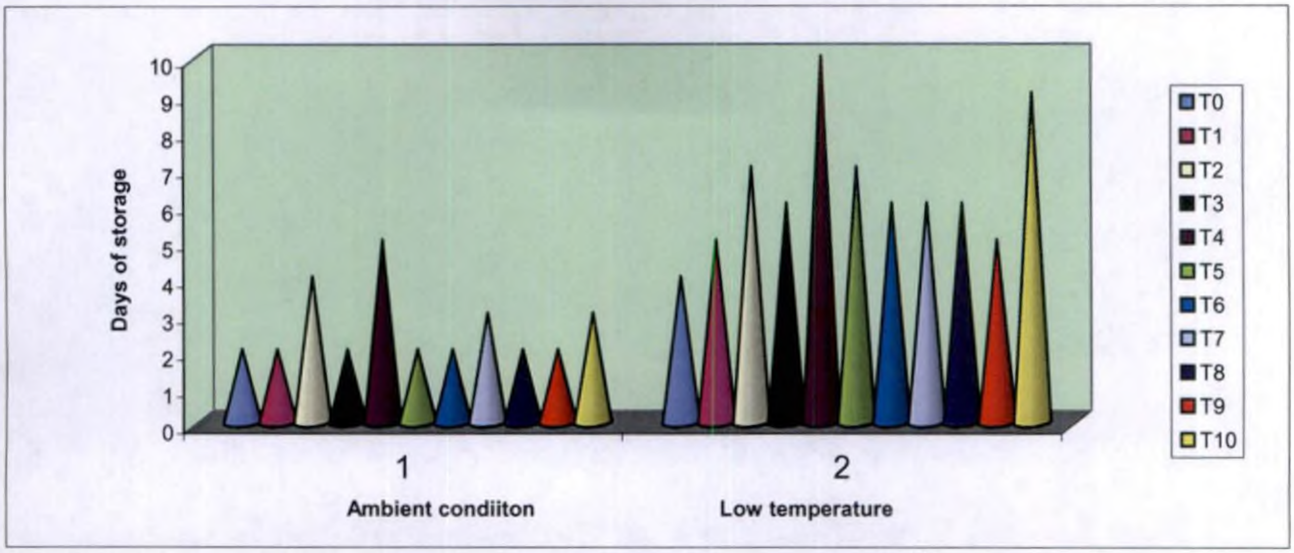


Fig. 6b. Effect of storage conditions on shelf life of fresh cut Brinjal

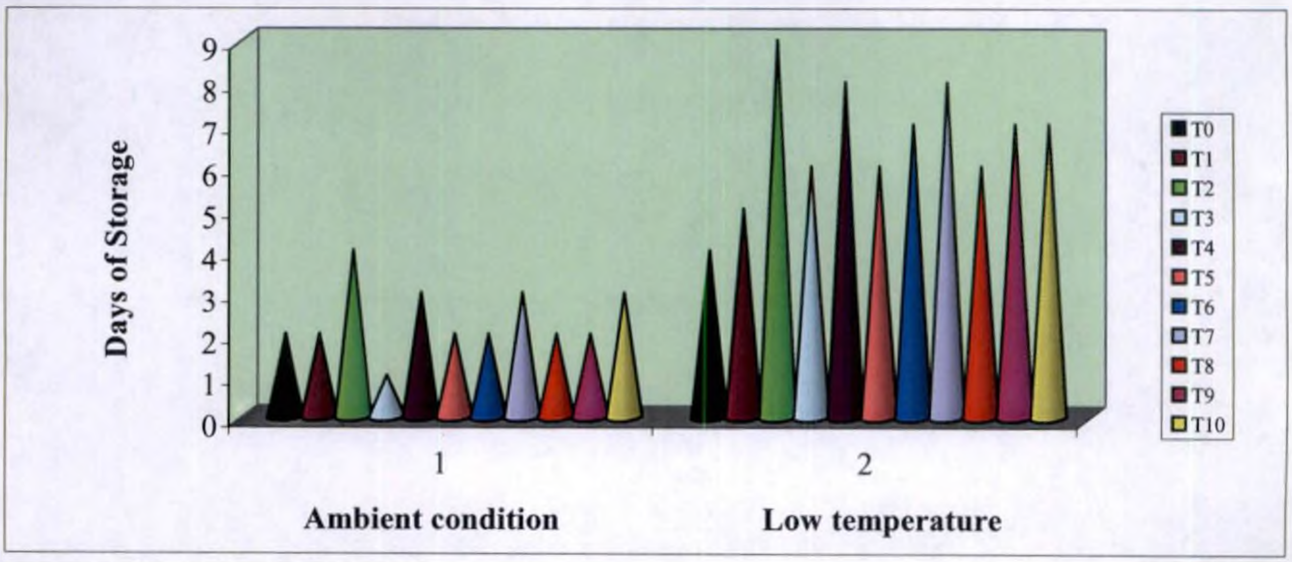


Fig. 6c. Effect of storage conditions on shelf life of fresh cut Ashgourd

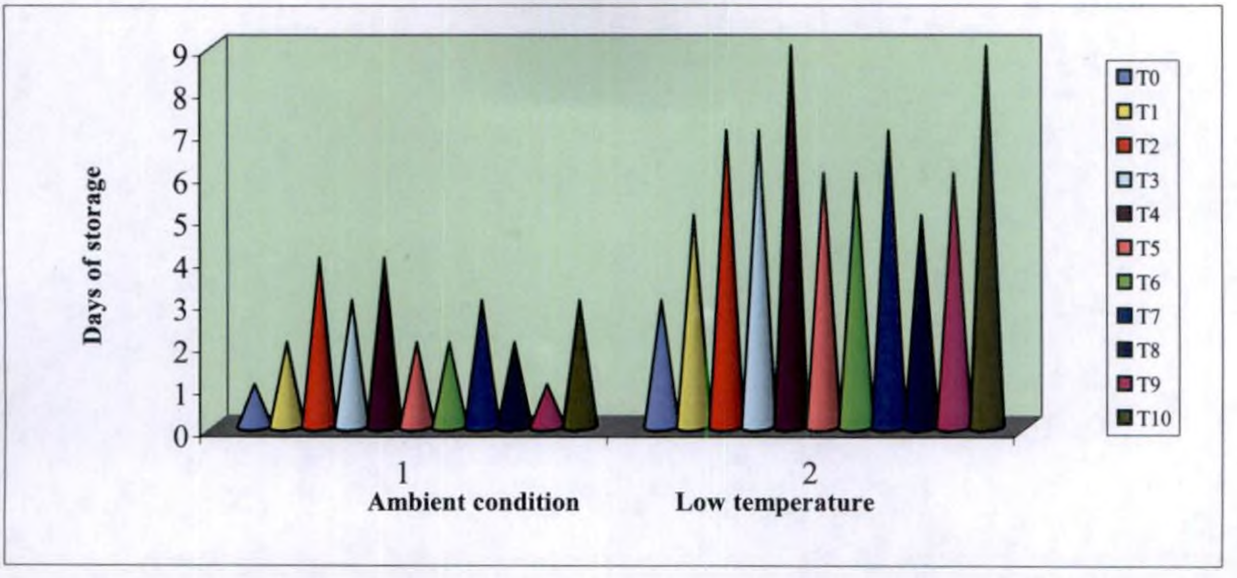


Fig. 6d. Effect of storage conditions on shelf life of fresh cut Elephant Foot Yam

