Year:**2013**, Volume: **1**, Issue: **2**
First page: (**131**) Last page: (**138**)
ISSN: **2321-2187**
Online Available at **www.florajournal.com**

International Journal of Herbal Medicine

Minimal Processing and Preservation of Fruits and Vegetables by Active Packaging

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Packaging should protect the product from contamination and prevent it from spoilage. Packaging has normally been expected to be inert towards the packaged product, but the potential for packaging to put in to the quality retention and the convenience of packaged goods was not utilized. In response to the dynamic changes in current market trends and consumer demand, the area of Active Packaging (AP) is becoming increasingly significant. Active packaging changes the condition of the packed foods with the use of the incorporation of certain additives into the packaging films or inside the packaging headspaces so as to extend the product's shelf life. Principal AP systems include those that involve moisture absorption and control, oxygen scavenging, carbon dioxide and ethanol generation, and antimicrobial (AM) migrating and non-migrating systems.

Keyword: Active packaging, Minimal Processing, Oxygen Scavenging, Microbial Changes

1. Introduction

There is an old adage that “If you package it right, you can sell just about anything.” It’s no different for packaging fruits and vegetables—they must be packaged so customers will buy them.A characteristic aspect of minimal processing is an integrated approach, where raw materials, handling, processing, packaging and distribution must all be properly considered to make shelf-life extension possible. New cultivars need to be selected and created or hybrids adapted to meet the specific requirements of minimal processing. The equipment used in unit operations, such as peeling and shredding, needs further development so that it can process produce more gently. There is no sense in disturbing the quality of produce by rough treatment during processing, and patching it up after-wards by the use of preservatives.

1.1 Functions of Packaging:

Packaging should protect the product from contamination and prevent it from spoilage, and at the same time it should:

- Extend shelf life
- Facilitate distribution and display
- Provide the consumer with greater ease of use and time-saving convenience
- Communicate with the consumer as a marketing tool

Active packaging changes the condition of the packed foods with the use of the incorporation of certain additives into the packaging films or inside the packaging headspaces so as to extend the product's shelf life.

Minimal processing can be defined as the handling preparation, packaging and distribution of agricultural commodities in a fresh like state, and may include processes

such as peeling, dicing, slicing, trimming and curing [1]. Many terms are applied to fruits and vegetables cleaned and prepared in fresh form: partially processed, minimally processed, prepared, precut fresh-processed, and lightly processed etc.
Minimal processing of raw fruit and vegetables have two purposes:

1) It is important to keep the produce fresh, yet supply it in a convenient form without losing its nutritional quality.
2) For feasible distribution to the consumers, the product should have a sufficient shelf life [2]. In an ideal case, minimal processing can be seen as 'invisible' processing. The microbiological, sensory and nutritional shelf life of minimally processed vegetables or fruit should be at least 4-7day, but preferably even longer, up to 21days depending on the market, the loss of ascorbic acid and carotenes is the main limiting factor of nutritional quality [3,4].

The processes by which quality of food is lost often involve interaction with substances taken up from their environment. This may mean a gain or loss of water, oxygen or ethylene, and contamination with micro-organisms. There are also somesubstances that build up in the packaged food on storage, including the cooking odors and containment resulting from the oxidation of oils and fats.
Some of these compoundsnormally lost when foods are cooked shortly before serving.
The utility of foods can be improved significantly if the package contributes to the processes ofheating or cooling. These effects are summarized in Table 1.

Table 1: Mechanism of food quality loss

S.No.	Quality Attribute	Result of Presence	Packaging Activity
1	Mold	Microbial spoilage	Antimicrobial surface Antimicrobial release Oxygen scavenging
2	Oxidation	Rancidity Color change Nutrient loss	Oxygen scavenging Odor absorption Antioxidant release Oxygen scavenging Oxygen scavenging
3	Food chemistry	Odor/flavor formation	Absorption
4	Water movement	Texture change Microbial spoilage	Dessication Humidity buffering Absorption of condensate
5	Senescence	Premature ripening	Ethylene scavenging 1-MCP release Atmosphere modification

Active Packaging 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 shelf life or enhance safety or sensory properties, while maintaining the quality of the product.

In active packaging, which includes various gas absorbents and emitters for minimally processed food [5]. Active packaging includes the components of packaging systems which are capable of scavenging oxygen; absorbing carbon dioxide, ethylene, moisture and/or flavor/odor taints; releasing carbon dioxide, antioxidants, ethanol and/or other preservatives; and/or maintaining temperature control and/or compensating for temperature changes.

