www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(5): 1551-1557

www.thepharmajournal.com
Received: 08-03-2022
Accepted: 16-04-2022

Harshdeep Singh
Department of Horticulture, Lovely Professional University, Phagwara, Punjab, India

Rupinder Singh
Department of Horticulture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author
Harshdeep Singh
Department of Horticulture, Lovely Professional University, Phagwara, Punjab, India

Recent advancements in packaging technology, considering the shelf life of fresh fruits: A review

Harshdeep Singh and Rupinder Singh

Abstract
Apart from the health benefits of fresh fruit, consumer interest in its quality is also increasing due to its numerous health benefits. Therefore, packaging is one of the simplest and most effective options through which the shelf life of fresh produce can be increased upto certain level. Temperature, oxygen levels, fruit variety, handling, ethylene rate, and respiration rate are few factors that have direct impact on the shelf life of fruits. Additionally, proper packing techniques and gas exchange plans can significantly extend fruit shelf life upto large extent. With ultramodern packaging ways similar as the modified actuated packaging, the active packaging, antimicrobial and smart packaging, the shelf life of produce can be increased significantly. This Review of the packaging techniques for fresh fruits gives a focus on the advances in the packaging technologies.

Keywords: Packaging, RFID, smart packaging, shelf life and antimicrobial packaging, holograms and barcodes

Introduction
India's total fruit production in year 2021-22 is estimated at 98.579 million metric tons under an area of 6.648 million hectares producing 14.82 MT/HA (NHB., 2022) [24]. Though India ranks 2nd in the fruit production in the world still more than 25% of the total production is wasted by various post-harvest losses at different post-harvest stages. Fruits are highly perishable commodity. Fruits are high moisture containing foods (75-95%) and with high equilibrium RH (95%). Proper packing of fruits is necessary because as they decay and dry at very fast pace causing wilting and loss of turgidity. In addition to transport considerations, handling, fresh-cut fruits and maintaining storage conditions that are conducive to customer satisfaction, Packaging will have an impact on food quality (Ghani *et al*., 2016; Realini & Marcos, 2014). All the fruits are the living products therefore they are very susceptible to the spoilage caused by different agents such as bacteria and fungi. Therefore, their shelf life is less under the ambient conditions. There are several ways to lower the respiration rate of fruits such as MAS (Modified atmosphere storage) and other packaging such as active, intelligent packaging, films and edible coatings. In the given review paper, published research work on recent advances in packaging of fresh fruits is keenly reviewed and opportunities for further future research work are provided.

Shelf life of fresh fruits: factors that affect it
Fruits with good quality, a firm texture and good taste are preferred by consumers. Moreover, fruit with good nutrients is also favoured. Produced goods are primarily inspected for texture, outer appearance, and long shelf life after harvest by producers and handlers. In addition to temperature, oxygen level, variety, handling, rate of respiration, and amount of ethylene in the fruit, there are many factors that will affect the shelf life of fruits. For example, as a result of a reduction of the storage temperature during ripening from 18 degree celcius to 13 degree celcius during ripening, it was found that bananas were less susceptible to impact bruising (Bugad *et al*., (2014)

Ethylene rate
A major factor to consider when packaging fruit is the ethylene rate. Ethylene is a ripening hormone that naturally occurs in fruit that influences how it is stored, grown, and developed. It also plays important role in response to the biotic and abiotic stress (Wang *et al*., 2018) [40]. At concentrations between parts-per-million (ppm) and parts-per-billion (ppb), this powerful plant hormone has powerful effects.

Ethylene is commodity dependent hormone but it also got affected by the temperature, time of exposure and the concentration used. Ethylene plays a vital role in the ripening of the produce. Some Climacteric fruits such as banana, sapota, mango is very sensitive to ethylene but fruit such as strawberry have very low rate of ethylene but is very sensitive to it. There is not any particular standard for the concentrations of the ethylene that are detrimental to fruits. Many commodities if exposed for maximum period of time are sensitive to ethylene concentrations as low as 0.1 ppm. Increase in ethylene production can occur due to the disease, decay, physical injury and also by exposure to low temperatures. As senescence is induced by ethylene it has great impact on the loss of fruit quality. On exposure to ethylene the climacteric fruit shows the early ripening that cause over ripening in the fruit and it becomes mealy. Exposure of non-climacteric fruit to ethylene also increases their respiration rates, that means their carbohydrate reserves are used more rapidly, as well as increasing their water loss. For example, the ethephon can also cause early cracking in durian fruit (Thongkum *et al*., 2018) [41].