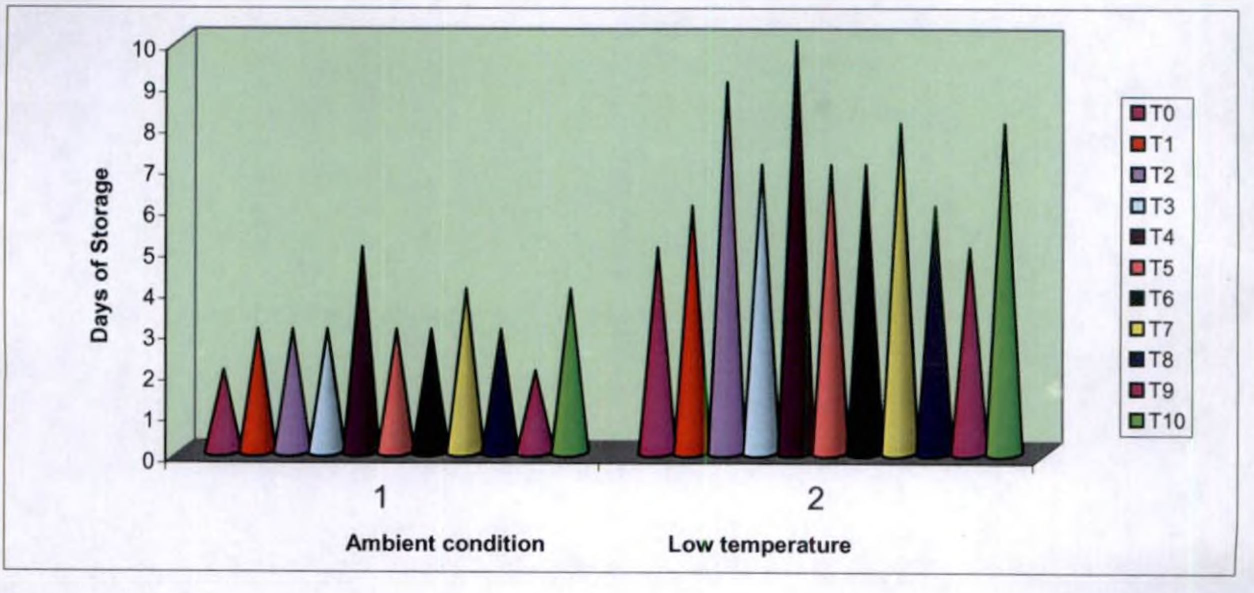


Fig. 6e. Effect of storage conditions on shelf life of fresh cut Pumpkin

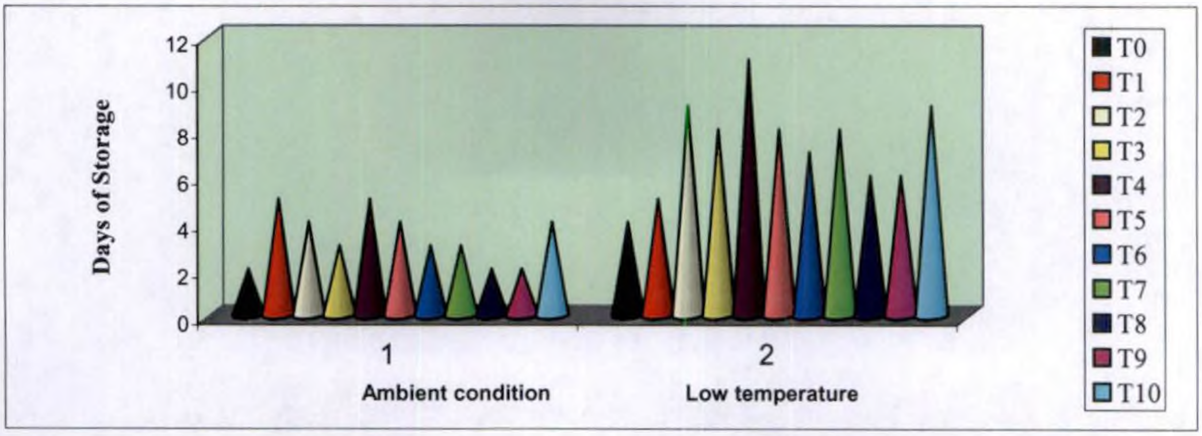


Fig. 6f. Effect of storage conditions on shelf life of fresh cut Okra

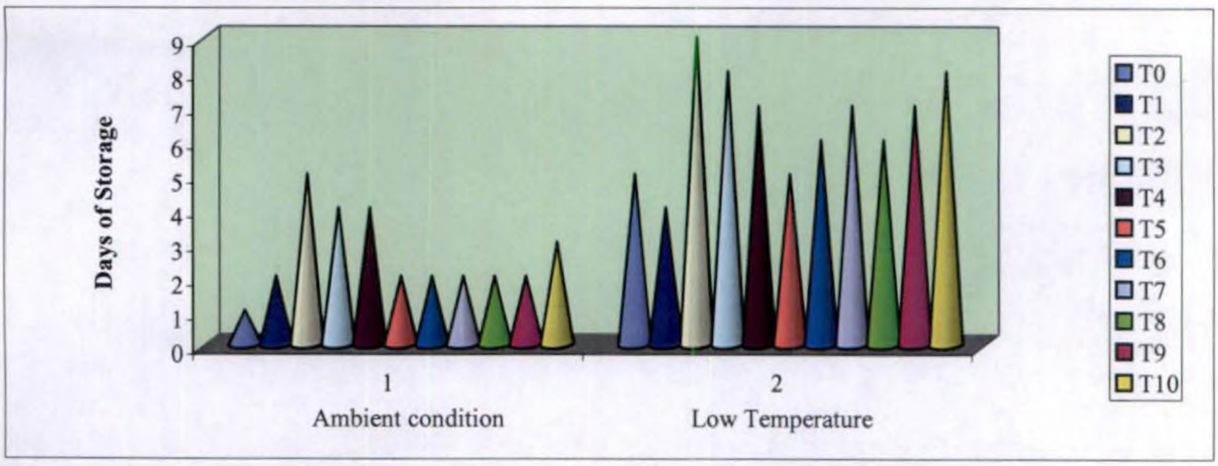
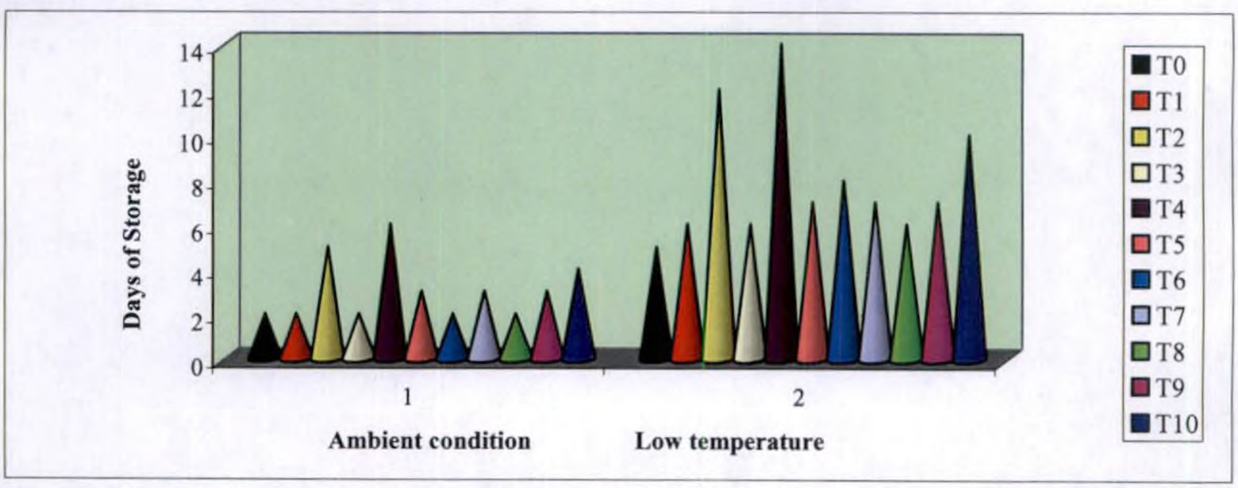


Fig. 6g. Effect of storage conditions on shelf life of fresh cut Drumstick



Fan *et al.*, (2003) had opined that higher doses of irradiation frequently resulted in increased loss of aroma and deterioration of visual quality in fresh cut green onions. Firmness of fresh cut Romaine lettuce was also reported to decrease with increasing dose of radiation. Variation in response to irradiation dose exhibited by different vegetables in the present investigation highlights the importance of standardising the dose of irradiation for each vegetable.

5.4.2 *Keeping quality of minimally processed products*

Under ambient conditions, shelf life of unpacked samples of cowpea, EFY, brinjal, drumstick and pumpkin was two days whereas for okra and ashgourd it was one day only. The corresponding shelf life under refrigerated storage was five days for drumstick, EFY and okra, four days for cowpea, and three days for brinjal, ashgourd and pumpkin. Among the different treatments tried for extension of shelf life of MP slices at ambient temperature, modified atmosphere packaging of the product in unventilated PP bags proved to be the best (Plate 10). Modified atmosphere packaging (MAP) is the method for extending the shelf life of perishable food products by altering the relative proportions of atmospheric gases that surround the food (Barmour, 1987; Day, 1992).

