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TRENDS IN PROLONGING THE POST-HARVEST LIFE OF STRAWBERRIES – A REVIEW

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Being known as highly perishable produce, strawberries became a recurrent fruit in the scientific research, with the aim of improving the shelf-life. As indicated by the literature, the most tested method for extending the shelf-life relies on the use of modified atmosphere packaging and combinations thereof. The positive results of modified atmosphere packaging have been translated into industrial applications and further used in supermarkets. This study however compiles and presents a series of other techniques that are worth the attention in prolonging the post-harvest life of strawberries. The point is to highlight their potential and shortcomings and to rise the interest in these perfectible alternative methods.

Keywords: strawberries, post-harvest shelf-life, modified atmosphere packaging, berries

Introduction

Throughout history, strawberries proved to have a variety of uses, including being considered the image of Venus, symbolizing love, thanks to its red color and its heart shape. Later, the Romans used strawberries for medicinal purposes, including kidney diseases or melancholy (Trinklein, 2012).

Nowadays, consumers enjoy the freshness, the aroma and the taste of strawberries, but they also benefit from the health properties (Wang, 2014; Battino et al., 2017) that come along with these fruits. The antioxidants contained by strawberries have been correlated to a reduced risk of heart problems and of cancer (Heinonen et al., 1998; Velioglu et al., 1998; Forbes-Hernández et al., 2016). In addition, the compounds found in strawberries are known to fight against type 2 diabetes, erectile dysfunctions, obesity and neurodegenerative illnesses, like Alzheimer (Battino et al., 2017; Cassidy, 2016).

Like in the past, at this moment, strawberries do not only serve as food, but they prove to be versatile plants, as they are also used and embraced by consumers in the form of decorative plants to be grown in home gardens. The increasing popularity of this approach is a result of the functionality of the strawberry plants: both ornamental and edible (Bentvelsen & Souillat, 2017).

At European level, strawberry consumption is increasing yearly. In 2017, it has been reported that the European consumers purchase around 1.2 tons of strawberries per year (http://www.hortibiz.com/item/news/eu-increase-in-strawberry-consumption).

Similar to other berries, strawberries are known to be highly perishable fruits, with a shelf-life ranging between 7 to 8 day when chilled, and only 1-2 days if they are kept under ambient conditions (http://www.eatbydate.com/fruits/fresh/how-long-do-strawberries-last/). Due to the fact of having a water content that reaches up to 90%, their texture and their high level of respiration, strawberries become subject of a short shelf-life by being exposed to microbial contamination (Samadi et al., 2017).

FAO informs that, annually, one third of the foodstuff goes to waste or loss, with the highest numbers recorded for vegetables and fruits (FAO, 2011). A study showed that 56% of the strawberries harvested in Ontario, Canada, are going to waste, with missuses within every link of the chain, but the highest percentage point for waste was registered at the consumer stage, 35% (Siu, 2015)

Trying to meet the consumer expectations regarding the quality of strawberries, as well as the related industry needs, scientists around the world are trying to find effective and feasible methods to prolong the shelf-life of strawberries.

In order to deliver this paper, 56 relevant articles in English have been carefully analysed. These 56 articles have been sorted out of a total of 65 articles. The rest, after being read the abstract, proved to be out of the topic of interest.

This paper consists of a literature review, compiling only the recent published work of scientists testing different modern techniques that are expected to show an improvement on the post-harvest life of strawberries. It is important to point out that lately, research is carried out and the results are published mainly with a turn for berries or other fruits in general, but not for strawberries, in particular.

In that sense, from the literature analysis it results that many researchers are investigating modified atmosphere packaging options, unconventional packaging materials, edible coatings, but also ultrasound or light treatments.

Techniques used for prolonging postharvest shelf life of strawberries

Modified atmosphere packaging (MAP)

Modified atmosphere packaging options have been extensively challenged by scientists, in order to find the proper conditions needed to extend the post-harvest life of strawberries. Thanks to the large amount of research in this area, modified atmosphere packaging is widely used at industrial scale and, subsequently, in supermarkets. As the topic was tackled by many authors (Farber, 1991; Stewart et al., 1999; Nielsen, 2008; Zhuang, et al., 2011; Peano, 2014), this present literature review will display other possible methods used in extending the shelf-life of strawberries.

Unconventional packaging materials or methods. Active packaging

Hydrobaric storage conditions have been reported to be useful in delaying the ripening of strawberries, cherries and grapes (Romanazzi et al., 2001) and it has been assumed that low pressure can create resistance of foodstuffs against pathogens (An et al., 2009). Respiration rate of strawberries was decreased under hydrophobic packaging at 3ºC and their quality was preserved at 50.3 kPa (An et al., 2009).

An application with active packaging was done using a system able to release 2-naonanone, a volatile that occurs naturally in fruits and proved to be efficient in postponing development of fungi. The experiment was noteworthy, since the quality of the strawberries was well-maintained and the fungal deterioration and senescence of the fruits were suppressed (Almenar et al., 2008).

Differently than for MAP, where the gas composition is considered to be the primary responsible factor for the atmosphere in the package, researchers considered it is worth taking into consideration the humidity level. As a result, humidity regulating trays (by adding salt into the polymer matrix) have been tested. Rux et al. (2016) observed that even if the trays were able to absorb humidity, the strawberries taken as sample lost more water than that absorbed by the packaging system, pointing to a potentially efficient method for shelf-life prolongation, after the optimization is made. The same trends of possible beneficial effects on the post-harvest life of strawberries of active packaging has been reported by many researchers, their ideas waiting for development and optimization (Sousa-Gallagher et al., 2013; Duran et al., 2016).

