Review

Postharvest Alternatives in Banana Cultivation

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Review

Postharvest Alternatives in Banana Cultivation

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Abstract: The banana, also known as plantain in some places, is a tropical fruit widely consumed and appreciated around the world. Its scientific name is Musa paradisiaca and it belongs to the Musaceae family. This fruit is native to Southeast Asia but is currently cultivated in various tropical and subtropical regions, is harvested throughout all the year and planted in 130 countries, 75% of which is produced mainly in India, Ecuador, Brazil, Colombia, Costa Rica and China. The use of some post-harvest treatments (gradening, modification of the atmosphere, coatings and refrigeration, among others) are important for guarantee of safe, healthy and high-quality foods in the century XXI. This review details mechanical damage after harvest, management of environmental parameters (temperature and relative humidity), control of gases involved in storage and transportation, treatment with wax, coatings, the use of antifungal compounds and packaging necessary for the export of the fruit.

Keywords: Banana; poscosecha; *Musa Paradisiaca*; alternativas poscosecha; Musáceas

1. Introduction

Banana is a natural source of energy due to its carbohydrate content; it is very nutritious and contains vitamin C, vitamin B6, potassium, iron, magnesium and dietary fiber. It also contains small amounts of other essential nutrients; due to its nutritional value it becomes a healthy and delicious choice to include in our daily diet. Throughout history, bananas have been an important subsistence food for many cultures, their ease of cultivation and transportation contributes to their global popularity and the main banana-producing regions include Latin American countries, such as Ecuador, Costa Rica and Colombia.

Banana is a very popular fruit, the production of banana faces challenges, such as diseases and pests that can affect the crops. Additionally, the banana industry has been the subject of debates about sustainable labor and practices environmental; This document details the post-harvest alternatives for the cultivation of bananas that generate an income economic, return social and environmental that must be considered to guarantee the quality of the export fruit in commercialization.

Postharvest treatments vary depending on the region, of the practices local agricultural, and country-specific, regulations and the market requirements [1]. The treatments are techniques and practices applied after of the harvest to prolong the shelf life of the fruit, maintain the quality and reduce the losses of product [2].

The banana is a fruit with an shape elongated and curved, in maturate state has a pee of color yellow with glow, pulp creamy, smooth and flavor characteristic sweet that is appreciable by consumers [3]. Exist several studies to treat viruses in musaceae, before harvesting, such as: bud cluster (*Banana bunchy top virus, BBTV),* cucumber mosaic *(Cucumber mosaic virus, CMV),* striatum (*Banana streak virus, BSV),* descending death (*Banana dieback die-back virus, BDBV),* among others [5].

Ecuador is considered the leading exporter of bananas, contributing 26% of the PIB agricultural nd the average loss exceeds 30% in post-harvest, a part is used as animal feed. Good practices must be followed when handling and storing fruit to guarantee the quality during its shelf life [8,11].

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The treatment post-harvest begins with the selection and classification according to their size, quality and degree of maturity, this allows us separate those for consumption and export Chacón-Cascante & Crespi, 2006). The secretion of latex when cutting the hands of the crown affects the quality, (Ramírez et al., (2011), concluded that an immersion treatment at 45°C for a time greater than 10 minutes reduces the latex stain [8].

The fruit is cleaned to eliminate pesticide residues and other contaminants, by washing with water or disinfectant solutions [16]. Compounds fungicide and pesticide help prevent the development of fungal diseases and pest attacks [17]. During the ripening, the banana is cooled to maintain the freshness and prolong its shelf life, applying refrigeration techniques, such as cold rooms or systems of air cooling forced around 13°C. During ripening, can be used 1-methyl-cyclopropene (1-MCP) with an application of 30 nL L^{-1}, adding 4 days of shelf life [19].

The bananas are packed in boxes or trays to protect during transport and facilitate the handling. It is produced 12% of organic bananas and 88% of conventional bananas [4]. Appropriate materials are used to that the fruit have ventilation and avoid physical damage according to the regulations and standards of established and food safety regulations [20]. During the transportation, are used refrigerated containers with control systems for temperature (12 - 13°C) and relative humidity (90% - 96%) [21,22].

Boxes of bananas are labeled with information about the origin of the fruit, company name, harvest dates and possible expiration to facilitate traceability and quality control [22]. Banana exports are considered a positive impact because they are a source of non-oil income for the country [4]. Next, some of the most common postharvest treatments used in the banana industry are described:

2. Handling Mechanical Damage and Proper Packaging

Before packing, it is necessary to inspect to identify and separate the fruits damaged or injured, and leave the optimal ones for marketing [24]. The selection of packaging materials is important to certify the physical protection of bananas [16]. The materials must be resistant, but also allow air circulation to prevent the accumulation of moisture.