In the present study, precut okra and brinjal packed in unventilated PE bags and kept under refrigeration were found to have a shelf life of nine days as against five and four days respectively at ambient temperatures. Packing minimally processed products in polypropylene cover under refrigeration would prolong shelf life. The shelf life attained was 14 days for drumstick, nine days for cowpea, ashgourd and pumpkin, eight days for okra and EFY under such conditions(Fig. 6a-6c). Additional shelf life obtained is due to the cocktail effect of low temperature and modified atmosphere packaging as explained by Wills *et al.*, (1989).

The result of the present study revealed that under low temperature ($7 \pm 2^{o}C$), packaging precut vegetables in unventilated polyethylene or polypropylene would impart maximum shelf life. The shelf life was found to be more than that at ambient storage under the same treatments. This is because the relative humidity under refrigerated conditions is higher compared to ambient conditions hence the vapour pressure is reduced, resulting in lower rate of moisture loss from the commodity. Besides, lower temperature would have reduced the rate of respiration and hence the relative increase in the shelf life. Packaging MP products in unventilated PP or PE bags, both under ambient condition and refrigerated storage was superior to other treatments. This is in conformity with the findings of Gorny (2003). In the present study MP products packaged in unventilated PE bags exhibited a significant delay in softening compared to unwrapped samples. This behavior is attributed to the modified atmosphere condition created by packaging and the subsequent delay in softening rate.