Rate of respiration

Respiration is the major process involved in the ageing as well as decay of the fruits. In respiration the fruits generally take oxygen from the surrounding and use it for oxidative reduction process. Oxygen is converted to carbon dioxide, water and heat. Heat as a by-product which is produced in process of respiration elevates the temperatures around the produce. This heat should be eliminated either by refrigeration or air ventilation. CO2 being another product of respiration could sum up around the fresh fruit and can cause oxygen depletion in the poor ventilation conditions, that can result in another process called fermentation. If the commodity is kept in a sealed container the death of fruit could occur due to increase in level of carbo dioxide and depletion of oxygen. In absence of oxygen the chemical reactions occur resulting in cellular breakdown, production of alcohol. Off and odd flavours that cause complete decay of fresh fruit. Higher rate of respiration is directly in proportion to the rate of decay. Fast respiration results in the faster senescence of the commodity. Respiration rate can cause mass loss of fruits (Bovi *et al*., 2018) [39].

Temperature during storage

Temperature plays the largest role in determining product quality. Biochemical responses impacting fresh fruit quality require appropriate temperature for post-harvest alterations, which have been established by different researchers for fresh fruits such as pineapple (Hong *et al.*, 2013) [11] pears, and banana. Every product has its own storing temperature that is best for it. The temperature required for ideal storage is dependent upon the origin of the product. Fruit from the tropics cannot withstand low temperatures therefore should be stored at temperature above 13-degree Celsius. While the fruits from temperate, cooler regions can be easily stored at degrees Celsius (Tucker *et al*., 2009) [35]. Cooling the product immediately after the harvest is termed as precooling. It is important aspect of as it clearly enhances the storage and shelf life of the fresh produce. Some of the advantages of the low temperature or cooling is the decreased susceptibility to diseases and reduced respiration and moisture loss. The use of low temperatures during transportation and storage is also common practice, particularly for tomato, peach, and apricot products. The RIN gene methylation of tomato, and probably other fruits, can be affected by low temperatures, which can negatively affect taste (Zhang *et al*., 2016) [37] In general, the lower the storage temperature, the longer the shelf life of the given product, as long as freezing is avoided. But lowest temperature is not every time safe for all fruits as sometimes they get chilling injury or increased chances of disease. For example, lower fruit temperatures (2.5–3.8 °C) increased cherries' bruising sensitivity compared with higher temperatures (7–10 °C) (Zoffoli *et al*., 2014). Therefore, optimum temperature is required for every product.

Handling of the fruits

To avoid any damage to fruits by friction or other ways, they should be handled very carefully. People should be trained to prevent damage to fruit during harvesting. Accidents can occur if no care is taken. Injuries may include the bruises on fingers, damage to fruit or plant. Maximum of the fruits are damaged by the high temperature and sunlight therefore they should be harvested in the early morning when temperature is low. Some fruits like melons should be harvested in the late day to avoid cracking in them.

Active packaging and its types

Food packaging with some function that extends the shelf life of the fresh fruits or exhibits some desirable characteristics is known as "active food packaging" (Biji *et al.*, 2015) [2]. Intelligent food packaging, on the other hand, is a type of packaging that monitors the conditions of the food inside it and provides information on its safety and quality (Kuswandi *et al*., 2011 & Ghaani *et al*., 2016) [20, 8]. Intelligent packaging emphasizes on communication, while active packaging emphasizes the active function to increase food quality (Callaghan & Kerry, 2016) [26]. A fruit's packaging that comes with active and intelligent features protects and preserves the fruit, but also provides information about its quality and safety from distribution to the display, this intelligent packaging is primarily used for reducing the food waste, and it can also help control distribution and rotate product stocks. An active package contains certain active ingredients that are capable of prolonging the shelf life of a product through enhancing and preserving its health properties. Foods with active packaging methods have a longer shelf life and are consumed for longer periods of time, ensuring that the food is of great quality. For several decades, active packaging has been considered as significant part of the packaging since the use of desiccants in dry product containers. Active packaging, as opposed to traditional packaging solutions, is critical for maintaining the freshness and safety of fresh-cut food. Therefore, active packaging technology can be considered an excellent solution in the area of food packaging (Singh *et al*., 2019) [32].

