INTRODUCTION AND RESEARCH OBJECTIVES

1.1 INTRODUCTION

India has emerged as the second largest producer of fruits and vegetables in the world only next to China, and in terms of total area and production our country is designated as “fruit and vegetable basket” of the world. Presently, India is producing around 71 million tones of fruits and 133 million tonnes of vegetables under a vast area of 6 and 8 million hectares, respectively (NHB, Indian Hort. Database 2010). According to Baisya (2009) world production of fruits and vegetables stands at 550 million tonnes and 910 million tonnes, respectively and India produces about 64 million tonnes of fruits and 126 million tonnes of vegetables annually which is about 12 and 14 per cent of the world production respectively.

Fruits, being highly nutritive, are important component of human diet, but possess very short post-harvest shelf-life. As they ripen, become very soft and more prone to injuries, which make them highly perishable. In India, around 30 per cent of the total produce is wasted due to spoilage. Hence, there is an urgent need to develop technologies to overcome post-harvest losses of fruits (Surendranathan, 2005), as these raw materials perish due to their harvest, storage, grading, transport, packaging and distribution. As fresh horticultural produce has limited shelf-life ranging from a few hours to few weeks at ambient temperature, so packaging is required not only for food preservation and protection but also is assumed to maintain multifunctional role by serving as a symbol of value addition, food quality and assurance, and ultimately a tool for convenient storage marketing (FAO, NHB 2000). The main purpose of food packaging is to protect the food from external microbial or other contamination including oxygen, water vapour and light and it also plays an important role in determining the shelf-life of a food (Floros et al., 1997). One of the most important package related parameters that could affect the post-harvest metabolism and post processing deterioration is storage gas composition and every fruit and vegetable needs a different and
sometimes a very specific gas composition ratio to maximize its shelf-life, although the gas concentrations depend on storage temperature and duration (Argenta et al., 2004).

In recent years, the major driving forces for innovation in food packaging technology is perhaps due to the increase in demand for minimally or lightly processed foods. Minimal processing means application of operations like washing, sorting, trimming, peeling, slicing or chopping and preventing browning that affect the freshness of fruits and vegetables. Fresh-cut fruits and vegetables are produce that are minimally processed and altered by peeling, slicing or chopping with or without washing (FDA, 2007). These products are processed from fresh fruits and vegetables which remain metabolically active even after harvesting and undergo ripening and senescence processes. Most fresh-cut fruits and vegetables are usually consumed fresh and a non-thermal preservation method is applied before consumption. Because of these minimal processing operations, the shelf lives of these commodities are very short, even when kept at the optimum storage conditions of refrigeration and humidity (Abadías et al., 2008). Packaging materials for minimally processed produce should ideally have higher permeability to gases and ethylene, or contain gas absorbers to cope with high respiration and ethylene production.

![Minimally processed fruits and vegetables](image)

**Fig. 1.2: Minimally processed fruits and vegetables**

In this study, Active or smart packaging techniques are proposed for better quality retention and shelf-life extension of fresh as well as minimally processed (MP) products of fruits and vegetables. The term ‘active’ reflects to perform some role other than providing an inert barrier to external conditions. “Active packaging (AP) is an innovative concept that can be defined as a mode of packaging in which the package, the product and the environment interact to prolong the shelf-life or enhance safety or sensory properties, while maintaining nutritional quality of the product” (Suppakul et al., 2003). This type of packaging plays an additional role in maintaining the quality of minimally processed produce as compared to traditional packaging systems which are specifically designed to control produce’s deterioration reactions by utilizing active ingredients that have been deliberately included in the packaging material or the headspace of the package (Day, 2008) by inhibiting the growth of pathogenic and spoilage microorganisms, preventing and/or indicating the migration of contaminants, and displaying any package leaks present, thus ensuring food safety. Currently, most active packaging technologies for fruits and vegetables depend on sachet technology,
which contains the active ingredients inside small bags that are placed in the food package and these bags are usually permeable to gases but impermeable to the in-sachet contents (Ozdemir and Floros, 2004). Potential technologies being used in active packaging are O₂ scavenging, ethylene absorbing, CO₂ scavenging/emitting, moisture/humidity regulating, antimicrobial or antioxidant releasing and taint removal systems.

1.2 APPLICATIONS OF ACTIVE PACKAGING TECHNOLOGIES/SYSTEMS

Active packaging systems can be classified into active scavenging systems (absorbers) and active-releasing systems (emitters). Scavenging systems remove undesired compounds such as oxygen, excessive water, ethylene, carbon dioxide, taints and other specific food compounds whereas releasing systems actively add compounds to the packaged food such as carbon dioxide, water, antioxidants or preservatives. Both absorbing and releasing systems aim at extending shelf-life and/or improving food quality (Vermeiren et al., 1999). Modified atmospheric conditions are created inside the packages by the commodity itself and/or by active modification techniques by involving the use of O₂, CO₂ and ethylene scavengers within the package.