Shelf life was slightly reduced in some vegetables packed in polystyrene trays covered with lid of the same material. Shelf life obtained was eight days for EFY and pumpkin, seven days for drumstick, ashgourd and six days for cowpea. Packing in areca sheath tray and wrapping with cling film provided a shelf life of seven days under refrigeration for brinjal and okra.

Thermocol and vaccum packaged samples registered comparatively lower shelf life both under ambient and refrigerated conditions. This may be probably due to the higher permeability of thermocol to gases and water vapour resulting in faster degradation of the products.

The results of the present study indicated that unventilated polymeric films are the most ideal packaging material for cut vegetables. Polypropylene for cowpea, ashgourd, EFY, pumpkin and drumstick and PE for okra and brinjal in terms of visual attributes and keeping quality. Packaging in polystyrene trays and wrapping with cling film can also be recommended for enhanced visual and keeping quality of MP products. Semi rigid plastic packaging is a popular packaging form for cut vegetables, when they are presented as catering or snack rays. A superior view of the produce is made possible in such materials.

Plate 10. Ideal packaging materials for fresh cut vegetables

10a.

10b.

10c.

10d.

10a. Okra packed in PE cover
10b. Brinjal packed in PE cover
10c. Drumstick packed in PP cover
10d. Ashgourd packed in PP cover

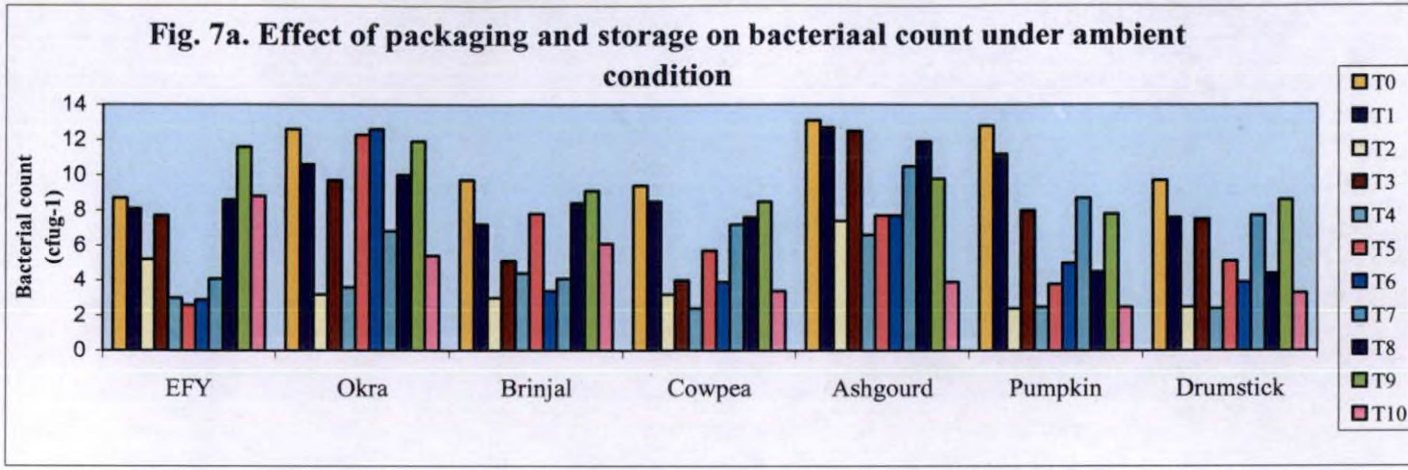


Fig. 7a. Effect of packaging and storage on bacteriaal count under ambient condition
Bacterial count (cfug-1)
14
12
10
8
6
4
2
0
EFY
Okra
Brinjal
Cowpea
Ashgourd
Pumpkin
Drumstick
T0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10

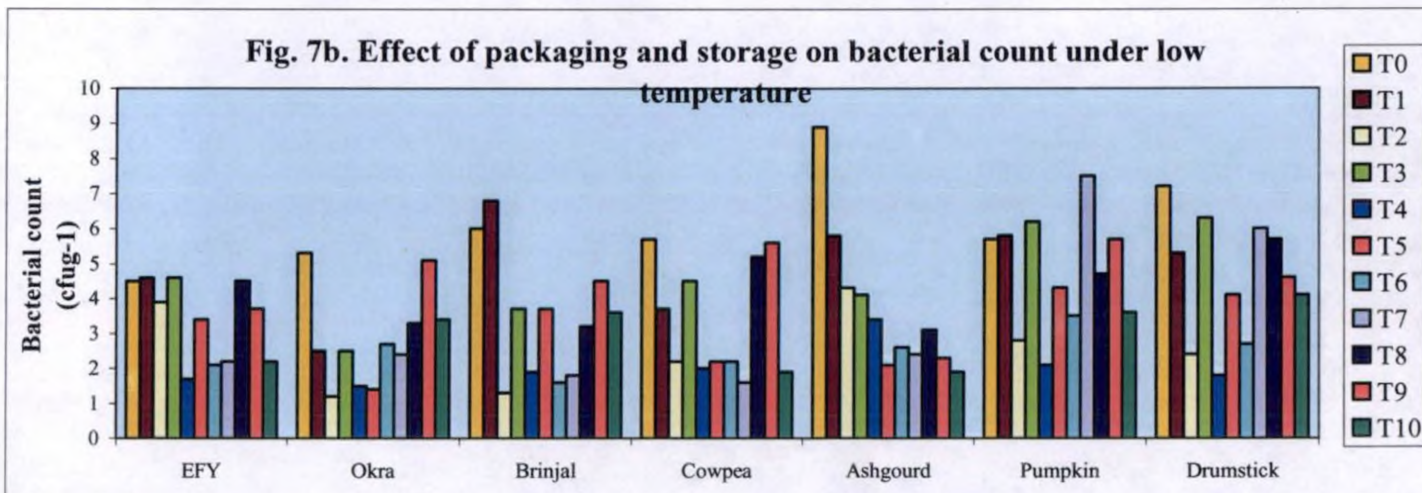


Fig. 7b. Effect of packaging and storage on bacterial count under low temperature
Bacterial count (cfug-1)
10
9
8
7
6
5
4
3
2
1
0
EFY
Okra
Brinjal
Cowpea
Ashgourd
Pumpkin
Drumstick
T0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10

