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FOOD AND ENVIRONMENT SAFETY

SUSTAINABLE PACKAGING SOLUTIONS FOR ORGANIC FRESH BERRIES

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Abstract: *Climate changes and particularly global warming are topics carefully treated by specialists already since decades. The most pregnant factor that influences climate change is pollution, namely the high level carbon dioxide emissions. Besides other substances used by the most of the industries (oil, charcoal, fertilizers, etc.), plastics are not to be ignored when talking about pollution. Plastic waste affects animals and humans, as well as their habitat.*
In this respect, food industry engages in preserving the good functioning of the environment by developing and using biodegradable and bio-based resources for food packaging.
The aim of this literature review was to identify the optimal sustainable packaging solution used for berries. The results of the study pointed out that the most used environmentally friendly packaging technique is the one that involves modified atmosphere. In terms of packaging materials, the literature is limited when it comes to biodegradable/bio-based solutions. However, active packaging gains popularity among researchers, considering the endless possibilities to include sustainable compounds in a biopolymer based matrix, in order to prolong the shelf-life of berries or fruits in general.

Keywords: *organic fresh berries, sustainable packaging, biodegradable/bio-based materials*

1. Introduction

Over the last few years, consumers started to appreciate the advantages of convenience food in general, and of fresh fruits and vegetables in particular. This trend comes together with a series of challenges for the food business operators that try to stay on the market by offering the desired attributes of fresh produce and seek for better post-harvest solutions to avoid operating at a loss [1].
It became common knowledge that fruits and vegetables are rich in components that sustain human health and wellbeing, and, as a results, they are promoted to be consumed in a daily basis. The benefits of consuming fresh fruits and vegetables are highlighted by the correlations between specific compounds of the produce and their favorable effects in the fight against cancer, neurodegenerative diseases, obesity, inactivity, poor diet or even erectile dysfunctions. The recent scientific evidence in that respect acts as an engine for promoting consumption of fresh fruits and vegetables and it leads to a market growth of such products [2], [3], [4].
The perks of having a larger part of the population interested in this kind of goods come with the reality of producing enough marketable harvest. The most coming to the forefront challenge of fresh fruits and vegetables producers is the fast decline of the quality characteristics, as well as the short shelf-life.
An important role in the changes that occur on the quality of fresh fruits and vegetables is played by the metabolism of the products, as well as by the mechanical

swelling or physiological defects. These undesired changes can lead to depreciation of the nutritional value, taste, color, texture, and make the products less attractive to the consumers. In addition, they can lead to the deterioration of the quality attributes and in financial loss for the food business operator, [1], [5], [6], [7].

Food is a dynamic system [8] and it is subject of both chemical and biological spoilage. Chemical spoilage can occur as a result of the oxidation process, but the most widely spread type of spoilage is the biological one. It can be caused by enzymatic degradation, contamination (with protozoa, parasites, or viruses), or microbial contamination. In the case of microbial spoilage, the nature of the food (pH, texture, water activity, amount/type of nutrients and oxygen contained), plays a vital aspect with regards to the microorganism that can cause spoilage – be it bacteria, yeast or moulds [9]. In the case of fruits, as they are mostly acid products, their resistance to bacteria is higher than to fungi [10], [11].

In order to reduce post-harvest waste and loss, as well as to prolong the timeframe in which the fruits meet the consumer demands and expectations, post-harvest technologies are being developed and optimized accordingly. In this respect, optimal methods and techniques are still being investigated, having the purpose of maintaining high quality of fruits and to extend their shelf-life. Amongst the most recognized and successfully applied chemical or physical techniques are: the use of ozonized water, sanitizers, heating, UV light treatments and irradiating [1], [12], [13].

Food packaging in general and also of fruits in particular, has the primary function of protecting them from mechanical injuries to maintain quality and to delay microbial growth [9], [14]. The most widely spread material used in packaging is plastic, which is known to have negative effects on the environment. Plastic waste affects animal and humans, as well as their habitat. The United Nations draws attention that before 2050, plastics will exceed the fish in the oceans if people keep using plastic at the same rate [15].