Careful handling of the fruit in the post-harvest avoids physical damage, such as bumps, bruises, falls, peel lesions). These damages accelerate the maduration and reduce the shelf life of the product; in one study, the gibberellic acid was applied as a ripening retarding agent [24,14].

The packaging avoids excessive compression, with the use of cushions, covers, wraps or cushioning materials, cardboard boxes or plastic trays, protect the fruit from mechanical damage while maintaining good air circulation, chicha contributes to prolonging its shelf life. shelf, reducing weight loss [20,26,27].

The packaging is isolated from direct sunlight, as well as other environmental factors that may affect its quality. The size of the packaging must be adequate to accommodate the bunches in a maximum of 4 rows, without compressing them in an adequate arrangement to avoid damage due to crushing during transport. Packaged bananas are stored under adequate conditions of temperature and relative humidity [25]. By implementing practices proper of handling and packaging, can be reduced the mechanical damage and maintained the freshness in the storage and distribution, generate consumer satisfaction and reduced the postharvest losses.

3. Management of Environmental Parameters

Bananas are sensitive to changes in temperature and relative humidity in the field, in the post-harvest, and the measures are applied to keep them in optimal conditions until sale [28,29]. Are used with chambers cooling systems to avoid damage due to cold or heating [30].

Temperature Treatments

Temperature control is essential in the post-harvest of bananas to maintain their quality and prolong their shelf life. Next, are described some temperature treatments:

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Rapid cooling: After of the harvest, the green bananas are subjected to rapid cooling to reduce their internal temperature using cold rooms or cooling systems with forced air to slow the ripening process and minimize the risk of deterioration [31].

Cold storage: they can be stored in cold rooms at temperatures (13 - 15) °C, avoiding freezing to help prolong the shelf life of the banana and prevent the appearance of post-harvest diseases. The duration of cold storage depends on the banana variety and the specific conditions of each crop [33].

Refrigerated transportation: starts from the farm to the markets, refrigerated containers or trucks are used to maintain the temperature. Refrigerated transportation helps preserve the quality of bananas and prevent damage from sudden changes in temperature Martinez et al., 2003).

The specific temperatures used in each stage may vary depending on the banana variety, climatic conditions, market requirements and established quality standards. Must have refrigeration equipment and reliable temperature control systems to ensure that bananas are maintained in optimal conditions throughout the post-harvest process [35].

Humidity Treatments

Humidity is another critical factor in banana management; there are precipitation values that can be simulated with the use of software 8, to model the growth and production of bananas in the field. In post-harvest, coating or wax is used to reduce moisture loss, avoid dehydration and deterioration of the fruit that reduces its volume and weight (Arce Ortiz et al., 2016; and Villamizar, 2015). Next, some of the humidity treatments used are described:

Control of the relative humidity: in post-harvest, the dirt is removed, the fruits are cleaned and a could be applied light humidification to rehydrate the banana peel and prevent moisture loss in storage and transportation [38]. The recommended relative humidity should be controlled between 85% and 95% of the surrounding environment to preserve quality; This is achieved with the use of humidification systems or the selection of appropriate containers and packaging materials [35].

Proper packaging: The use of appropriate containers and packaging materials helps control the humidity of the banana. Materials that allow ventilation are preferred to avoid the accumulation of humidity and prevent the formation of conditions conducive to the development of diseases [39].

Coatings and waxes: reduce the loss of humidity relative and improve the appearance of bananas; They form a protective layer on the peel that helps to retain the natural humidity of the banana and prevent dehydration [40]. In addition, they can improve disease resistance and prolong the shelf life of bananas Durán, 2023).

Humidity must be controlled to be carefully balanced, because an excess or lack of humidity can negatively affect the banana quality and shelf life. Therefore, it is essential to regularly monitor the humidity of the environment and take the necessary measures to maintain it in an optimal range Agroindustria, 2007).

4. Gas Control

Bananas produce ethylene, a plant hormone that accelerates their ripening process and is produced naturally. Techniques can be applied to control the concentration of ethylene in the environment, such as the use of ethylene absorbents or air purification systems that are accepted by the European Union Castellanos et al., 2011). Strategies used to control gases in bananas are described below:

Air filtration: these systems are used in storage or transport chambers to eliminate ethylene and other undesirable gases in the environment [46]. It can be stored or transported in individual areas or containers to avoid exposure to ethylene produced by other fruits or vegetables [35].