Scavengers of oxygen

Typically, food stored in an oxygen-rich environment spoils because of oxidation or microorganisms (Cruz *et al*., 2012) [6]. High oxygen levels in the package usually hasten the deterioration of respiring fruits' quality and cause an increase in ethylene production. Excess oxygen induces oxidative alterations in vitamins, pigments, lipids, and taste compounds, which promote aerobic microbe growth. It is effective in keeping fresh fruits from quality deterioration that is closely related with oxygen, such as, colour change, safety losses, off flavour development and nutritional value reduction, while managing the oxygen concentration. An experimental study has demonstrated the significance of scavengers (oxygen) that contain powder of iron in food packaging. These results proved that fresh strawberries can have a shelf life beyond four weeks when scavengers of oxygen are used as opposed to control fruits scavengers of oxygen (Kartal *et al*., 2012) [14]. As a solution, MAP can be applied to manage oxidation inside food packages due to the oxygen present. There are many oxygen-scavenging molecules, including ascorbic acid, iron, salts, enzymes and some fatty acids like oleic and linoleic acid, as well as dyes and yeasts which are photo-sensitive. It is possible to combine them with other agents, as a result, oxygen-scavenging agents have been enhanced (Cruz *et al*., 2012) [6]. Any chemical employed as an oxygen scavenger must meet a number of criteria, including being safe, nontoxic, odourless, cost-effective, and easy to handle, as well as absorbing a substantial amount of oxygen at an adequate rate. Oxygen scavengers are active additives that are employed for absorption of residual oxygen in the packaging system through a chemical process that occurs after the container has been sealed. Iron powder and ascorbic acid are two often utilised chemicals. A MAP can be used along with this oxygen scavenger in order to achieve better O_2 removal inside the package. It is commercially used to remove atmospheric gases, and then a low-cost oxygen scavenger cleans up any remaining oxygen within MAP.

Carbon dioxide absorber/emitters

When there is an abundance of carbon dioxide present in packaged fruits available headspace, it slows down the growth of aerobic microbes, which slows down respiration and senescence. Carbon dioxide absorbers and generators are available as sachets or labels. The carbon dioxide usage as absorbents has resulted in growth reduction of microorganisms, spoiling, reduced metabolic rate of microbes, and protect fruit quality by excluding or minimising oxygen concentration (oxygen causes food quality to deteriorate) used in fruits like sweet cherry, strawberry (Aday *et al*., 2011; Wani *et al*., 2014) [1. 37]. Carbon dioxide generators lower the rate of respiration, whereas carbon dioxide reduces or eliminates oxygen concentration, causing fruit quality to deteriorate. Among the carbon dioxide absorbing or emitting compounds are iron calcium hydroxide or iron powder, metal halides or ferrous carbonate. One study suggests ethanol vapor postharvest treatments of vapour slowed harvest senescence, preserved quality in storage, and improved volatile aromatic compound levels of harvested oriental sweet melons (Jin *et al*., 2013) [13].

Ethylene scavengers

Ethylene is a plant growth hormone that, even at extremely low concentrations, accelerates the respiration process to produce ripening, softening, and senescence in fruits. In gaseous form, ethylene has double bonds that make it extremely reactive. It can be modified or degraded in a variety of ways (Chowdhury *et al*. 2017) [5] During the senescence stage, ethylene causes climacteric fruits to have a higher rate of fruit respiration, as well as textural and colour changes, than non-climacteric fruits. As a result, regulating the concentration in the package, of ethylene extends the shelf life (Nayik *et al*., 2014) [25]. ACC and S-adenosyl-L-methionine (SAM) are both intermediates in ethylene biosynthesis, which is produced from methionine. By inhibiting the binding site, ethylene scavengers can lower the rate of ethylene production. Furthermore, for the importation and exportation of fresh fruits the use of ethylene scavengers is essential to postponing the maturity rate of climacteric fruits. Sodium permanganate ethylene, otherwise known as potassium permanganate, is commonly used to catalyze the conversion of ethylene to ethanol or acetate. Through ethylene's double bond being broken by potassium permanganate, potassium permanganate is the most commonly used scavenger for removing ethylene from storage spaces (Brennan *et al*., 2012) [3]. It is impossible to use KMnO4 as a packaging material that is in close contact with fruits since it is toxic. To utilize this poisonous compound in bundling, $KMnO_4$ (4-6%) is joined with an inactive substance with an enormous surface region, for example, alumina, silica gel, enacted carbon, vermiculite and perlite are put away in a pouch, after which it is put to the packaging. When activated carbon is used along with palladium chloride (as a catalyst) has stopped the ethylene accumulation kiwifruits head space. Evert-Fresh (USA), Peakfresh (Australia), Bio-fresh (Israel) and Orega (Korea), are commercial examples (Mehyar *et al*., 2011) [23]. Green keeper ethylene absorbent at 13 °C and 90% RH formatured "Robusta" banana (80%) stuffed in the MAP utilizing LDP film created an upgraded time span of usability of as long as 7 weeks. As a result, ethylene scavengers can help preserve the freshness of vegetables and fruits during storage (Kudachikar *et al*., 2011) [16].