Table 1.1: Types of active packaging systems

<table>
<thead>
<tr>
<th>Type of AP</th>
<th>Ingredients/Substances used</th>
<th>Application</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₂ absorbing</td>
<td>Powdered iron oxide, ascorbic acid, glucose oxidase-glucose</td>
<td>Dried fruits, potato chips, fruit tortes, nuts</td>
<td>Inhibit lipid oxidation, mould growth and discolouration</td>
</tr>
<tr>
<td>CO₂ absorbing /emitting</td>
<td>Activated charcoal, iron powder-calcium hydroxide, ferrous carbonate-metal halide</td>
<td>Fruits, vegetables, ground coffee and cheese</td>
<td>Absorbs CO₂ produced to prevent package swelling</td>
</tr>
<tr>
<td>Moisture absorbing</td>
<td>Silica gel, diatomaceous earth</td>
<td>Dry products, fruit and vegetables</td>
<td>Control moisture</td>
</tr>
<tr>
<td>Ethylene absorbing</td>
<td>Activated charcoal, silica gel, zeolite, Fuller’s earth</td>
<td>Whole and MP fruits and vegetables</td>
<td>Control fruit &amp; vegetable ripening</td>
</tr>
<tr>
<td>Antimicrobial releasing</td>
<td>Sorbates, benzoates, propionates, silver salts, ethanol, peroxide, sulfur dioxide</td>
<td>Fruits, vegetables dry apricots, bakery products and cheese</td>
<td>Inhibit microbial growth</td>
</tr>
<tr>
<td>Antioxidant releasing</td>
<td>BHA, BHT, TBHQ, ascorbic acid, tocopherol</td>
<td>Ready-to-eat dry cereals</td>
<td>Inhibit lipid oxidation</td>
</tr>
</tbody>
</table>

The presence of oxygen in food packages can trigger many food deteriorative reactions which can cause off-flavour and off-odour development (e.g., rancidity due to lipid oxidation), colour changes (e.g., pigment oxidation), nutrient losses (e.g., oxidation of vitamin C) and may facilitates microbial growth, thereby causing significant reductions in the nutritive value and shelf-life of foods. It also has a considerable effect on the respiration rate
and ethylene production of respiring food stuffs such as fruits and vegetables. (Lopez-Rubio et al., 2004). Oxygen scavengers are active additives used in the packaging system to absorb residual oxygen that remains after the package is sealed and that originated from the product’s respiration reduces O$_2$ and the package permeability. Therefore, the control of oxygen levels in food packages is important to limit the rate of these deteriorative and spoilage reactions in foods.

High levels of carbon dioxide (CO$_2$) usually play a beneficial role in retarding microbial growth on meat and poultry surfaces and in delaying the respiration rate of fruits and vegetables as this gas is more permeable than oxygen through many plastic films used for the food packaging, most of CO$_2$ inside the package usually permeates through the film; where the package has a high permeability to CO$_2$, a carbon dioxide emitting system may be necessary to reduce the rate of respiration and suppress the microbial growth (Ozdemir and Floros, 2004). On the other hand, commercial CO$_2$ scavengers make use of the sachet technology either by employing CO$_2$ absorbers or adsorbers suitably named as CO$_2$ controllers when applied inside the package increases CO$_2$ concentration in some foods due to foods due to deterioration or respiration reactions and excess CO$_2$ may adversely affect the product (anaerobic metabolism, pH reduction and colour and flavour changes) or damage the package (Brody et al., 2001).

The control of excess moisture inside the food packages is important to suppress microbial growth and prevent foggy film formation. Due to low permeability of the fruit package to water vapour, water accumulation inside is more pronounced and therefore, the excess water deposition inside a fruit package usually occurs due to the ongoing transpiration of the fresh produce, temperature fluctuations in high equilibrium relative humidity of the food packages. Commonly used moisture scavengers are silica gel, calcium oxide and several natural clays.

Ethylene is a growth stimulating hormone that accelerates ripening and senescence by increasing the respiration rate of climacteric fruits and vegetables and also accelerates the rate of chlorophyll degradation in leafy vegetables and fruits. Hence, the removal of ethylene gas from the package headspace slows senescence and maintains an acceptable visual and organoleptic quality of the product. The most common, inexpensive ethylene scavenger consists of potassium permanganate embedded in silica which is usually contained in sachets placed inside the package.

Research into the area of antimicrobial food packaging materials has increased significantly during the past ten years (Cooksey, 2001) as an alternative method to control undesirable microorganisms on foods by means of the incorporation of antimicrobial
substances in or coated onto the packaging materials (Han, 2000). Direct surface application of antimicrobial substances has limited benefits because the active substances are neutralized or diffuse rapidly from the surface into the food mass. Therefore, the use of packaging films containing antimicrobial agents could be more efficient if high concentrations are maintained where they are needed by slow migration or action of the agents onto the surface of the product (Quintavalla and Vicini, 2002). The major potential food applications for antimicrobial films include meat, fish, poultry, bread, cheese, fruits, vegetables and beverages, which can play an important role in reducing the risk of pathogenic contamination, thereby extending the shelflife of foods.

1.3 OBJECTIVES OF THE RESEARCH WORK

Limited research has been done on Active Packaging (AP) of fruits and vegetables in our country. Therefore, the present work has been undertaken to study the uses/applications and effects of AP in prolonging the shelf-life of fruits and vegetables. The goal of the present study was to extend the shelf-life of a product, while maintaining its nutritional quality with minimum changes in terms of physico-chemical, microbial and organoleptic parameters with storage. In order to achieve this broad objective, the framework of this investigation was developed by classifying this study under the following main task areas:

- To standardize the technique of preparation of minimally processed products from fruits and vegetables.
- To study and compare the application and uses of various active packaging ingredients on whole (fresh) as well as minimally processed (MP) products of fruits and vegetables.
- To evaluate the shelf-life of whole fruits/vegetables and their MP products under various active packaging treatments up to initiation of product spoilage.
- To assess the organoleptic and microbial quality of all the products.