Air purification: Air purification systems, such as ozone generators or photocatalysis systems, can be used to remove ethylene and other harmful gases using photochemical reactions or chemical processes to break it down into harmless compounds to the fruit [47].

Ethylene absorbers: used to eliminate or reduce the concentration of this hormone in the storage or transportation environment. They are materials that can capture and retain gaseous ethylene,

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avoiding accelerating the ripening of bananas. Ethylene absorbers are activated carbon pellets, zeolites or potassium permanganate Najafabadi, 2015).

The concentrations of ethylene and other gases, as well as the strategies used for their control, can vary depending on factors such as the banana variety, the stage of maturity and environmental conditions. Monitoring gas levels and adjusting strategies as necessary is essential to ensure optimal quality and prolonged shelf life of the fruit (Kader, 2011 and Balaguera-López et al., 2014).

Controlled Atmosphere

The banana is harvested in green stages and is subjected to specific conditions to control its ripening process [50]. To create a controlled atmosphere, storage chambers or sealed packaging systems are used to control gas concentrations [21].

At the disembarkation is undergoes a controlled ripening process using special chambers. During this process, temperatures, humidity and the concentration of oxygen (O_2), carbon dioxide (CO_2) and ethylene (C_2H_4) are adjusted, ethylene to accelerate the ripening process of bananas and guaranteeing that they reach the optimal point of consumption at the desired time (Nieto & Rangel, 2022 and Gasex, 2021). The objective of this alternative is to reduce the rate of respiration and ripening of the fruits, which helps to prolong its useful life and maintain its quality. The steps of this treatment are described below:

Selection of green bananas in appropriate stages of development, generally when they have reached a degree of physiological maturity but have not yet begun their natural ripening process (Merodio & Escribano, 2003 and Agronomía, 2005). The selected bananas undergo a conditioning process, during this step, impurities are removed and the fruits are cleaned FAO, Italia, 1993).

Temperature and humidity control: the bananas are placed in ripening or refrigeration chambers and the optimal temperature is controlled, the range of which varies depending on the fruit, an adequate relative humidity level is maintained to avoid dehydration of the bananas and the humidity range recommended is between 85% and 95% Thompson, 2003).

Gas concentration control: a controlled concentration of gases can be introduced into the chamber to accelerate or slow down the process according to the requirement. This can be achieved through the use of gaseous ethylene generators or absorbers in the environment Brackmann et al., 2006).

Monitoring and control: color, texture and firmness are regularly monitored to determine the optimal maturity time, without overripe or deterioration, currently are used sensors and control devices Brackmann et al., 2006).

Storage and distribution: upon reaching the desired degree of maturity, they are removed from the refrigeration chamber and stored under adequate temperature (12 – 14) °C and relative humidity (85 – 95)% to maintain their quality until the fruit is distributed Castellanos et al., 2011).

Generally, the concentration of O_2 is reduced and increase the concentration of CO_2 in the atmosphere surrounding the bananas, because a lower concentration of O_2 delays the respiration rate and the production of ethylene, which slows down the ripening of the fruits. An increase in CO_2 concentration also has an inhibitory effect on ripening Kader, 2011).

To accelerate ripening, the temperature and ethylene concentration can be increased and to delay ripening, these variables can be reduced.

The controlled atmosphere has several benefits:

- Uniformity of the degree of maturity, this facilitates marketing and distribution logistics.
- Supply and sale planning, according to the availability of ripe bananas at specific times to meet market demand.
- Improves and preserves quality, at the optimal level of flavor, texture and color, improving sensory quality, by minimizing physiological changes, decomposition and the appearance of diseases.
- Prolonging shelf life by reducing the speed of ripening, bananas can be kept fresh and in optimal conditions for a longer period, extending their shelf life and reducing post-harvest losses.

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Modified Atmosphere

The gas composition around the bananas is altered, with the use of permeable films or bags that control the concentration of oxygen and carbon dioxide, helping to delay ripening and maintain the quality of the banana (Castellanos et al., 2011; Siqueira et al., 2017).

Unlike the controlled atmosphere, in the modified atmosphere is the optimal gas composition is maintained to slow down ripening and preserve the quality of the bananas. For this technique, specific packaging techniques and packaging materials are used, which can be permeable or impermeable to certain gases, which allows the concentration around the fruits to be regulated Artes, 2006).