The quality changes of diced onions with and without a commercial gas absorbent is based on potassium permanganate and activated alumina, observed byHoward et. al. [6]. Ethylene was effectively removed by the gasabsorbent, and reduced thelevels of sulphur volatiles and CO, in the package of diced onions. Acceptablequality diced onions can be kept at 2°C for 10daysusingthe potassium permanganate gas absorbent concluded by Howard et al.[6].

Before applying this technology, it should be noted that all food products have a unique deterioration mechanism that must be understood. The shelf-life of packaged food is dependent on various factors such as the intrinsic nature of the food (e.g. pH, nutrient content, occurrence of antimicrobial compounds, water activity, redox potential, respiration rate and biological structure) and extrinsic factors (e.g. storage temperature, the surrounding gaseous composition and relative humidity). These factors will directly influence the biochemical, chemical, physical and microbiological spoilage mechanisms of individual food products and their achievable shelf-lives. By carefully considering all of these factors, it is possible to evaluate existing and developing active packaging technologies and apply them for maintaining the quality and extending the shelf-life of different food products [7].

In some cases, it also changes the package's permeation properties and/or the concentration of different volatiles and gases in the package headspace during storage. Moreover, this packaging technique actively adds, in small amounts, antimicrobial, antioxidative or other quality improving agents via the packaging materials into the packed food.

Active packaging also plays a role in food preservation other than just providing an inert barrier to the external conditions [8]. Active packaging techniques can be divided into two categories. The first category is absorbers or scavengers, where the systems remove undesired compounds such as oxygen, carbon dioxide, ethylene, and excessive water. The second category is the releasing systems, which actively adds or emits compounds to the packaged foods or into the headspace of the package - such as carbon dioxide, antioxidants and preservatives.

1. Different Changes that Influence Properties of Food:

1.1 Physiological and Biochemical Changes

Polyphenol oxidase,the most important enzyme with regard to minimally processed fruit and vegetables,which causes browning[4,9,10]. Four different components: oxygen, copper, anoxidizing enzyme and a suitable substrate are required for enzymatic browning. At least one of these components must be removed from the system toprevent browning; another important enzyme is lipooxidase, which catalyzes peroxidation reactions, causing the formation of numerous bad-smelling aldehydes and ketones'. The amount of ethylene can also increase following minimal processing and since ethylene contributes to the biosynthesis of an enzyme involved in maturation of fruits, it may be responsible for physiological changes in sliced fruit, such as softening. There is an increase of 1.2-7.0 fold or even more in respiration activity of minimally processed produce depending on its cutting grade and temperature [10,11] and there is formation of ethanol,ketones and aldehydes if the package conditions are anaerobic [12].

1.2 Microbiological Changes

Most of minimally processed vegetables fall into low acid category (pH 5.8-6.0), the large number of cut surface and high humidity can provide ideal conditions for the growth of microorganisms [13]. Pseudomonas and Erwinia spp., are predominant microflora of fresh leafy vegetables with an initial count approximately 10^5 Colony forming units (CFU) per gram and low number of yeasts and molds are also present [10,13]. Pectinolytic strains of Pseudomonas are responsible for bacterial soft rot,during cold storage of minimally processed leafy vegetables [10,13]. In various commercial vegetable salads [14] found high initial counts for psychrotrophicbacteria and total mesophillicbacteria exceeding 10^8cfu/g. More contamination were found on mixed salads and carrots than green or red chicory. *Aeromonashydrophila*counts (10^6cfu/g) were also found high by these authors.

1.3 Key requirement for Minimal Processing of fruits and vegetables:

a) Good quality of raw materials (correct cultivar variety, correct cultivation, harvesting and storage condition)
b) Strict hygiene and good manufacturing practices, use of hazard and critical control point principles.
c) Correct temperature and humidity during distribution and retailing.
d) Low temperature during processing.
e) Use of mild additives in washing water for disinfection or the prevention of browning.
f) Careful cleaning and/or washing before and after peeling.
g) Good quality water (sensory, microbiology,pH) for washing.
h) Gentle spin drying following washing.
i) Correct packaging materials and packaging methods.
j) Gentle peeling
k) Gentle cutting, slicing and/or shredding.

1.4 Active Packaging Technologies:

Active packaging is normally designed to deal with one property or requirement of the food or beverage. The property normally selected is that most critical as the first limiter of shelf life or quality. To this extent, active packaging is provided to fine-tune the properties of the packaging to meet the necessities of the food, this is not different from the normal aim of the packaging technologist to match the requirements of the food with the properties of the packaging.

