ABSTRACT

In recent past years, a lot of research work has been done to develop innovative films and coatings for packaging of fruits and vegetables which improve their qualitative parameters during storage. Recently, researchers are focusing to design films and coatings based on biodegradable materials which would serve as covering to the food and reduce the hazards caused by use of plastics and by degrading biologically. The objectives behind the preparation of packaging such films and coatings is to reduce the loss of moisture, migration of gases and to extend the shelf life of the fruits and vegetables. This paper not only reviews introduction and need of coating but also provide the knowledge about types of coating on different fruits and vegetables. The main focus on the review is on the coating of fruits and vegetables based on natural sources.

Keywords: Coating, fruits, vegetables, natural sources, shelf-life

Fruits and vegetables are important part of daily diet and in recent years, they are in high demand from most of the population. They are rich in vitamins, essential minerals, antioxidants, bioflavonoids, dietary fibers and flavor compounds because of which they get exposed to abiotic and biotic adversities. Due to perishable nature of fruits and vegetables they are easily attacked by microorganisms and insects; respiration and transpiration processes leads to faster deterioration of the quality (Tiwari et al. 2014). In addition to this, spoilage of fruits and vegetables is caused due to external and internal factors. Environmental factors mainly O₂, CO₂, ethylene gas, temperature and other stress factors are categorized under external factors while the internal factors include the species, cultivar and stage of harvesting (Kluge et al. 2002). Also, the skin of fruits and vegetables is responsible for contamination of the flesh which increases the possibilities of the spoilage and results in biochemical deterioration such as browning, off-flavour and texture breakdown. This decreases the quality of fruits and vegetables and consumers get exposed to risk due to the presence of pathogenic microbes (Harris et al. 2003). Principal factors which determine the quality of fruits and vegetables include texture, colour, appearance, flavor, nutritional value and microbial safety contribute to the marketability. Deterioration of fruits and vegetables due to post-harvest losses is a serious problem for which finding a solution is very necessary. Spoilage of fruits and vegetables results in a decrease in commercial value and lots of damages are caused to the producer. According to report given by Food and Agriculture Organization (FAO), half of the fruits and vegetables are lost and wasted every year because of storage problems, retail, transportation and post harvest
processing. The report also reveals that the loss and wastage of fruits and vegetables in Southeast Asia and South Asia is maximum i.e. almost 20% during packaging and transformation. In India, about 44.6% vegetables, 34% fruits and 40% combined fruits and vegetables are unable to be sold by farmers (Pandey, 2018).

Owing to big losses in harvested fruits and vegetable, farmers are facing income losses all over the world. Hence, there is a need to adopt advance techniques and post-harvest processing to reduce these losses which are quantitative and qualitative as well.

**PREVENTIVE MEASURES FOR SPOILAGE OF FRUITS AND VEGETABLES**

To prevent the spoilage and to prolong the shelf life of fruits and vegetables, use of various processes such as low temperature processes, modified atmospheric packaging, irradiation and coating have been done (Xanthopoulos et al. 2012; Castagna et al. 2013; Sanudo et al. 2009). It has been found that different preservation techniques including cold storage, UV irradiation, modified atmospheric packaging and ozonization are used to reduce the spoilage, increase shelf life and retain the nutritional value of fresh fruits (Duan et al. 2011). Because of economical cost and reduction in nutrients due to some preservation techniques, other preventive measures also have been found by researchers. Edible films and coatings is one of them which is gradually developing day by day and have proven to improve shelf life of fruits and vegetables by many workers.

**EDIBLE COATING AND ITS TYPES**

Thin layer of material which can be consumed and provide a barrier to oxygen, moisture and solute movement and microorganisms of an external source for food is defined as edible coating. It increases the shelf life by reducing the loss in water content and migration of solutes, exchange of gases, respiration and rates of oxidative reactions as well as it decreases physiological disorders on fresh-cut fruits by offering the semipermeable barrier (Baldwin et al. 1996). Guilbert et al. (2005) defined edible coating as a thin layer of material that covers surface of the food and can be eaten as a part of the whole product. Therefore, composition of edible coatings must fulfill the regulations that apply to the related food product. Hence, the edible coatings are defined by European Directive (Directive 95/2/CE; Directive 98/2/CE) and the US Code of Federal Regulation (FDA 21 CFR 1722006).