Permeable packaging materials allow a controlled exchange of gases between the inside and outside of the packaging, while impermeable ones prevent the entry or escape of gases. The modified atmosphere in bananas offers several benefits:

- Delayed ripening: the gaseous composition slows down the respiration rate of bananas, which in turn delays their ripening and keeps the fruits in a fresh state for longer.
- Quality preservation: By controlling the gas conditions, the quality of the bananas is preserved, including their texture, flavor and appearance, offering the consumer fresh and attractive bananas.
- Reduction of losses: By prolonging the shelf life of bananas, the modified atmosphere helps reduce post-harvest losses and increases the quality of the fruits

Specific modified atmosphere parameters may vary depending on banana cultivar, storage conditions, and market preferences.

5. Banana Coatings

In the postharvest of bananas, some coatings are used to protect the fruit, reduce moisture loss and prolong its useful life [67]. Coatings are substances that are applied to the surface of bananas to form a protective layer [68].

Coatings on banana have several benefits, including:

- Moisture retention: they form a barrier that reduces moisture loss from bananas, maintaining their texture and freshness.
- Physical protection: prevents damage to the surface of the banana, such as bumps, abrasions or bruises, during handling and transportation.
- Improving appearance: they can give bananas a shine and attractive appearance, improving their visual presentation.
- Delayed ripening: some contain antioxidant compounds or ethylene inhibitors and help delay the ripening of bananas and prolong their shelf life.

It is very important that the selection of the appropriate coating must be based on local regulations and standards, ensuring the quality and safety of the coated banana according to the specific market requirements [69]. Below are some types of coatings used on bananas:

Wax Coating

When evaluating the bioactive compounds of 19 banana genotypes, the presence of total carotenoids and flavonoids was evident [70]. The application of a layer of wax on the banana peel reduces moisture loss and delays ripening, acting as a barrier to dehydration and oxidation [71]. It improves the appearance of the banana by giving a natural and uniform shine, prolongs the shelf life and reduces mechanical damage during handling and transportation [72].

Beeswax coatings with sauce and garlic extracts were made on Gran Enano banana, resulting in sweeter fruits with a greater characteristic odor [71]. Additives or fungicides may be included in the wax, which must be approved and safe for human consumption, however, due to its indigestible nature, the wax layer is not consumed, but is removed by washing or peeling the fruit before

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consumption [73]. Natural waxes, such as carnauba wax or beeswax, are used to restore the surface of the banana.

Barco et al., (2009) evaluated and compared the effect of the commercial wax "Cerabrix de Banano" (TAO QUÍMICA LTDA.) and a natural coating based on hydrolyzed cassava starch on banana (*Musa sapientum*); The reported results indicated that the pH and maturity index are not affected while the bananas covered with Cerabrix had greater firmness, compared to the natural coating.

Coatings based on synthetic resins, such as polyethylene or polypropylene, are used to create a protective layer on the surface of the banana, providing an effective barrier against moisture loss and protecting the fruit from possible external contaminants (Dussán et al., 2023 and Fernández Valdés et al., 2015).

Edible Coatings

Prepared from natural ingredients, such as starch, pectin or proteins, to protect the banana [76]. These coatings are safe for human consumption and may have antimicrobial or antioxidant properties that help maintain the quality of the banana during storage [77].

Banana starch has a low solubility index, high viscosity, and low tendency to swell [33]. A biopolymer was designed whose structure consists of cellulose, lignin, lipids and starch, was obtained a product with good mechanical resistance, durability and physical appearance [40].

The shelf life of banana is short due to the process of ripening, respiration and attacks by microorganisms, the fruit coated with a composition of 1.5% CHI (chitosan) and 3% WPI (whey) showed better results in loss weight, humidity and color [68].

Uscocovich et al., (2023) evaluated the effect of different percentages of chitosan (0.75%, 1%, 1.25%, 1.50% w/v) on the physical quality of banana in postharvest (percentage of weight loss (%), total soluble solids (°Brix), firmness (N), making a coating.

Whey protein is a by-product of the cheese-making process, it is produced when milk coagulates and separates into two main components: rennet (cheese) and liquid (whey) which contains nutrients, proteins, lactose, minerals (calcium and potassium), vitamins (B complex), beneficial bioactive compounds [79]. Quality depends on the manufacturing process, on the specification of the final product by following guidelines and regulations [36].