Active packaging perform traditional functions of packaging such as providing barriers to gases, moisture and vapor, preventing product contamination from outside, and making food handling and identification easy [15,16]. Additionally, the active packaging has secondary functions such as antioxidation, antimicrobial, and product traceability; thus it helps in further improvement of produce properties.

1.5 What Can Happen Inside a Package?

Fresh foods just after harvest or slaughter are still active biological systems. The atmosphereinside a package constantly changes as gases and moisture are produced during metabolicprocesses. The type of packaging used will also influence the atmosphere around the foodbecause some plastics have poor barrier properties to gases and moisture. The metabolism of fresh food continues to use up oxygen in the headspace of a package and increases the carbon dioxide concentration. At the same time water is produced and the humidity in the headspace of the package builds up. This encourages the growth of spoilage micro organisms and damages the fruit and vegetable tissue.

Many food plants produce ethylene as part of their normal metabolic cycle. This simple organic compound triggers ripening and aging. This explains why fruit such as bananas and avocados ripened quickly when kept in the presence of ripe or damaged fruits in a container and broccoli turn yellow even when kept in the refrigerator.

Extensive trials have shown that each fresh food has its own optimal gas composition andhumidity level for maximizing its shelf life. Active packaging offers promise in this area; it isdifficult with conventional packaging to optimize the composition of the headspace in apackage. The atmosphere surrounding the food also influences the shelf life of processed foods. For some processed foods, lowering of oxygen is beneficial for slowing down the discoloration of cured meats and powdered milk and for preventing rancidity in nuts and other high fat foods.

High carbon dioxide and low oxygen levels can pose a problem in fresh produce leading toanaerobic metabolism and rapid rotting of the food. However, in fresh and processed meats,cheeses and baked goods, carbon dioxide may have a beneficial antimicrobial effect.

1.6 Active Packaging Systems

Active packaging employs a packaging material that interacts with the internal gasenvironment to extend the shelf life of a food. Such new technologies continuously modifythe gas environment (and may interact with the surface of the food) by removing gases fromor adding gases to the headspace inside a package. Recent technological innovations for control of specific gases within a package involve theuse of chemical scavengers to absorb a gas or alternatively other chemicals that may release aspecific gas as required. The table below sets out some areas of atmosphere controlling in whichactive packaging is being successfully used.

Active packaging systems can be classified into active scavenging systems (absorbers) and active releasing systems (emitters)[17,18]. The active packaging systems are oxygen and ethylene scavengers, moisture absorbers, ethanol and carbon dioxide emitters and antimicrobial releasing systems[19,20,21].

Active Packaging System	Application
Oxygen scavenging	Most food classes
Carbon dioxide production	Most food affected by moulds
Water vapour removal	Dried and meld-sensitive foods
Ethylene removal	Horticultural produce
Ethanol release	Baked foods (where permitted)

1.7 Ethylene Scavenging

A chemical reagent, incorporated into the packaging film, traps the ethylene produced byripening fruit or vegetables. The reaction is irreversible and only small quantities of thescavenger are required to remove ethylene at the concentrations at which it is produced. Afeature of this system is its pink color, which can be used as an indicator of the extent ofreaction and shows when the scavenger is used up.

Systems developed in othercountries are already commercially available. These usually involve the inclusion in thepackage of a small sachet, which contains an appropriate scavenger. The sachet material itselfis highly permeable to ethylene and diffusion through the sachet is not a serious limitation.The reacting chemical for ethylene is usually potassium permanganate, which oxidizes andinactivates it. Potassium permanganate is the most common agent of ethylene removal,it oxidizes ethylene to ethanol and acetate [22]. Activated carbon or zeolite by the physical adsorption on active surface can remove ethylene.

1.8 Oxygen Scavenging

Oxygen can have significant detrimental effects on foods. The presence of oxygen in food packages accelerates the spoilage of many foods. Oxygen can cause off-flavour development, color change, nutrient loss and microbial attack.Oxygen scavengers (also referred to as oxygen absorbers) can therefore help preserve food product quality by decreasing food metabolism, inhibiting undesirable oxidation of labile pigments and vitamins, reducing oxidative rancidity, controlling enzymatic discoloration and inhibiting the growth of aerobic microorganisms [7,8].