Ethanol Emitters

Among the various preservatives available, ethanol is a broad-spectrum antibacterial that has long been used to preserve foods and fruits (Jin *et al*., 2013) [13]. Ethanol vapour can prevent degradation, extend its shelf life, and keep its natural textural quality in mango fruit cherry fruit and also the grapes. By establishing an anti-mold environment, ethanol can help extend the shelf life of high-water activity items. Although there have been a few commercial ethanol emitters available, they are made by the direct adsorption of on adsorbents of ethanol, such as silica and packaged as sachets. Traditionally, in ethanol emitters, ethanol is found in liquid form. The practical applications of such an ethanol emitter were limited due to its high unregulated release rate, volatilization and other drawbacks. Ethicap is made up of silicon dioxide powder (35%) with adsorbed alcohol (35%), as well as water (10 percent). The sachet is made of ethyl vinyl acetate laminate or paper, which has one of the lowest ethanol vapour barriers of any frequently used material. Another sort of sachet employed has a dual purpose, in that it emits ethanol while also scavenging oxygen. The Negamold®, also from Freund Industrial, Co., and the Ageless® SE from Mitsubishi are two commercially available options.

Antimicrobial packaging system

The principal cause of fresh food shelflife expiration is surface microbial decomposition. Transportation, packaging, uncontrolled harvesting, and processing procedures are the most common sources of microbial contamination. Antimicrobial bundling strategies can be isolated into two classes: We can categorize antimicrobial mechanisms in packaging into two categories: Release mechanisms are characterised by diffusing and decreasing effects over time, while contact mechanisms are characterized by antimicrobial effects through direct contact and surface-immobilization. Packaging films that contain antimicrobial agents to suppress the activities of targeted microorganisms have been used to delay spoilage and improve food safety. (Sung *et al*., 2013) [30]. Adding antimicrobial chemicals to the washing water, such as ozone, peroxyacetic acid, hydrogen peroxide, chlorinated water and plant extracts, shows effective antimicrobial activity but does not completely eliminate microbial deterioration on fruit surfaces. Antimicrobial drugs' modes of action are mainly dependent on the breakdown of the cell wall or membrane antimicrobial drugs also function by inhibiting numerous enzymes in the cell of microbes or by destroying the protoplasm's structure of genes. To keep up with food item quality and wellbeing while additionally broadening time span of usability, antimicrobial specialists like chlorine dioxide, bacteriocins, chelating specialists, natural acids and inorganic acids expand the slack stage thereby decreasing the development period of microscopic organisms. Antimicrobial agents in active films can either form a chemical bond with the film's surface (known as immobilised films) or can move to the surface of food, for releasing their active compounds, organic acid-containing packaging films need to be in direct contact with the food antimicrobial agents blended into packaging material increased the microbiological stability of apple slices and strawberries. Antimicrobial food packaging can be classified into four categories. 1 Packages with antimicrobial agents embedded in sachets; 2 packaging materials with antimicrobial agents adsorbing directly to surfaces; 3 packaging materials with antimicrobial agents embedded directly in films; 4 and packaging materials with antimicrobial agents embedded in packaging materials Antioxidant-releasing films, flavour-emitting systems and flavour absorbing, oxygen emitters, anti-fogging films and light-regulating and blocking chemicals are some of the various active packaging methods that may become commercially accessible.