It is a component of fruit coatings, because it retains moisture on the surface of the fruits, prevents dehydration and maintains freshness, protects against physical damage such as bruises, bumps or scratches, delays ripening by reducing enzymatic activity and ethylene production, It improves its quality, its visual presentation with natural brightness and prolongs its useful life [80]. It is also used in the manufacture of functional ingredients, such as protein isolates or concentrates, modified lactose, cosmetic food industry, nutritional and sports supplement (Melo et al., 2021).

Arce et al., (2016), developed a coating based on whey (WPI) and chitosan (CHI), known as antifungals for being a barrier for the transfer of water vapor, preserving the fruit, and determined that the best coating was CHI 1.5% - WPI 3%. Glycerol is a liquid, colorless and viscous chemical compound used in fruit coatings and acts as a plasticizer in the formulated solutions [82]. Muñoz et al., (2017) formulated an edible coating made from candelilla wax, pectin and glycerol to evaluate the shelf life of fruits.

In addition to the benefits, it delays the ripening of fruits by forming a barrier that reduces exposure to oxygen, protects against physical damage to the fruit by forming a protective layer on the surface of the fruit (Lafuente Aranda, 2017 and Umpierre & Machado, 2013).

Cassava starch is a product derived from the root of cassava (manioc or cassava), it is used in coatings because it has properties that make it suitable for the formation of films that adhere to the surface of fruits [85]. It delays the ripening process by reducing ethylene production, it can give a more attractive appearance to the fruits, providing a natural shine and improving their visual presentation Cañizares et al., 2019).

Agar agar is an extract of red seaweed that is used as a gelling agent, stabilizer and thickener, it has the ability to form a flexible and resistant film on the surface of fruits, improves the appearance

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by providing a natural shine, delays the ripening of the fruits. fruits by acting as a barrier that reduces exposure to oxygen and other factors that accelerate ripen

(Ruiz et al., 2015) evaluated the performance of an edible coating based on agar and citric acid using fresh potato (*Solanum tuberosum*) as a test model. This was treated by immersion with solutions of agar (A), agar-citric acid (AC), agar-glycerol (AG) and the mixture of the three (ACG). The AC-based film presented the lowest values of thickness and water vapor transmission rate.

6. Antifungal Treatments

Pest control is essential to prevent damage to plants and guarantee healthy production, with greater emphasis on post-harvest Begoña et al., 2015). To control pests and diseases, fungicidal treatments are used, pesticides that prevent and control the development of diseases (Asobanca & Centro Ecuatoriano de eficiencia de recursos, 2020; and Porcell Gómez, 2019). They can be classified into:

Integrated pest management (IPM): combines different strategies to control pests effectively and sustainably. It includes preventive, cultural, biological and chemical methods, with the aim of minimizing the use of pesticides (Sánchez et al., 2021). Maddela & García, (2021) It is based on the constant monitoring of pests and making informed decisions about control [18].

In cultural control, agronomic practices are applied to reduce pest populations, using resistant varieties, crop rotation, selection of planting sites, sanitation of the growing area and elimination of diseased or infested plants or fruits (Sánchez et al., 2021 and Palou, 2011). Biological control uses living organisms to control pests, predatory insects, parasitoids and pathogenic microorganisms that are released into the crop [91].

Chemical control uses pesticides according to good agricultural practices and local regulations, for each pest the recommended doses and application intervals must be followed to protect human health and the environment. It is necessary to look for alternatives that improve the performance of organic fungicides [93].

Regular monitoring allows early detection of pests before they become a significant threat to take timely control measures and prevent proliferation. Training and advising farmers on this topic with specialized technical advice will provide specific and updated guidance for pest control [94].

Antifungal treatments are applied to prevent fungal growth and delay the appearance of spots and rot in bananas Alfonso, 1999). Essential oils are volatile, aromatic compounds extracted from plants with antimicrobial and antioxidant properties; therefore, in fruit coatings, essential oils have been used as natural ingredients to provide benefits additional Gimeno & Mar, 2020).

Due to their antimicrobial activity, essential oils inhibit the growth of bacteria, fungi and yeast on the surface of fruits, due to their antioxidant properties they protect fruits from oxidation and deterioration caused by free radicals, their aromatization that improves the natural aroma of fruits and the sensory experience when consuming them.