This research proposes to point out possible suitable methods for sustainable packaging for berries.

2. Materials and methods

This study consists of a literature review. It aims to identify optimal solutions for sustainable packaging for organic fresh berries. In order to deliver our statements and arguments, 53 articles in English have been taken into our attention. After being analyzed, 38 out of 53 articles proved to be relevant for our investigation.

3. Overview of available, promising packaging options

Antimicrobial packaging

The concept of active packaging is fairly new, but the research in this field knows a rapid development and the directions taken within the subject are multiplying [15], [16]. The main purpose of the active packaging technology consists of creating a mutual action between food and the package itself, at the same time as assisting the microenvironment generated within the unit. Active packaging should provide microbial safety, maintain the quality of the product, its nutritional value and prolong its shelf-life [17].

Antimicrobial packaging can drag out the time frame of realistic usability by deterring the development of target food spoilage microorganisms either by broadening their lag-phase or by reducing their growth rate [9], [16]. The mechanism used for designing active packages roots in introducing antimicrobial agents (in this case, chemical) into the packaging structure. Later on, however, edible coatings are available, as well as emitting sachets, sheets, films or gases. In addition, it is also possible to induce vacuum, which does not only inhibit the oxidation process of foods, but it also has antimicrobial and antifungal characteristics, targeting aerobic bacteria [9].

Having in mind the actual need of environmentally friendly options, to avoid plastic and food waste, a dynamic film based on methylcellulose and maqui berry (*Aristotelia chilensis*) extract was challenged against microorganisms and oxidative reactions. Because methylcellulose's availability to bind with water, it was cross-linked with glutaraldehyde at various concentrations. The glutaraldehyde concentration added proved to be proportional with the amount of the antioxidant agent released [18].

Similarly, extruded recycled PET was enriched with potassium sorbate in two concentrations (2,5 and 4,0 wt%). The rate of the *Botrytis cinerea* growth was proportional to the quantity of potassium sorbate added as antifungal agent. After the migration tests were performed for potassium sorbate, it was found that the results were within the legal limits [19].

Another successful experiment done on wild berries was performed by adding a naturally occurring volatile compound, 2-nonanone to an equilibrium modified atmosphere package [20].

Outstanding results were also obtained by using a combination of modified atmosphere packaging and eugenol or thymol. Grapes were stored in said conditions for 56 days. After the observations, it was concluded that losses caused by sensorial, functional, nutritional and fungal decay were significantly lower on the samples where eugenol or thymol was used [21].

Biomaterials

Biomaterials, besides being environmentally friendly and highly demanded by consumers, can be cheap to procure, as they can be by-products from other industries or the materials can be easily found in nature [22], [23].

Pectin, a resource that is available in apples and citrus fruit, is biodegradable, non-toxic and renewable. It is already used in biomedicine and films made with pectin proved to extend shelf-life of foodstuffs and can be used in drug delivery systems [23]. Polylactic acid (PLA) is synthetized from corn and it is also a widely used material as an alternative to conventional plastics [24]. Almenar *et al*. (2008) recommend PLA to be used in packaging for fresh berries – it prolonged the post-harvest life of blueberries at different temperatures and suggests sensory tests to be performed concerning flavour discrepancies [25]. A combination of rice starch, fish protein and oregano essential oil proved to be worth considering in the development of active, biodegradable packaging [26]. Aloe vera gel was also used for an edible coating on grapes, proving to have the capacity of inhibiting microbial (yeast and moulds) growth [10].

Chitosan is another remarkable biomaterial used for extending the post-harvest life of fresh fruits and vegetables. It was effectively used to extend the shelf-life of apples, litchi fruits and peaches [22]. In an interesting experiment carried out on strawberries stored at 7ºC, chitosan beads supplemented with lavender essential oil extended the fruits' shelf-life to 8 days, comparing to the control sample that after 2 days of storage was already mouldy [27].