Severaldifferent systems are being investigated to scavenge oxygen at appropriate rates for therequirements of different foods. The most commonly used scavenger is ferrous oxideothers include sulfites, ascorbic acid, unsaturated hydrocarbons, photosensitive dyes,ligands and enzymes such as glucose oxidase. In meat industry, oxygen scavenging technologies have been used successfully

A promising application is the use of active packaging to delay oxidation of and therefore rancidity development in vegetable oils. Again the use of discrete sachets containing oxygen absorbents has already found commercial application. In this instance the scavenging material is usually finely divided iron oxide. These sachets have been used in some countries to protect the color of packaged cured meats from oxygen in the headspace and to slow down staling and mold growth on baked products, e.g. pizza crusts. This approach of inserting a sachet into the package is effective but meets with resistance among food packers. The active ingredients in most systems consist of a non-toxic brown/black powder or aggregate which is visually unappealing if the sachet is broken. A much more attractive approach would be the use of a transparent packaging plastic as the scavenging medium.

1.9 Humidity Control

Condensation or 'sweating' is a problem in many kinds of packaged fruit and vegetables. It isof particular concern in cartons of fresh flowers for which there is important export trade.

Unless the relative humidity around flowers is kept at about 98 per cent, water will be lost from bunches. Such high humidity levels mean there is a very real risk of condensationoccurring during transport as the temperature of the flowers may fluctuate by several degrees.

When one part of the package becomes cooler than another, water is likely to condense in thecooler areas. If the water can be kept away from the produce there may be little harm. However when thecondensation wets the produce, nutrients leak into the water encouraging rapid meld growth.When the condensation inside packages is controlled, the food remains dry without drying outthe product itself. Therefore sensitive products such as flowers and table grapes are protectedfrom contact with water. This helps to reduce growth of meld.

1.10 Carbon Dioxide Release

High carbon dioxide levels are desirable in some food packages because they inhibit surfacegrowth of micro organisms. Fresh meat, poultry, fish, cheeses and strawberries are foods,which can benefit from packaging in a high carbon dioxide atmosphere. However with the introduction of modified atmosphere packaging there is a need to generatevarying concentrations of carbon dioxide to suit specific food requirements. Since carbondioxide is more permeable through plastic films than oxygen, carbon dioxide will need tobe actively produced in some applications to maintain the desired atmosphere in the package. So far the problems associated with diffusion of gases, especially carbon dioxide, through thepackage, have not been resolved and this remains an important research topic.

3. Release of Microbial Inhibitors

3.1 Ethanol

Antimicrobial activity of ethanol (or common alcohol) is well known and it is used in medicaland pharmaceutical applications. Ethanol has been shown to increase the shelf life of breadand other baked products when sprayed onto product surfaces prior to packaging. A novel method of generating ethanol vapour, recently developed in Japan, is through the useof an ethanol releasing system enclosed in a small sachet which is included in a food package.Food grade ethanol is absorbed onto a fine inert powder which is enclosed in a sachet that ispermeable to water vapour. Moisture is absorbed from the food by the inert powder andethanol vapour is released and permeates the sachet into the food package headspace.

3.2 Sulfur Dioxide

Sulfur dioxide is primarily used to control meld growth in some fruits. Serious loss of tablegrapes can occur unless precautions are taken against meld growth. It is necessary torefrigerate grapes in combination with fumigation using low levels of sulfur dioxide.

Fumigation can be conducted in the fruit cool stores as well as in the cartons. Cartonfumigation consists of a combination of quick release and slow release systems, which emitsmall amounts of sulfur dioxide. When the temperature of the packed grapes rises due to inadequate temperature control, the slow release system fails releasing all its sulfur dioxide quickly. This can lead to illegalresidues in the grapes and unsightly bleaching of the fruit. Considerable amount of work is done to develop systems, which gradually release sulfurdioxide and are less sensitive to high temperature and moisture than those presently used. These systems have potential use for fresh grapes and processed foods permitted to containsulfur dioxide such as dried tree fruits and wine.

4. Conclusion

Traditionally, packaging is desired to help in the safeguarding of the quality of the food at the level achieved at the final stage of its processing. In practice, the quality decreases in packaged storage because, in part, the combination of packaging material and packaging process availability does not exactly match the specific necessities of each food or beverage. Packaging has normally been expected to be inert towards the packaged product, but the potential for packaging to put in to the quality retention and the convenience of packaged goods was not utilized.In response to the dynamic changes in current market trends and consumer demand, the area of Active Packaging (AP) is becoming increasingly significant. Principal AP systems include those that involve moisture absorption and control, oxygen scavenging, carbon dioxide and ethanol generation, and antimicrobial (AM) migrating and non migrating systems. Of these active packaging systems, the AM version is of great importance. Active packaging involves the manipulation of the environment in the package to enhance food quality and safety, and thus, to extend the shelf-life.

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