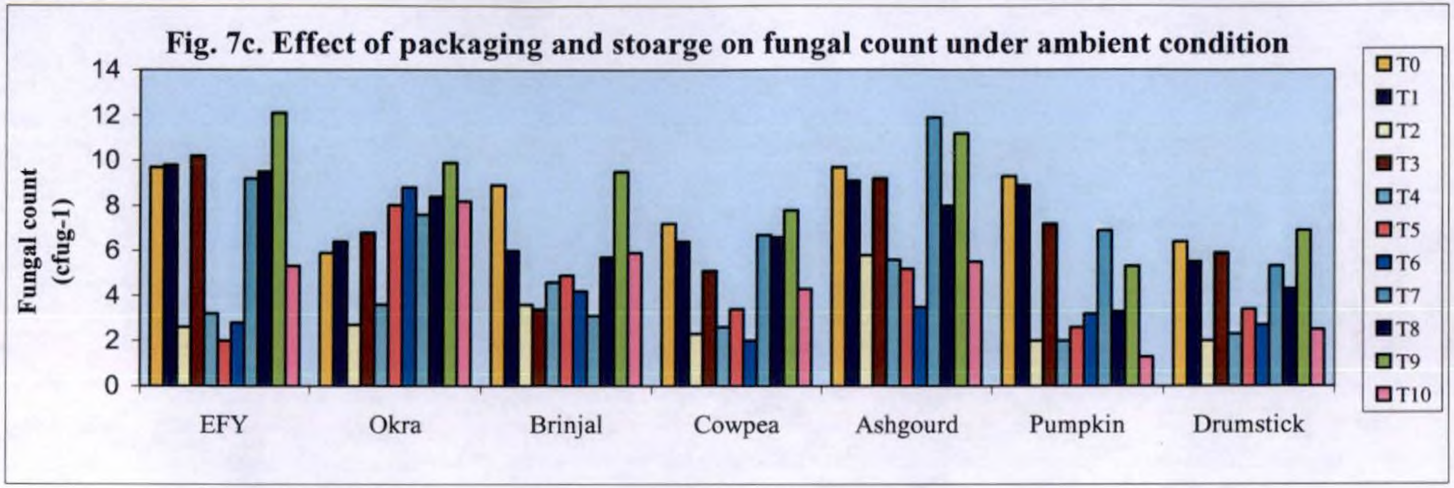


Fig. 7c. Effect of packaging and stoarge on fungal count under ambient condition
Fungal count (cfug-1)
14
12
10
8
6
4
2
0
EFY
Okra
Brinjal
Cowpea
Ashgourd
Pumpkin
Drumstick
T0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10

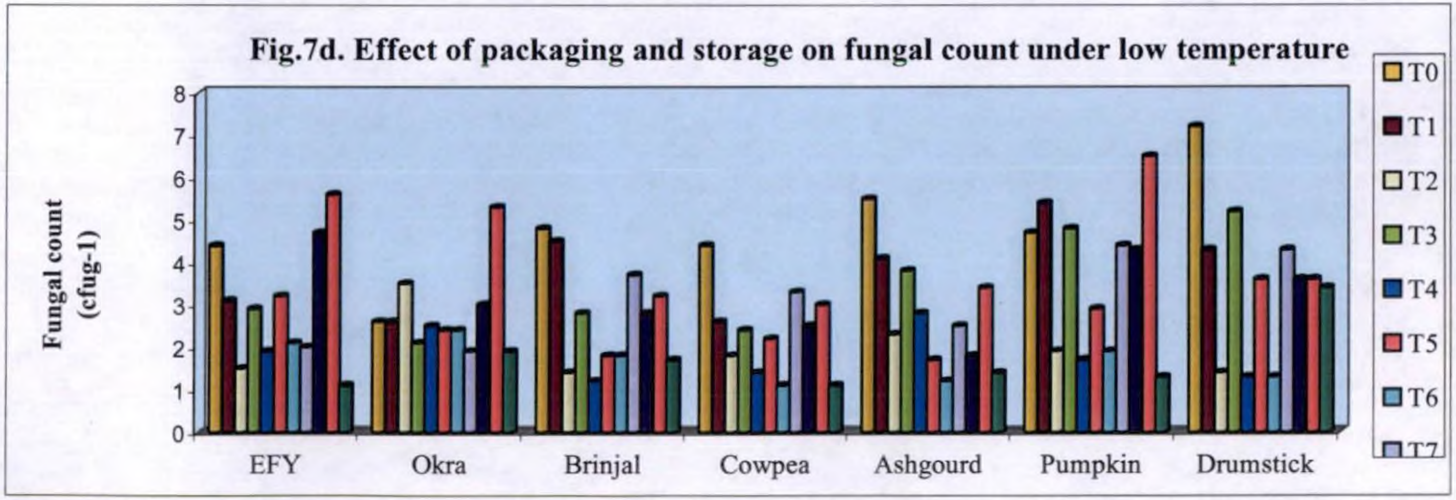


Fig.7d. Effect of packaging and storage on fungal count under low temperature
Fungal count (cfug-1)
8
7
6
5
4
3
2
1
0
EFY
Okra
Brinjal
Cowpea
Ashgourd
Pumpkin
Drumstick
T0
T1
T2
T3
T4
T5
T6
T7