Intelligent packaging and its types

In order to ensure food safety and its quality, it is imperative that the food is continually monitored during storage, selling and the distribution also at the point of sale (Kuswandi *et al*., 2011; Tirtashi *et al*., 2019; Thakur *et al*., 2013) [20, 34, 33]. Biochemical, physical-chemical and serological methods are used to test food quality. A type of packaging referred to as intelligent packaging is a packaging that uses sensors to monitor the properties of the products it encloses, such as fruit, allowing the manufacturer, retailer, and consumer to be informed on the status of these properties. Assisting the recording, detection, sensing, tracking, and communication of information, intelligent packaging extends shelf life, ensures product quality, provides information, and warns of any internal or external problems (Ramos *et al*., 2013) [31]. Indicators like (TTIs) time-temperature indicators, ripeness, gas sensors, toxin, biosensors, and RFIDs that determine whether a product is good or not directly inside the package, are all examples of intelligent packaging. By using sensors, chemical and biological compounds (genes, enzymes, DNA, bacteria) can be detected, as well as indicators (pH indicators, dyes, etc.). The detection of biological molecules, chemical compounds, ethylene gas detection, and pH monitoring all use Freshness Indicators. Oxygen and CO_2 indicators both have Integrity Indications. Diffusion, enzymatic reactions, microbiological reactions, reactions using Time-Temperature Indicators: chemical, photochemical, and polymerization reactions. Radio frequency identification is referred as RFID.

Sensors

In chemical or physical analysis, a sensor detects and quantifies chemical or physical signals to determine chemical or physical qualities. Principles of sensors.1 Analyze and detect chemical and biological samples (DNA, microbes, enzymes). 2 Chemical compound detection (pH indicators, reagent dyes, gas, etc.). The sensor is made up of four primary parts:

1. An energy form is converted into a physicochemical signal by the receptor of a sensor.
2. Analytical signals are generated from the physicochemical signal of the receptor by the transduction element.
3. Transducer, which generates the desired output via a signal processing unit.
4. Analog or digital displays are used to display quantitative results (Ghaani *et al*., 2016; Thakur *et al*., 2013) [8, 33].

Sensors of the ideal type should have high selectivity and sensitivity, while the response time must be fast, dynamic range should be wide, long-term stability and reliability must be high, and linearity must be high (Ghaani *et al*., 2016) [8].

Sensors that improve food quality detection methods include gas sensors, fluorescence-based oxygen sensors, and biosensors (Thakur *et al*., 2013) [33].

Inspecting an external instrument, gas sensors can change their physical constraints in response to a gas presence. Optoelectronic and electrochemical sensors, field effect transistors, polymers composed of organic conducting materials, semiconductors made of metal oxides, and piezoelectric crystals are examples of gas sensors. The gas sensor technology has been suggested as a fast or traditional method of detecting rancidity in meats, as well as a biosensor for detecting carbamate pesticides in fruits in the past. These systems are totally based on the effects of direct contact with a target analyte, such as heat generation or luminescence quenching. Optical gas sensors come in three forms: colorimetric sensors based on absorption, fluorescent pH-sensitive indicators based on fluorescence, and phase fluorimetric sensors based on energy transfer. Foods that contain high levels of protein can be detected using pH-sensitive dyes, which are gas sensors that can detect basic volatile amines. (Kuswandi *et al*., 2012; Kuswandi *et al*., 2014) [34, 19].

In oxygen sensors, luminescence is quenched by oxygen to produce the fluorescence (Grist *et al*., 2010) [9]. Fluorescence-based oxygen sensors have been proved to be beneficial and successful in meat packing applications. Remotely measuring headspace gases in packaged products with fluorescence-based oxygen sensors is a promising system. These sensors may measure oxygen by adjusting the luminescence properties of the oxygen-sensing element when it comes into contact with liquids or gases, according to a specified calibration (Janjarasskul *et al*., 2010) [12].

Recognition and detection systems work together in biosensors through a biochemical mechanism (Thakur *et al*., 2013) [33]. The recognition system in biosensors interfaces with the detection system via a biological mechanism (Thakur *et al*., 2013) [33]. There are several biological components that make up the receptor of a biosensor, including enzymes, nucleic acids, antibodies, and cells, among others (Thakur *et al*., 2013) [33]. Bioreceptors recognize analytes through immobilised sensitive elements (enzyme substrates, enzyme inhibitors, complementary DNA, antigens, etc.). There are a variety of immobilization techniques, including adsorption, microencapsulation, inclusion, crosslinking, and covalent bonding. Infected seasonal crops can be detected or identified using biosensors.

Indicators

It is a device or equipment that uses a colour shift to show that an analyte is present or absent, or how it reacts with another analyte (Tirtashi *et al*., 2019) [34]. They differ from sensors in that they lack a specialised transducer, and they simply convey data about food conditions through visual changes (Tirtashi *et al*., 2019) [34]. Consumers can learn about the freshness and integrity of food product inside the package using indicator technology. In smart packaging for fresh-cut fruits, a wide array of indicators can be used, including time-temperature, freshness, temperature and also the integrity indicators.