Sodium alginate was also used in edible coatings for apples and for sweet cherries delaying their ripening time outstandingly [28].

Essential oils (EOs)

With respect to natural antimicrobials, scientific literature suggests that the most common methods to apply the treatments are by spraying, rinsing, washing, vaporing or edible coatings [29]. Essential oils continue to prove efficiency in fighting and inhibiting spoilage microorganisms in both fresh fruits and fresh vegetables. Thyme, oregano and lemongrass EOs in combination with MAP were successfully used to extend the shelf-life of cabbage [30]. In strawberries, *Botrytis cinerea* was inhibited or delayed using thyme or lavender EO [30], [31], [32].

In order to avoid the disadvantage of EOs, they can be introduced into a polymer matrix, so the release is done gradually. A study of Jurmkuwan *et al*. (2016) showed that by encapsulating thyme and lavender essential oils into a chitosan matrix, inhibited the growth of *B. cinerea* and maintained the quality of strawberries, without interfering with their taste [32]. The concentrations of EOs used in food packaging are being optimized, as the taste resulted after the treatments can be unacceptable by the consumers. Consequently, studies with panels are organized and it can be remarked that the right concentration of EO can be both effective in prolonging the post-harvest life of food and adequate for the consumers [20].

Modified atmosphere packaging

Modified atmosphere packaging (**MAP)** has been used already since the first half of the previous century, when New Zealand shipped lamb and beef to the UK stored under CO_2 conditions [33]. Ever since then, methods and gas concentrations are being optimized and perfected. As a result of its relatively long history, the technology of MAP has been largely approached in literature too. However, we will bring to bear on recent research done on the use of MAP to extend the shelf-life of fruits and vegetables and particularly, of berries.

The effect of MAP was tested on pomegranate seed pods. After being flushed with low O_2 atmosphere, the seeds were suitable for consumption for up to 6 and 9 days (depending on the tray they were placed in). Differently, when the pomegranate arils were flushed with high O_2 atmosphere, their accepted quality was prolonged to over 9 days. The authors of this experiment (Banda *et al.*, 2015) recommend optimization of gas levels, and to avoid introducing low levels of O_2 in trays sealed with high barrier polymeric films, since this combination leads to off-odours [34]. Thus, it can be observed that failing to create appropriate environment may and in shortening the shelf-life of the foodstuffs [35].

Table grapes have also been taken into research, results showing that MAP was effective in extending the period in which the rachises kept their green color. This attribute is directly correlated with the quality of the grapes after harvest. This study suggests, however, that are still elements to be optimized for assuring a stable potential technology [36].

When storing blueberry under MAP, it was found to be more effective when the sample kept in perforated bag was fumigated with SO_2. Differently, the blueberries placed under MAP only, were subject of weight loss, decay, softening and dehydration [37].

Another experiment performed on table grapes tested whether proper MAP can have beneficial effects on the sugar, anthocyanin and organic acid content, as well as on the antioxidant activity. The fruits were stored for 3 months at 0ºC either in perforated polyethylene bags or in ZOEpac MAP bags, with or without sachets emitting ethanol vapours (Antimold®30, Antimold®60 or

Antimold®80) or pads emitting SO_2. It was observed that SO_2 was effective in maintaining the sugar and organic acid levels, as well as preserving the anthocyanin content, but it transferred an off-taste to the grapes [38].

4. Conclusions

After reviewing the relevant scientific literature, it can be concluded that many options are potentially effective in extending the post-harvest life of berries. However, not much information is available on suitable biodegradable materials. From what recent literature provides, we can observe that science knows various directions with regards to shelf-life prolongation of fresh fruits and vegetables, but are still many details to be polished before we can benefit from technologies that can represent the knowledge transfer from laboratory level to industry scale.

In addition, aside the need adjust the said details, it should be considered researching for further solution regarding convenient biodegradable materials to be combined with technologies intended to assist shelf-life and quality of fresh fruits and vegetables.

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