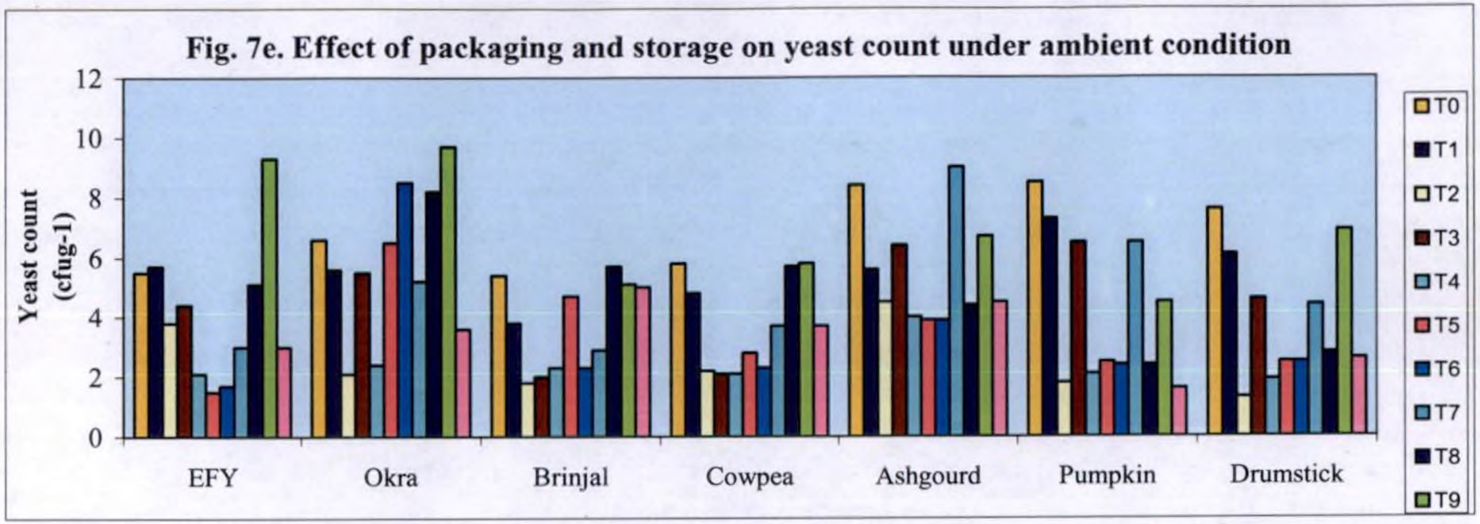


Fig. 7e. Effect of packaging and storage on yeast count under ambient condition
Yeast count (cfug-1)
0
2
4
6
8
10
12
EFY
Okra
Brinjal
Cowpea
Ashgourd
Pumpkin
Drumstick
T0
T1
T2
T3
T4
T5
T6
T7
T8
T9

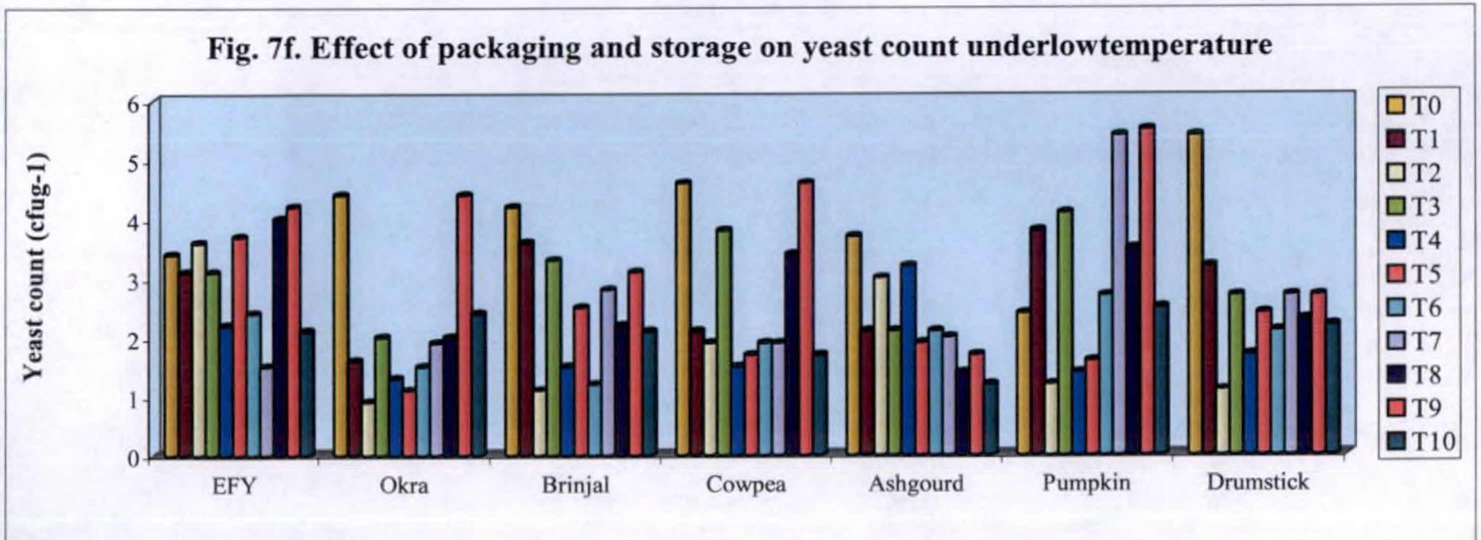


Fig. 7f. Effect of packaging and storage on yeast count underlowtemperature
Yeast count (cfug-1)
0
1
2
3
4
5
6
EFY
Okra
Brinjal
Cowpea
Ashgourd
Pumpkin
Drumstick
T0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10

Safety must be the prime concern in any food product. Growth of bacteria, fungi and yeast directly limit the life of fresh cut products in appearance and/or texture of the product that make them inedible. The growth of the microorganisms is facilitated by plant cell injury, senescence or stress. Factors that influence microbial growth on fresh cut products include temperature, relative humidity and gas composition of the environment (Omary *et al.*, 1993; Babic and Watada, 1996) as well as the pH and composition of the product (Breidit and Fleming, 1997).Maintenance of low temperature is the single most important factor for inhibiting microbial growth (Heard, 1999).