(TTIs) Time temperature indicators

(TTIs) are devices used to examine how food products change depending on the evolution of their temperature over time. A TTI is used to alert consumers when products have been transported or stored at temperatures exceeding the target temperature, which is particularly important for alerting consumers about temperature abuse of chilled or frozen products (Pavelkova *et al*., 2013). Fresh fruits can be kept fresh longer if the temperature is carefully controlled. Temperature indicators are used to show whether products have been heated or cooled over or below a set temperature. In a cold chain distribution network and in fresh fruit and meat supply chains, TTIs provide a monitoring system of microbial safety and quality (Kim *et al*., 2013) [15]. The shelf life of products which are perishable can be detected using freshness indicators. The majority of Time temperature indicators are self-adhesive labels that may be simply applied to a product or package. Commercially available TTIs support enzyme, photochemical, diffusion, microbiological, polymer-based systems and barcode based. Strawberries and other soft fruits that are susceptible to temperature conditions experience maximum loss, requires the use of a real-time temperature monitoring system (Nayik *et al*., 2014) [25]. Bionest, the largest organic strawberry producer in Spain, has implemented an active RFID tag that provides data on the remaining shelf life of strawberries TTIs have a number of demerits, such being protected from radiation and having to be used at low temperature. As a result, TTIs are costly, and their reliability must be established before they are used. As a result, in order for TTIs to be more commonly used, these drawbacks must be addressed (Lee *et al*., 2015) [21].

RFID (A radio frequency identification system)

RFID tags have the purpose of transmitting and storing data without human interference. They store identifying information that can be retrieved by a reader from a database without interference and acted upon accordingly (Todorvoic, Neag, & Lazarevic, 2014) [35]. These comprises of three basic parts that are antenna, tags and a software to work. Signal is sent by the reader and then it receives the responses from the tags. An RFID middleware component connects RFID hardware and apps, such as a web server or local network (Ghaani *et al*., 2016) [8]. Active RFID tags, semi passive RFID tags, and passive RFID tags are the most prevalent types (Kuswandi, 2018) [17]. The passive type tags work without batteries whereas the active tags have batteries to enhance the range of tag-to-tag type communications. Relative humidity information, nutrition information, temperature and cooking instructions can be stored in RFID chip technology. In some fruits and vegetables, RFIDs have been incorporated with temperature indicators of critical temperatures - for fresh fruits, 18 °C and 19 °C are crucial temperature ranges (Lorite *et al*., 2017) [22]. The use of RFID tags can be used to send a variety of perishable products under strictly controlled conditions. There is still a need however for new technologies that provide traceability, such as mobile-based barcodes with quick response times (Todorovic *et al*., 2014) [35]. The food industry must therefore develop new systems utilizing multiple technologies.

Barcode systems and Holograms

A barcode normally consists of parallel lines and spaces containing encrypted data that is hidden. An optical barcode scanner reads and decodes the signal, sending it to a computer for further processing (Ghaani *et al*., 2016; Han, 2013) [8]. There are different types of barcodes that are used by the food industry are 1-D and 2-D. Single Dimensional barcodes carry information such as item numbers and identification numbers, and take up less space for the storage purpose (Drobnik, 2015) [7]. While the 2-D barcodes can hold for more data as compared to 1-D in the less space. Apart from these Holograms are also used nowadays in the food industry, they are used for creating the intelligent systems. Food smart packaging could benefit from the use of holograms as an attractive tool to aid in protecting brand names and combating counterfeiting. Holograms change patterns with time, so counterfeiters cannot alter food products or product labels. When counterfeiting occurs, the above polyester film is also removed, indicating that the item has been tempered (Pareek & Kunteta, 2014) [27].

Conclusion

Fresh fruit quality declines due to the formation of off-odours, off flavours, discolorations, moisture loss, and microbiological deterioration. Active and intelligent packaging has proven to be a useful strategy for keeping fruits fresh and safe. These active and intelligent packaging developments hold the potential for improving current food packaging systems, in particular fruit packaging.in the near future, to provide customer benefits and convenience. However, the adoption and cost-effectiveness of this sort of packaging will be dependent on industry and consumer approval. Furthermore, innovative systems will undoubtedly improve and enhance the quality, safety, and security of fresh fruit, reducing the amount of consumer complaints. Due to technical restrictions and the increased cost of smart packaging, there are gaps or barriers in commercial applications for these technologies. To commercialize these intelligent packaging solutions, an interdisciplinary perspective is needed because they are cost-effective, smaller in components, and have durable and reusable indicators or sensors. Currently, some researchers are working on coupling TTI and RFID for real-time communication of fresh cut fruit quality in the distribution chain, such that information and communication about food products can be provided immediately (Lorite *et al*., 2017) [22]. It is imperative to conduct more studies for integrating active and intelligent packaging so that fresh-cut fruits can be packaged with active and intelligent features that improve safety plus quality, as well as reduce waste and fruit losses.