Deflowering in the field does not reduce the presence of *Colletotrichum spp.* and *Fusarium spp.*, however, washing the bunches with pressurized water reduces the fungal load Randy, 2015). The germicidal effect of UV-C irradiation is carried out in various foods, considered as an alternative for disinfection on the surface of products without residue, it effectively combats *Penicillium spp.* with effective and non-phytotoxic doses between 5 and 10 KJ/m^2 Vázquez-Ovando et al., 2018).

Collectotrichum spp. is one of the main fungi that affect the fruit and research is carried out to inhibit or control its growth. Salazar et al., (2012), studied the in vitro sensitivity to 3 fungicides (thiabendazole, imazalil and myclobutanil) [104]. Alternatives are constantly made to control *Colletotrichum spp*. pests, through hydrothermal treatment, genetic manipulation and induced resistance Narváez Baque et al., 2017).

To control anthracnose caused by the fungus *Colletotrichum musae,* Maqbool et al., (2010). investigated the antifungal effects of gum arabic and chitosan, concluding that the optimal concentration was 10% gum arabic and 1% chitosan, improving weight loss results, firmness, concentration of soluble solids and titratable acidity.

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In the research with Musa de Háwái, by Martínez (2023), clones were used in in vitro plants carrying the banana buncky top virus (BBTV). In addition, ozone fumigation is used for 10 minutes at a concentration of 1.5 L/min [107].

7. Packaging for Bananas

Packaging in the field is necessary to avoid damage caused by insects in flowering and fruiting or viral diseases Garrido et al., 2005). Among the packaging used for bananas, the cardboard box is considered first and then plastic is used [2]. In one investigation, a bunch protection cover impregnated with chlorpyrifos was used [100].

The characteristics of mechanical properties of banana (*Cavendish Valery*) define firmness and physical-chemical characterization [110]. Oca et al., (2023), carried out a study to assess the properties of banana quality in different types of packaging (wooden box, cardboard and in bulk), rectifying that the cardboard box is the best alternative [112].

Cardboard packaging for bananas is a type of packaging used to protect and transport bananas safely [16]. These packages are designed to provide protection against physical damage and minimize the risk of impacts and crushing of the fruits [2].

The cardboard is resistant, rectangular or square in shape, supports the weight of the bananas without breaking, is permeable to air, maintains the freshness and quality of the bananas during transport and storage [2], it can count with openings or slots in the sides to allow air circulation and prevent moisture buildup.

The foil used to package bananas is known as "banana plastic foil" or "banana plastic sleeves." These sheets are made of low-density polyethylene (LDPE) or high-density polyethylene (HDPE), which are flexible and resistant plastic materials, they cover and protect the fruits from humidity, dust and dirt, and help prevent dehydration. and premature deterioration, are generally transparent for visual control [113].

The sheets have a standard size, some may have small holes or perforations to allow air circulation and prevent the accumulation of condensation. Other more sustainable alternatives are currently being explored, such as biodegradable or compostable sheets to reduce the environmental impact of plastic waste. [114], studied the effect of color and density of polyethylene covers to cover bananas in the field.

Vacuum covers, the politubo and the polipack are three types of packaging used in the banana industry, but they differ in their design and function. Banana vacuum bags are a type of packaging that protects and preserves by removing air from the inside of the bag and sealing it airtight, creating a vacuum environment around the bananas.

The vacuum covers reduces the amount of oxygen present in the storage environment, by eliminating air it minimizes the oxidation of the fruit, delays its ripening and maintains its freshness for longer in its modified atmosphere. The use of this packaging requires a vacuum sealing machine to extract the air and properly seal the bags [115].

The "banana polytube" is another type of packaging, it consists of a flexible plastic tube that physically protects the fruits and maintains humidity. In addition, the plastic used in the polytube can be permeable to air and moisture, allowing gas exchange and preventing the accumulation of condensation because it does not create a vacuum environment, because air is not extracted or sealed hermetically.

"Polipack" is not a standard term in the banana industry, so there may be some confusion, but it is a durable, flexible material sleeve with perforations that can offer physical protection to bananas in cardboard boxes, it can also help to maintain humidity and prevent dehydration of the bananas, just like the polytube, the polipack does not create a vacuum environment or extract air.

8. Conclusión and Future Prospects

Postharvest alternatives vary according to the specific needs to accelerate or delay the ripening of the banana.

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Vacuum covers create a vacuum environment around the packaged fruit, which seal hermetically, while polytube and polypack offer physical protection and a moisture barrier, but do not create a vacuum environment.

In future research, it is recommended to carry out a study of the physiological change of the fruit depending on the type of packaging.

9. Declarations

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