The effect of packaging materials and storage conditions on microbial population on precut vegetables was investigated. Microbial count was significantly low under refrigeration as compared to ambient conditions. Under low temperature storage, microbial growth is greatly retarded (Fig. 7a-7f). The influence of low temperature in inhibiting microbial growth on precut products has been reported by many workers Bartz and Tamplin (2002).

Packaging of precut vegetables brought about significant reduction in microbial population under all storage conditions. Modified atmosphere packaging of precut vegetables in unventilated polymeric films significantly lowered the microbial population. Microbial count was low in cowpea, pumpkin, drumstick and elephant foot yam packed in polypropylene and brinjal and okra in polyethylene cover. In the case of ashgourd, however least microbial count both under ambient and refrigerated storage was found in polystyrene tray wrapped with cling film.

In all the fresh cut vegetables the population of yeast and mould was less numerous than bacteria. Similar trend was reported by Nuguyan and Cartin, (1994).

Modified atmosphere storage affects both plant physiology and microbial growth. Most postharvest plant pathogens are aerobes and have only limited ability to infect plant tissues when O_2 is limited. However the extreme levels of O_2 or CO_2 injure plant tissue (Saltveit, 1997) Ferrier *et al.*, (2002) observed significant inhibition of microbial growth in MAP of fresh cut mango and pineapple. MAP coupled with low temperature was very effective in inhibition of microbial growth and consequently lesser deterioration was observed in fresh cut vegetables under such conditions. Combination of irradiation, MAP and refrigeration resulted in even better inhibition of microorganisms in ashgourd and brinjal only. However microbial population in irradiated fresh cut vegetables under refrigeration was significantly lower than unpacked samples. The results of the study indicate that MAP in unventilated PP cover coupled with refrigerated storage in the most ideal for precut cowpea, drumstick, and pumpkin in respect of visual and keeping quality and optimum microbial inhibition. The most suitable packaging material under the same conditions for okra and brinjal is nonventilated PE cover and for ashgourd, polystyrene tray wrapped with cling film.

The cost of the packaging material was estimated as rupees 3.0,1.25,0.75,0.20 and 0.10 respectively for polystyrene tray, areca sheath tray, thermocol cup, polyethylene and polypropylene.

5.5 Protocol for minimal processing

The protocol for minimal processing in each vegetable was developed based on the superior treatments identified from the previous experiments. The visual quality and shelf life of cut vegetables prepared following this protocol was studied. The cut vegetables could be stored for a period of 9-14 days with maximum visual quality when the complete protocol in minimal processing was followed. Shelf life could be extended by two days in elephant foot yam, pumpkin and one day in okra and ashgourd as compared to shelf life obtained by modified atmosphere packaging and low temperature storage. Browning or other discolouration could be effectively inhibited when pre storage treatments were given before packaging and storage.

Summary

SUMMARY

The present study on "Standardization of minimal processing techniques for selected vegetables" was carried out at the College of Horticulture, Vellanikkara, Kerala Agricultural University, Thrissur during 2004 – 2006.

The primary objective of the study was to develop the protocol for minimal processing in seven vegetables viz, cowpea, okra, ashgourd, elephant foot yam, brinjal, pumpkin and drumstick. Standardisation of prestorage treatments, packaging materials and storage systems for preserving quality, reducing the microbial contamination and enhancing shelf life of fresh cut products was envisaged under the study.

The efficacy of different sanitizing agents on surface decontamination of fresh cut vegetables was investigated. Shriveling, browning and rotting were the major problems during storage of cut vegetables under ambient condition. Surface sanitation with 30ppm sodium hypochlorite was found to be the most effective treatment for preserving the visual quality in all the cut vegetables.

Physiological loss in weight was observed during storage of cut vegetables, maximum weight loss was in pumpkin (79.7%) and minimum in drumstick at the end of storage. Surface sanitation with NaCl 1% accelerated weight loss in all the vegetables.

Immersion of vegetables in sanitizing solutions for ten minutes before minimal processing effectively reduced the microbial population during storage. A four fold reduction in bacterial and fungal population was recorded after surface sanitation with 30 ppm hypochlorite solution. Yeast count was significantly reduced following treatment with NaCl 1%.

Surface sanitation with sodium hypochlorite was also effective in prolonging shelf life in all the precut vegetables as compared to control The shelf life attained was five days in elephant foot yam and drumstick, four days in cowpea, okra,

pumpkin and three days in ashgourd and brinjal, whereas the untreated samples had only two days shelf life under ambient condition.

The influences of prestorage treatments for controlling decay, reducing browning and retaining firmness of cut vegetables were evaluated. Browning was observed in control samples of brinjal, okra and cowpea. Colour retention was better in samples immersed in a solution containing ascorbic acid (0.1%) and potassium metabisulphite (0.1%). Cystiene (2%) was also effective in controlling browning in brinjal. Hot water (80° C) treatment adversely affected visual quality of the fresh cut vegetables.

Significant variation was observed among the treatments in reducing microbial population on fresh cut vegetables. In all the vegetables a four fold reduction in bacterial count and a three fold reduction in fungal and yeast count as compared to control was observed. Among the treatments, the combination of potassium meta bisulphite 0.1% + ascorbic acid 0.1% was the most effective in reducing microbial population.

The results of the study revealed that shelf life could be extended by prestorage treatment with chemical preservatives like potassium metabisulphite or sodium benzoate coupled with acidulants like ascorbic acid or citric acid. The maximum shelf life for pretreated cut vegetables was four to five days under ambient conditions. Potassium meta bisulphite in combination with citric acid proved to be the most effective in cowpea, elephant foot yam, brinjal and ascorbic acid in pumpkin and drumstick for prolonging shelf life under ambient conditions. In ashgourd and okra combination of treatment of sodium benzoate with antioxidant ascorbic acid was more effective in extending shelf life.

The fresh cut vegetables, were exposed to gamma irradiation at doses varying from 25 to 200 Gy. Colour and firmness was preserved best in ashgourd and brinjal slices irradiated at a dose of 100 Gy. Fresh cut pumpkin, cowpea, drumstick, elephant foot yamand okra could withstand a irradiation dose of 200 Gy with minimum deterioration in visual quality. Radiation exposure resulted in significant reduction in microbial population in fresh cut vegetables. A six fold reduction in bacterial and fungal count and three fold reduction in yeast was observed.