References

1. Aday MS, Caner C, Rahvalı F. Effect of oxygen and carbon dioxide absorbers on strawberry quality. Postharvest Biology and Technology. 2011;62(2):179-187.
2. Biji KB, Ravishankar CN, Mohan CO, Srinivasa Gopal TK. Smart packaging systems for food applications: A review. Journal of food science and technology. 2015;52(10):6125-6135.
3. Brennan JG, Day BPF. Packaging, in Food Processing Handbook, ed. by. Brennan JG and Grandison AS, Wiley, Hoboken, NJ, 2012, pp. 337-339.
4. Bugaud C, Ocrisse G, Salmon F, Rinaldo D. Bruise susceptibility of banana peel in relation to genotype and post-climacteric storage conditions. Postharvest Biology and Technology. 2014;87:113-119.
5. Chowdhury P, Gogoi M, Borchetia S, Bandyopadhyay T. Nanotechnology applications and intellectual property rights in agriculture. Environmental Chemistry Letters. 2017;15(3):413-419.
6. Cruz RS, Camilloto GP, dos Santos Pires AC. Oxygen scavengers: An approach on food preservation. Structure and function of food engineering. 2012;2:21-42.
7. Drobnik O. Barcodes with iOS: Bringing together the digital and physical worlds. Simon and Schuster, 2015.
8. Ghaani M, Cozzolino CA, Castelli G, Farris S. An overview of the intelligent packaging technologies in the food sector. Trends in Food Science & Technology. 2016;51:1-11.
9. Grist SM, Chrostowski L, Cheung KC. Optical oxygen sensors for applications in microfluidic cell culture. Sensors. 2010;10(10):9286-9316.
10. Han JH. A review of food packaging technologies and innovations. Innovations in food packaging, 2014, 3-12.
11. Hong K, Xu H, Wang J, Zhang L, Hu H, Jia Z, *et al*. Quality changes and internal browning developments of summer pineapple fruit during storage at different temperatures. Scientia Horticulturae. 2013;151:68-74.
12. Janjarasskul T, Krochta JM. Edible packaging materials. Annual review of food science and technology. 2010;1:415-448.
13. Jin YZ, Liu WW, Qi HY, Bai XH. Ethanol vapor treatment maintains postharvest storage quality and inhibits internal ethylene biosynthesis during storage of oriental sweet melons. Postharvest Biology and Technology. 2013;86:372-380.
14. Kartal S, Aday MS, Caner C. Use of micro perforated films and oxygen scavengers to maintain storage stability of fresh strawberries. Postharvest Biology and Technology. 2012;71:32-40.
15. Kim E, Choi DY, Kim HC, Kim K, Lee SJ. Calibrations between the variables of microbial TTI response and ground pork qualities. Meat science. 2013;95(2):362-367.
16. Kudachikar VB, Kulkarni SG, Prakash MN. Effect of modified atmosphere packaging on quality and shelf life of ‘Robusta’ banana (*Musa* sp.) stored at low temperature. Journal of Food Science and Technology. 2011;48(3):319-324.
17. Kuswandi B. Freshness sensors for food packaging. In Reference module in food science, Elsevier, 2018. https://doi.org/10.1016/B978-0-08-100596-5.21876-3.
18. Kuswandi B, Oktaviana R, Abdullah A, Heng LY. A novel on-package sticker sensor based on methyl red for real-time monitoring of broiler chicken cut freshness. Packaging technology and science. 2014;27(1):69-81.
19. Kuswandi B, Restyana A, Abdullah A, Heng LY, Ahmad M. A novel colorimetric food package label for fish spoilage based on polyaniline film. Food control. 2012;25(1):184-189.
20. Kuswandi B, Wicaksono Y, Abdullah A, Heng LY, Ahmad M. Smart packaging: Sensors for monitoring of food quality and safety. Sensing and Instrumentation for Food Quality and Safety. 2011;5(3):137-146.
21. Lee SY, Lee SJ, Choi DS, Hur SJ. Current topics in active and intelligent food packaging for preservation of fresh foods. Journal of the Science of Food and Agriculture. 2015;95(14):2799-2810.
22. Lorite GS, Selkälä T, Sipola T, Palenzuela J, Jubete E, Viñuales A, *et al*. Novel, smart and RFID assisted critical temperature indicator for supply chain monitoring. Journal of Food Engineering. 2017;193:20-28.
23. Mehyar GF, Han JH. 14 Active Packaging for Fresh-Cut Fruits and Vegetables. Modified atmosphere packaging for fresh-cut fruits and vegetables, 2011, 267.
24. NHB D. National horticulture board, 2022.
25. Nayik GA, Muzaffar K. Developments in packaging of fresh fruits-shelf-life perspective: A review. American Journal of Food Science and Nutrition Research. 2014;1(5):34-39.
26. O’Callaghan KA, Kerry JP. Consumer attitudes towards the application of smart packaging technologies to cheese products. Food Packaging and Shelf Life. 2016;9:1-9.
27. Pareek VIKAS, Khunteta A. Pharmaceutical packaging: current trends and future. Int J Pharm Pharm Sci. 2014;6(6):480-485.
28. Pavelková A. Time temperature indicators as devices intelligent packaging. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 2013;61(1):245-251.
29. Postharvest Biology and Technology, 86, 372-380.
30. Sung SY, Sin LT, Tee TT, Bee ST, Rahmat AR, Rahman WAWA, *et al*. Antimicrobial agents for food packaging applications. Trends in Food Science & Technology. 2013;33(2):110-123.
31. Ramos B, Miller FA, Brandão TRS, Teixeira P, Silva CLM. Fresh fruits and vegetables: An overview on applied methodologies to improve its quality and safety. Innovative Food Science & Emerging Technologies. 2013;20:1-15.
32. Singh S, Gaikwad KK, Lee YS. Development and application of a pyrogallic acid-based oxygen scavenging packaging system for shelf-life extension of peeled garlic. Scientia Horticulturae. 2019;256:108548.
33. Thakur MS, Ragavan KV. Biosensors in food processing. Journal of food science and technology. 2013;50(4):625-641.
34. Tirtashi FE, Moradi M, Tajik H, Forough M, Ezati P, Kuswandi B. Cellulose/chitosan pH-responsive indicator incorporated with carrot anthocyanins for intelligent food packaging. International Journal of Biological Macromolecules. 2019;136:920-926.
35. Todorovic V, Neag M, Lazarevic M. On the usage of RFID tags for tracking and monitoring of shipped perishable goods. Procedia Engineering, 2014;69:1345-1349.
36. Tucker G, Hanby E, Brown H. Development and