Edible coatings and films

According to Quintavalla & Vicini (2002), the use of incorporated antimicrobial agents into edible coatings constitutes a subsection of active packaging. Aiming at a longer shelf-life of strawberries and soft fruits, research is being done taking into observations edible coatings and films, containing usually a chitosan matrix and adding different other antimicrobial substances. A combination of nisin, natamycin, pomegranate and grape seed extract, together with chitosan was tested on strawberries and demonstrated to have a good effect on their texture, pH and on the total soluble solid content. In addition, the coatings offered protection against microbial spoilage extending the shelf-life of the fruits for up to 40 days at a temperature of 4ºC (Duran et al., 2016). Another study showed that edible coatings consisting of carboxymethyl cellulose, hydroxypropylmethyl cellulose and composites with chitosan are acting as a gas barrier and have the ability to modify the internal atmosphere of the fruit hence preserving their quality (Gol et al., 2013).

Literature shows that chitosan is used to control weight loss of strawberries, by creating a semi-permeable film on their surface that obstructs respiration and by possessing antimicrobial attributes (Jiang, 2005; Bautista-Banos, 2006; Vargas, 2006; Campaniello, 2008). Having in mind an effective waste management, edible films were also designed by using olive oil residues extract incorporated in chitosan – the idea proved to have positive results in improving the characteristic of chitosan to contrive films but also its antimicrobial activity against Penicillium expansum and Rhizopus stolonifer (Khalifa, 2016).

Essential oils of limonene, of red thyme and of peppermint were incorporated in chitosan and the resulting coating was applied to fresh strawberries. The formulations had antifungal properties, but the repetition where the emulsifier Tween®80 was present, has shown better results (Vu et al., 2011). The use of essential oils, despite being known to have antimicrobial properties, do not always show their expected benefits: citral and eugenol have been used to enrich an edible coating based on pectin and sodium alginate and then applied to fresh strawberries with the scope of reaching a longer shelf-life of the fruits. Compared to the control sample, the coatings did not show significand changes in the quality of the strawberries, but they reduced the microbial spoilage (Guerreiro et al., 2015).

Ultrasound or light treatments

Ultrasound treatment represents an emerging technique tested for extending shelf-life of produce. When measuring its effectiveness, time, power and wave frequency are the variables to be controlled (Mohapatra et al., 2013). The method was applied to dairy products, vegetables, fruits and fruit juices (Sagong et al., 2011, Yang et al., 2011) in order to inhibit microbial spoilage. Aday et al. (2013), however, have looked on the effect of ultrasounds on the physico-chemical properties of strawberries. They examined the effect of different power (30W, 60W, 90W) and treatment time (5 min, 10 min) and found that time did not have a significant influence in extending the shelf-life or strawberries, but the power of 30W and 60W maintained the fruit's pH during storage. It has also been observed that a 90W power can lead to water loss and changes in color, such power affecting the cell structure (Fernandes et al., 2009) and the anthocyians stability (Tiwari et al., 2010), respectively. As a result, Aday et al.'s (2013) study highlighted the need of adjusting the ultrasound power depending on the desired outcomes.

Duarte-Molina et al., (2016) examined the influence of pulsed light on fungal decay, water loss and mechanical attributes of strawberries stored at 6ºC for up to 6 days. Differently than the UV-C light, pulsed light is considered to have a better emission power and abilities for deeper penetration (Gómez-López, 2007). Pulsed light treatments are non-thermal and free of residues and have been successfully used in fungal disinfection of food surfaces and food packaging (Oms-Oliu, 2010). Possible applications in pharma and medicine have also been proposed (Wekhof, 2000). Duarte-Molina et al.'s (2016) research proved that doses of 2.4–47.8 J/cm^2 can diminish fungal decay by 16-42%, but it can also have beneficial responses regarding the firmness of strawberries. Gladdening outcomes on strawberries are presented by Luksiene et al. (2013) too: no influence of the high power pulsed light has been observed in the nutritional value, color and firmness of the fruits, but their shelf-life was prolonged by 2 days.

Other techniques

With the scope of inhibiting the growth of microorganisms, researchers are taking into consideration non-conventional possibilities, including the use of bacteria and of fungi with antagonist behaviors (Garbeva, 2014; diFrancesco et al., 2015).

Quin et al. (2016) demonstrated that the volatile compounds of the yeast strain Hanseniaspora Uvarum can reduce the infection of Botrytis cinerea in strawberries, preserving their firmness, presentation and total soluble solids.

The possible positive effects of MAP in combination with other methods to prolong the shelf-life of fruits may prove to be of a greater value. For instance, low dose (1 kHy) gamma irradiation and MAP had significantly increased the strawberries' shelf-life. In their study, Jouki & Khazaei (2014) observed that samples irradiated and kept under active EMAP1 (CO_2 10%: O_2 5%; N_2 85%) did not spoil and kept their visual attributes after 14 days of storage at 4ºC.

Except for the ultrasound treatments, other non-thermal technologies have also been tested by scientists, such as vapors of ethyl pyruvate (500 mL) that demonstrated to be a good option in maintaining the strawberry's texture and weigh, as well as in preventing spoilage. The same test was done for cherries too, and the results showed that the method is even more effective than for strawberries.

Conclusions

The literature review revealed that not many publications have been released in the last years, on strawberries in particular, but focusing on berries, in general.

Both for the food industry and researchers, as well as for policy makers, the challenge is to upgrade the existing old and modern techniques, but also to discover and develop new ones. A longer shelf-life of strawberries would lead to an extended period in which the consumers could benefit from having fresh strawberries longer at home and for a more effective waste management. In addition, the farmers, the pickers and the transportation companies also be direct beneficiaries of strawberries having a longer shelf-life, with diminished losses along the value chain.

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