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Review

Bioaromas – Perspectives for sustainable development

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ABSTRACT

Background: Aroma compounds can be produced using three main methods: chemical synthesis, extraction from nature, and biotechnological process (bioaromas). In the latter method, when compared with chemical synthesis and direct extraction from nature, the (bio)aroma compounds obtained present numerous advantages, in such a way that this approach meets two important demands of modern society: the first one refers to products obtained by biotechnological processes, which can be considered as natural, and the second one is related to the concept of sustainable development, since such production processes are aligned with the best practices in environmental preservation.
Scope and approach: In this review we demonstrate that the technological development of the production of aroma compounds using microorganisms is effectively promising as a process that allows the inextricably approach of the three pillars of sustainability: environment, economics, and social aspects.
Key findings and conclusion: This review shows that bioaroma production consists of renewable processes that employ mild conditions of operation, do not generate toxic waste, uses biodiversity rationally, and may also avail agro-industrial residues or by-products in a special way. Moreover, biological (e.g., antioxidant, anticancer, anti-inflammatory) activities attributed to some terpene biotransformation products are increasingly being reported, indicating that their applications may transcend food industry.

1. Introduction

Aroma compounds can be produced using three methods: (i) chemical synthesis, (ii) extraction from nature, and (iii) biotechnology. In the case of chemical synthesis, this method is marked by high yields and low cost. However, it generates low quality products. That is because, considering its low regio- and enantioselectivity, a mixture of products is obtained at the end of the process. In addition, aromas obtained using this method cannot be labeled as natural. Another questionable point about this method refers to the process parameters, which generally require a high energy cost (high pressures and temperatures), in addition to generating environmental liabilities (use of large volumes of organic solvents) (Akacha & Gargouri, 2014).

On the other hand, aroma compounds obtained by the method of direct extraction from nature or by biotechnology can be labeled as "natural". Thus, products obtained using such processes have an undisputed marketing appeal. However, the method of direct extraction from nature is full of challenges, among which we can highlight: (i) seasonality (the availability of a product is related to certain periods of the year), (ii) ecological, social and political issues, and (iii) low yield, which results in a high price for the product. In the case of the last challenge, the vanilla essence produced from the orchid *Vanilla planifolia* illustrates this scenario. According to Gallage and Møller (2015), it is estimated that approximately 500 kg of pods of the aforementioned orchid are required for 1 kg of essence, in a process that takes more than twelve months.

Thus, the biotechnological production of aroma compounds outstands as a very promising option to overcome problems associated with these other methods of production. Among the main advantages of this method, we can highlight: (i) high enantioselectivity, which allows obtaining aromas of high optical purity, beneficially impacting sensory characteristics of the product; (ii) continuous production throughout the year and without seasonal

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interference; (iii) adoption of parameters of processes that are less stringent (thus reducing energy costs and the use of reagents harmful to the environment) (Berger, 2015); and, (iv) controllable and optimizable process conditions.

Therefore, the production of aroma compounds by biotechnology meets two major demands of modern society. The first one refers to the supply of natural products, meeting the expectations of consumers and contributing to a higher quality of the final product. The second one is related to the concept of sustainable development, since such production processes align the company with the best practices in environmental preservation, in addition to increasing the credibility of the consumer regarding such company (Manget, Roche, & Münnich, 2009). This last aspect, in particular, deserves great prominence for being one of the most important topics in the modern world.

1.1. Sustainable development

The sustainable development concept was created from the need to combine industrial activities with the environment in a harmonious way. Therefore, it is a relatively new term that still finds barriers to its comprehensive understanding. That is because, often, sustainability is directly associated with the fulfillment of laws allowing only environmental protection (Cristina & Diana, 2014).

However, the creation of technologies that seek sustainable development must inextricably address three aspects that effectively provide the sustainability of this new process, namely: environmental, economic, and social aspects. In fact, the concept of sustainable development would be subjected to a considerable limitation if only the environmental aspect was necessary to the detriment of economic and social development (Ciegis, Ramanauskiene, & Startiene, 2009).