Optimum radiation dose for maximum visual quality and microbial inhibition was 200 Gy in precut okra, elephant foot yam, pumpkin, cowpea and drumstick and 100 Gy in brinjal and ashgourd respectively. Higher dose of radiation can had adverse effect on sensory qualities in ashgourd and brinjal.

The influence of modified atmosphere packaging coupled with low temperature storage and irradiation on shelf life and quality of precut vegetables were investigated. The unpacked samples of cut vegetables exhibited deterioration in visual quality from the second day of storage under ambient conditions.

Browning was severe in brinjal compared to other vegetables. Shriveling was observed in all the vegetables but the intensity was less in elephant foot yam and drumstick. Visual quality of fresh cut vegetables was preserved for comparatively longer period under refrigerated storage. The intensity of shriveling, softening, and browning or other deterioration was less severe in all cut vegetables under refrigeration. Periderm formation observed in elephant foot yam as a response to wounding was delayed by modified atmosphere packaging and low temperature storage.

The shelf life of the cut vegetables was significantly prolonged when kept under refrigeration. Shelf life of unpacked samples under refrigerated storage was five days for drumstick, EFY and okra, four days for cowpea, and three days for brinjal, ashgourd and pumpkin.

Precut okra and brinjal packed in unventilated polyethylene covers recorded a shelf life of nine days under refrigeration as against four and five days respectively under ambient conditions. The shelf life of the cut vegetables packed in unventilated polypropylene cover under refrigeration was fourteen days for drumstick, nine days for cowpea, ashgourd, pumpkin and elephant foot yam.

Packaging of precut vegetables brought about significant reduction in microbial population under all storage conditions. Modified atmosphere packaging of precut vegetables in unventilated polymeric films significantly lowered the microbial population. Microbial count was the lowest in cowpea, pumpkin, drumstick and elephant foot yam packed in polypropylene and brinjal and okra in polyethylene cover. In the case of ashgourd, however least microbial count both under ambient and refrigerated storage was found in polystyrene tray wrapped with cling film. In all the fresh cut vegetables the population of yeast and mould was less numerous than bacteria.

The results of the study indicated that unventilated polymeric films are the most ideal packaging materials for cut vegetables, polypropylene for cowpea, ashgourd, elephant foot yam, pumpkin and drumstick and polyethylene for okra and brinjal in terms of visual attributes and keeping quality. Packaging in polystyrene trays and wrapping with cling film can also be recommended for enhanced visual and keeping quality of minimally processed products.

Shelf life obtained for pretreated and packed cut vegetables under refrigeration were nine days for cowpea, brinjal, okra, ashgourd, ten days for pumpkin, elephant foot yam and fourteen days for drumstick.

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* Orginals not seen

Appendix

APPENDIX

COMPOSITION OF MEDIA

1. Nutrient Agar Media (For bacteria)

Glucose	:	5 g
Peptone	:	5 g
Beef extract	:	3 g
Agar	:	20 g
Sodium chloride	:	5 g
Distilled water	:	1 lit
pH	:	6.5-7.5

2. Rose Bengal Agar Base (For Fungus)

Papaic digest of soybean meal	:	5 g
Dextrose	:	10 g
Monopotassium phosphate	:	1 g
Magnesium Sulphate	:	0.5g
Rose Bengal	:	0.05g
Agar	:	15.0 g
pH	:	6.5-7.5

3. Sabouraud Dextrose Agar (For Yeast)

Glucose	:	40.0 g
Agar	:	15.0 g
Pancreatic digest of casein	:	5.0 g
Peptic digest of animal tissue	:	5.0 g

STANDARDISATION OF MINIMAL PROCESSING TECHNIQUES FOR SELECTED VEGETABLES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The study "Standardisation of minimal processing techniques for selected vegetables" was undertaken at the Department of Processing Technology, College of Horticulture, Kerala Agricultural University, with the objective of developing the protocol for minimal processing in seven vegetables viz, cowpea, brinjal, okra, elephant foot yam, pumpkin, ashgourd and drumstick.

Shriveling, browning and rotting were the major causes of deterioration in storage of cut vegetables under ambient conditions. Surface sanitation with 30ppm sodium hypochlorite was found to be the most effective treatment for preserving visual quality, reducing microbial contamination and enhancing the shelf life of all the cut vegetables.

Prestorage treatment of cut vegetables with chemical preservatives potassium metabisulphite / sodium benzoate coupled with acidulants ascorbic acid / citric acid was effective in reducing browning, retaining firmness and controlling decay in cut vegetables. The treatment combination of 0.1% each of potassium meta bisulphite and ascorbic acid was found to be superior to the other treatments in maintaining visual and keeping quality in fresh cut vegetables. The prestorage treatments brought about a four fold reduction in bacterial and a three fold reduction in fungal and yeast count as compared to control.

Exposure of cut vegetables to gamma irradiation resulted in a six fold reduction in bacterial sand fungal and three fold reduction in yeast count. The optimum irradiation dose for maintaining visual quality and reducing microbial population was 200 Gy for precut okra, elephant foot yam, pumpkin, cowpea and drumstick and 100 Gy for ashgourd and brinjal. Shelf life of irradiated vegetables was not further extended when kept under refrigeration.

Refrigerated storage significantly reduced the intensity of undesirable physical changes microbial deterioration and enhanced shelf life of cut vegetables.

Unventilated polymeric films were found to be the ideal packaging material for cut vegetables, polypropylene for cowpea, ashgourd, elephant foot yam, pumpkin and drumstick and polyethylene for okra and brinjal in terms of visual attributes and shelf life. Packaging in polystyrene tray and wrapping with cling film can also be recommended for enhanced visual and keeping quality of minimally processed products. Shelf life obtained for pretreated and packed cut vegetables under refrigeration were nine days for cowpea, brinjal, okra, ashgourd, ten days for pumpkin, elephant foot yam and fourteen days for drumstick.