Different methods for the application of coating includes dipping, spraying, brushing and panning followed by drying. Preparation of edible film is carried out by using hydrocolloids, proteins, polysaccharides, lipids and composites (Donhowe and Fennema, 1993). An edible coating has shown to be a preservation technique which preserves fruit plumpness, fresh appearance and hardness as well as gives the shiny surface to fruits, therefore increases the commercial value of fruits (Xu and Chen, 2003). Traditionally, food corporations use polymeric films (polyethylene PE, plastic PP, polystyrene PS) to pack fruits and vegetables owing to their massive availability at a relatively low price and their good mechanical properties, a barrier to oxygen, carbon dioxide (Siracusa et al. 2008). But the major use of synthetic packaging films has resulted to serious ecological issues due to their total non-biodegradability. Thus, biodegradability is not solely a functional demand however, conjointly a very important environmental attribute. Renewable raw materials like starch and bio-derived monomers can be used as bio-based packaging fruits and vegetables by replacing petrochemical-based materials with biodegradable is increasing day by day (Tharanathan, 2003).

Edible films and coatings have got significant consideration in recent years on account of their benefits over synthetic films. The principal advantage of edible films over conventional synthetics is that they can be eaten with the package. There is no issue of disposal of the package even if the package has not been eaten, it would not take part in environmental pollution. These films are prepared by using renewable, edible ingredients and therefore are easy and faster to break down as compared to plastic.
The films can improve the qualitative properties of packaged food even though they are containing different additives such as flavours, colours, sweeteners (Bourtoom, 2008). Preparation of edible films and packages using natural waxes, resins and polysaccharides give an ideal packaging material as they can be eaten with the package. Renewable sources are used in making of such packaging materials whereas synthetic packaging is made up of paraffin, mineral oil, oxidized polyethylene and plastics which are manufactured from fossil fuels available in limited quantity (Baldwin, 1994). Taking into account, the demand for the healthier, safer, more natural and eco-friendly products have been developed recently as an alternative to synthetic waxes (Fresh Plaza, 2013). There are different types of coatings which based on natural sources like lipids, proteins and carbohydrates.

**LIPIID-BASED COATINGS**

A group of hydrophobic compounds, which are neutral esters of glycerol and fatty acids are lipids.

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**Table 1: Different lipid coating materials**

<table>
<thead>
<tr>
<th>Produce</th>
<th>Coatings Types</th>
<th>Effect on Produce</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guava</td>
<td>Carnauba wax</td>
<td>Delayed ripening and reduction in water loss and decay incidence. TSS, total</td>
<td>Jacomino et al. 2003; Kore and Kabir, 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>titratable acidity, and ascorbic acid less affected.</td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>Wax, oil</td>
<td>Increased shelf-life</td>
<td>Sabir et al. 2004</td>
</tr>
<tr>
<td></td>
<td>Wax + beeswax + soybean oil +</td>
<td>Reduced level of soluble solids, titratable acidity and ascorbic acid loss;</td>
<td>Torgul and Arslan, 2005</td>
</tr>
<tr>
<td></td>
<td>CMC</td>
<td>increased storage life up to 34 days</td>
<td></td>
</tr>
<tr>
<td>Candelilla Wax</td>
<td>Improved shelf life, excellent antifungal barrier and inhibit growth of natural</td>
<td>Ochoa et al. 2011</td>
<td></td>
</tr>
<tr>
<td>Peach</td>
<td>Wax</td>
<td>Reduced rate of physico-chemical changes; retained the quality</td>
<td>Chaynika et al. 2005</td>
</tr>
<tr>
<td>Passion fruit</td>
<td>Carnauba wax</td>
<td>Reduced fresh matter loss percentage and increased relative water retention;</td>
<td>Mota et al. 2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced level of peel percentage and pulp. Increased pulp/peel percentages</td>
<td></td>
</tr>
<tr>
<td>Pomegranate</td>
<td>Oil + starch</td>
<td>Decreased softening of arils, weight loss and % of browning index, loss of</td>
<td>Oz and Ulukanli, 2012</td>
</tr>
<tr>
<td>Huanghua pears</td>
<td>Wax + Pea starch (PS)</td>
<td>vitamin C, anthocyanin loss and delayed microbial spoilage</td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>Mineral oil wax</td>
<td>Retaining texture (especially for brittleness); maintained higher POD activity</td>
<td>Davila-Avina et al. 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and lowering activities of cell wall hydrolases such as PE, PG, and cellulose</td>
<td></td>
</tr>
<tr>
<td>Green pepper</td>
<td>Semperfresh</td>
<td>Retaining higher contents of Vit. ‘C’ and total ‘chlorophyll’</td>
<td>Ozden and Bayindirli, 2002</td>
</tr>
<tr>
<td>Pointed gourd</td>
<td>Semperfresh</td>
<td>Reduced physiological loss in weight and shrinkage</td>
<td>Chakraborthy et al. 2002</td>
</tr>
<tr>
<td>Mango</td>
<td>Carnauba Wax</td>
<td>Improved fruit quality characteristics including levels of fatty acids and aroma</td>
<td>Dang, 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volatiles. Prevented fruit ripening, fruit firmness retained.</td>
<td></td>
</tr>
</tbody>
</table>
Esters of long-chain monohydric alcohols and fatty acids known as “waxes”, comes under lipids category (Hernandez, 1994). Coatings based on lipids (Table 1) known to be good barriers to moisture loss. It extends the shelf-life by preventing moisture loss and reducing the respiration. It improves appearance by giving a shiny product in fruits and vegetables.