Because of this, the triple bottom line was created (Fig. 1), based on the inseparability of the aspects previously mentioned. Thus, a technology is only recognized as sustainable if it broadly and simultaneously meets the three pillars of that tripod (Gimenez, Sierra, & Rodon, 2012). Several indexes have been proposed to measure sustainability. However, as it is a complex quantification due to the different aspects involved and the related contexts, each index has positive and negative points, being better shaped depending on the situation involved (Ciegis et al., 2009).

Currently, the trend of industrial processes – mainly chemical ones – is focused on the replacement of all or part of the procedure for new technologies that use microorganisms (bioprocess). This fact is widely justified based on the best interests of industries in offering products that are environmentally friendly, socially equitable, involving high added value and thus meeting marketing trends (Toldrá, 2015).

Therefore, the objective of this review is to demonstrate that technological development for the production of aromas using microorganisms is a promising idea from the point of view of the sustainable development, since it allows the inextricably approach of the three pillars of sustainability, each being detailed in the next sections.

2. Environmental aspect

2.1. Operations conditions

Bioprocesses are used by mankind since ancient times, mainly in food and beverage production (Kwon, Nyakudya, & Jeong, 2014). However, over the years, the use of microorganisms as biological factories for the production of various products went beyond the food sector and, currently, this tool is used in distinct areas such as environmental remediation, pharmaceutical industry, and others (Heux, Meynial-Salles, O'Donohue, & Dumon, 2015). This fact clearly demonstrates the versatility, adaptability, and potential of using microorganisms in providing products with commercial interest. Moreover, industrial biotechnology might be advantageous in environmental terms, since they occur under mild conditions (process close to room temperature and atmospheric pressure) and there is a possible reduction in the volume of environmental liabilities (Boukroufa, Boutekedjiret, Petigny, Rakotomanomana, & Chemat, 2014).

In the case of the aroma industry, the production process of vanillin is a good example to understand the reasons for the tendency to replace classical processes with biotechnological processes (Gallage & Møller, 2015).

Vanillin is one of the main aroma compounds in commercial terms, with annual demand of approximately 2.0×10^4 tons (Fache, Boutevin, & Caillol, 2015). In the second half of the 19th century

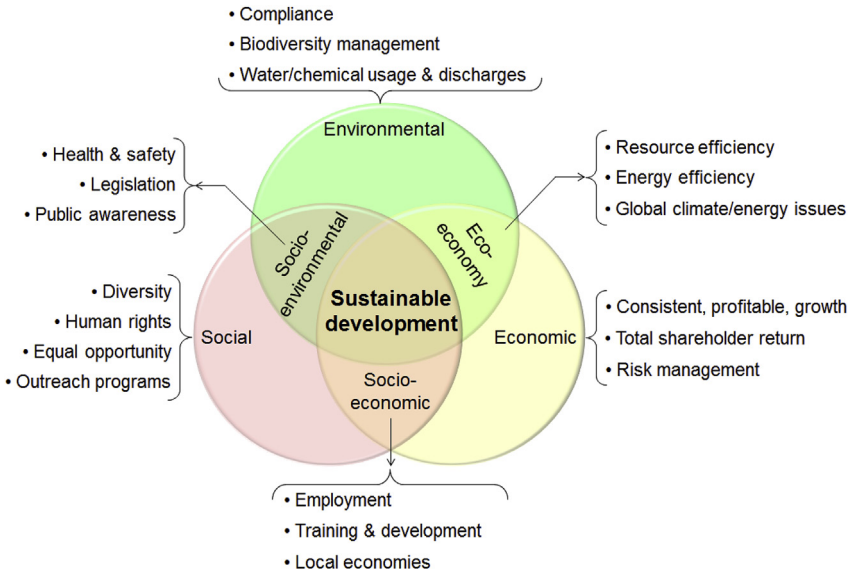

Fig. 1. Articulation of the triple bottom line that must be fully covered by a technology that seeks sustainable development. Adapted from: Sustainability – What do we mean?.