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Biological control of postharvest diseases on fruit: a suitable alternative?

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The use of microorganisms to control pest and diseases at field conditions is now a reality. Several products are already in the market and their use is increasing every year. However, the situation in the control of postharvest diseases of fruits and vegetables is very different. The research in this area started later and despite the progress made especially in the last 20 years their commercial application is still very limited.In the present overview we discuss about this situation, expose the state of the art, the main concerns and difficulties to increase their commercial use in postharvest. We postulate than is necessary to show consistent efficacy under commercial conditions but this fact is not enough, because some BCAs with reliable performance are not in the market for a complex combination of legal and economic aspects. In the future, it will be necessary to improve the bridge between researchers and private companies.

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Introduction

Estimates of the postharvest losses, especially produced by fungal pathogens are very hard to assess, however, there are some general data about it. In the U.S. an overall average of fresh fruit and vegetables losses could be around 12% between production and consumption [1] and in economically impoverished regions the losses could be higher than 50% [2]. Traditionally, the control of postharvest diseases has been achieved by spraying/treating fruit with synthetic chemical fungicides. However, a strong consumer demand of fruit free of pesticides followed by new and strict regulations on their registration and application have reduced the use of chemical products. Thus, a need to search and develop alternative strategies for the postharvest disease management remains as priority research line.

Plant hold very diverse microbial communities that are the source of the majority biocontrol agents (BCAs) against pathogens [3]. In this context, the use of microbial antagonists to control postharvest pathogens generated many expectative as a sustainable control method of fruit pathogen alternative to chemical products. The main reason to expect better success than soil and foliar diseases control were: (i) during postharvest processing and storage some environmental factors as temperature and humidity should be better regulate and fit to biocontrol agent; (ii) harvested commodities present a more concentrated target for their application; and finally (iii) the high value of the harvested commodity [4,5]. However, few antagonists have been commercially available yet and the reasons, difficulties and troubles related to this fact will be discussed along this paper. Many efforts, thus, need to be done yet to develop more biocontrol products addressed to postharvest market.

Use of microorganisms to control postharvest diseases

From the first work of postharvest biocontrol published by Tronsmo and Denis in 1977 [6] to currently, the literature on biological control in postharvest has exponentially grown. In a recent review by Spadaro and Droby [7] searching in the Scopus search engine found that more than 600 papers were published in the past ten years on this topic. Most of them describe the isolation, efficacy, mode of action, incorporation of alternative control means, extend the spectrum of action, and less papers describe the large-scale production, formulation and packaging to prolong viability and preservation of the BCAs.

The main characteristics for an ideal postharvest antagonist was indicated many years ago by Wilson and Wisniewski [8], and following some of these criteria many microorganisms, specially bacteria and yeasts, have been isolated and tested as antagonist of fungal postharvest pathogens (lists of microorganism described as BCAs are provided in different reviews [9–12]).

The general goal of most of the research groups is to develop a commercial biocontrol product. In spite of all efforts, only few of them are commercial available in postharvest as it has been recently described by Droby *et al.* [13•]. *Candida oleophila* (Aspire, Ecogen, Langhorne,

PA, US) [14], *Cryptococcus albidus* (YieldPlus, Lallemand, Montreal, Canada), *Candida sake* (Candifruit, Sipcam Iberica, Valencia, Spain) [12], *Pseudomonas syringae* Van Hall (BioSave, JET Harvest, Longwood, FL, US) [15], are considered the first generation of postharvest biocontrol products. However Aspire and Candifruit were commercialized only few years and, Biosave and YieldPlus has limited use in the US and Sudafrica markets respectively. More recently *C. oleophila* (Nexy, Leasafre, Lille, France) has received registration approval throughout the European Union in 2013 [16]. *Aureobasidium pullulans* (Boni-Protect, Bio-Ferm, Tulln, Austria), has a suggested use as a preharvest application to control wound pathogens that develop on pome fruit during storage [17]. Another product based on *Pantoea agglomerans* CPA-2 (Pantovital, Domca, Granada, Spain) was formulated but never commercialized [18]. *Metschnikowia fructicola* (Shemer, Bayer, Leverkusen, Germany) was acquired by Bayer CropScience (Germany) and then sublicensed to Koppert (Netherlands). However, none of them are used as real alternative of chemical products.