application of a new time–temperature integrator for the measurement of P-values in mild pasteurisation processes. Food and Bioproducts Processing. 2009;87(1):23-33.
37. Wani AA, Singh P, Gul K, Wani MH, Langowski HC. Sweet cherry (*Prunus avium*): Critical factors affecting the composition and shelf life. Food packaging and shelf life. 2014;1(1):86-99.
38. Zhang B, Tieman DM, Jiao C, Xu Y, Chen K, Fei Z, *et al*. Chilling-induced tomato flavor loss is associated with altered volatile synthesis and transient changes in DNA methylation. Proceedings of the National Academy of Sciences. 2016;113(44):12580-12585.
39. Zoffoli JP, Rodriguez J. Fruit temperature affects physical injury sensitivity of sweet cherry during postharvest handling. In VI International Cherry Symposium. 2009;1020:111-114.
40. Bovi GG, Caleb OJ, Herppich WB, Mahajan PV. Mechanisms and modeling of water loss in horticultural products. Food Sci. 2018, 1-5. https://doi.org/10. 1016/B978-0-08-100596-5.21897-0.
41. An JP, Wang XF, Li YY, Song LQ, Zhao LL, You CX, *et al*. EIN3-LIKE1, MYB1, and Ethylene Response Factor3 act in a regulatory loop that synergistically modulates ethylene biosynthesis and anthocyanin accumulation. Plant Physiology. 2018;178(2):808-823.
42. Thongkum M, McAtee PM, Schaffer RJ, Allan AC, Ketsa S. Characterization and differential expression of ethylene receptor genes during fruit development and dehiscence of durian (Durio zibethinus). Scientia Horticulturae. 2018;240:623-630.