PROTEIN BASED COATINGS
Sources of proteins used in edible coatings of plant-derived include corn zein, wheat gluten, soy protein, milk proteins and animal-derived proteins like collagen, keratin and gelatin (Zhang and Mittal, 2010). Different types of proteins that are used as coatings are given in Table 2.

CARBOHYDRATE-BASED COATINGS
Different types of polysaccharides are used to make edible coatings. Marine and agricultural plants and animals are generally used for the extraction of polymers to make the coatings. These coatings can be used to reduce the loss of moisture from food during the storage. Being hydrophilic in nature, polysaccharides, do not function well as physical moisture barriers. The approach by using which is they retard moisture loss by acting as a sacrificial moisture barrier to the surrounding so that the moisture content of the coated food can be maintained (Kester and Fennema, 1986). In addition to stopping moisture loss, some forms of polysaccharide films are less permeable to oxygen, that could assist to maintain the quality of foods. Some polysaccharides possess crystalline nature which causes processing and performance issues especially in terms of packaging of wet products. However, these polysaccharides make materials which possess impressive gas barrier properties. The commonly used polysaccharides for material production include cellulose, starch, gums, and chitosan. The linear structure of these polysaccharides include cellulose, amylose (a component of starch), and chitosan that offers toughness, flexibility, transparency to their films, and makes them resistant to fats and oils. The

<table>
<thead>
<tr>
<th>Produce</th>
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<th>Important finding</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>Whey protein + Gellan Gum</td>
<td>WPC-gellan coated fruits were rated highest for taste, glossiness, colour and overall acceptability and lowest loss in weight, no, better TSS and acidity content</td>
<td>Javanmard (2011)</td>
</tr>
<tr>
<td>Apples, potatoes, carrots, and onions</td>
<td>Soy protein isolate (SPI)</td>
<td>SPI coatings proved as a good moisture barrier and antioxidative property.</td>
<td>Shon J et al. (2011)</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>Rice Bran oil + Whey protein concentrate</td>
<td>Preserved colour, firmness, taste, and overall acceptability of the fruits, lowered increment in acidity and weight loss</td>
<td>Hassani et al. 2012</td>
</tr>
<tr>
<td>Cherry</td>
<td>Gelatine film</td>
<td>Lowest moisture loss</td>
<td>Lim et al. 2011</td>
</tr>
<tr>
<td>Apple</td>
<td>Carrageenan + whey protein Concentrate</td>
<td>Maintained the original colour during storage without changes in sensory properties.</td>
<td>Lee et al. 2003</td>
</tr>
<tr>
<td>Mango</td>
<td>Galactomannans + collagen</td>
<td>Effective in less (O₂) consumption and (CO₂) production</td>
<td>Lima et al. 2010</td>
</tr>
<tr>
<td>Zucchini</td>
<td>Casein proteins</td>
<td>Reduced water loss</td>
<td>Avena-Bustillos et al. 1994</td>
</tr>
<tr>
<td>Potato</td>
<td>Whey protein + calcium caseinate</td>
<td>Delayed browning</td>
<td>Tien et al. 2001</td>
</tr>
<tr>
<td>Apple slices</td>
<td>Milk protein</td>
<td>Decreased oxidative browning and moisture loss</td>
<td>Krochta et al. 1994</td>
</tr>
</tbody>
</table>
polysaccharides used in edible coating formulation discussed in Table 3.

**CONCLUSION**

The utilization of edible coatings and films as protective packaging techniques for the food industries has turned into a point of incredible intrigue on account of their potential for improving the shelf life of fruits and vegetables and maintaining quality attributes. These coatings inhibit the migration of water vapours, O\textsubscript{2}, CO\textsubscript{2}, aromas etc. They carry different food additives and retain the natural properties of food for longer time. However, coatings and films should be chosen for fruits and vegetables packaging as it offers lots of benefits over conventional packaging. Being biodegradable in nature it reduces the cost of packaging and health hazards which appear due to plastic packaging.
and Films to Improve Food Quality (J. M. Krochta; E. A. Baldwin; and M. O. Nisperos Carriedo; eds.); Technomic Publishing Company; Lancaster; PA: 25.


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