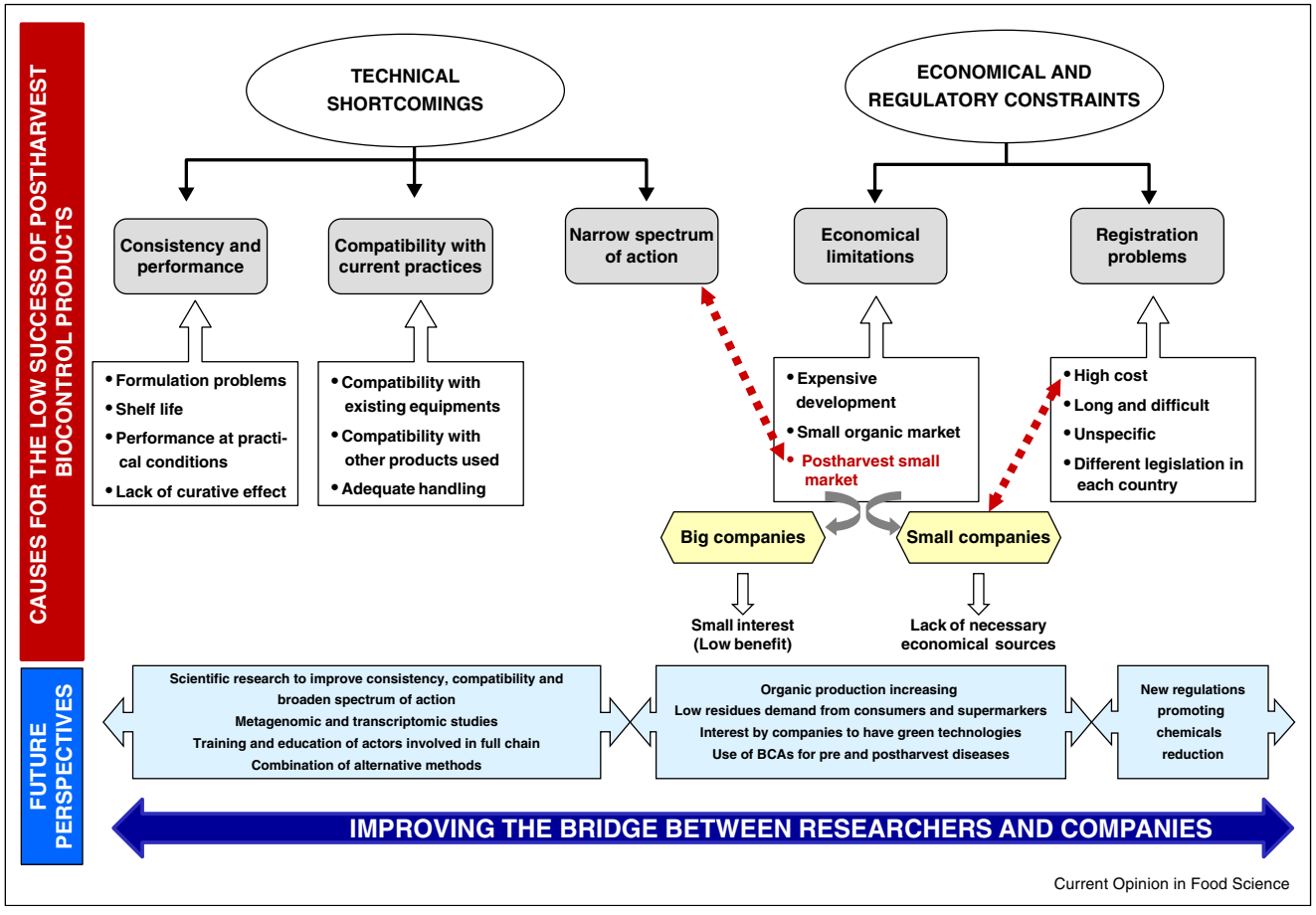
Causes for the low success of postharvest biocontrol products

Despite all the effort conducted during these last 30 years to develop biocontrol products to control postharvest diseases, the low success rate has been stated in the previous section, with a very limited number of products available in the market and applied exceptionally. In this section, constraints and shortcomings of these products have been analyzed and discussed in order to identify and understand the limitations, and later, we will suggest future perspectives (Figure 1).

Technical shortcomings

The first limitation that is pointed out by users would be the lack of consistency and unreliable performance at practical conditions of some postharvest BCAs. It is clear that a product that shows inconsistency under commercial conditions cannot be successful in the marked. Four important aspects are involved in this point: formulation problems, shelf life product, behaviour under practical conditions and the lack of curative activity.

Figure 1



Schematic representation of the most important constraints and shortcomings in the development and commercialization of biocontrol products as well as future perspective.