Commentary

Research in plant melatonin: Original and current studies

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ABSTRACT

Melatonin from plants, also known as phytomelatonin, was discovered in 1995, and since then, affecting many areas of research related to plants. Thus, the number of publications on phytomelatonin has grown exponentially in recent years, especially in Plant Physiology and Plant Molecular studies. In this paper, we try to expose the great incidence that the detection of this neurohormone in plants is having, and its relevance in areas such as agronomy, genetics, human nutrition and food chemistry/technology, animal nutrition and other more specific fields of interest such as cosmetics and nutraceuticals.

Key words: Melatonin, phytomelatonin, plant growth regulator, nutraceuticals, phytogenics

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Melatonin (*N*-acetyl-5-methoxytryptamine) is a well-known animal neuronal hormone with pleiotropic actions in mammals, highlighting its regulatory action of wake-sleep cycles, locomotion, appetite, mood, sexual behavior, its modulating action of the immune system and its regulatory action of basic metabolism, among others (1). This molecule, was first discovered in 1958, in cow by Lerner *et al.* (2), it was rediscovered in 1995 following its detection in various plant species such as tomato, and other horticultural plants. Interestingly, melatonin in plant tissues was described the same year by three different groups of researchers in three different publications almost simultaneously (3–5).

The period of 1995-2010 can be described as uncertain and lacking data demonstrating the importance of melatonin in plants, highlighting pioneering studies such as those that first described the action of melatonin as a promoter of plant growth, its foliar anti-senescence role, and its key involvement in abiotic stress processes (6). Since 2011, there has been a growing interest in many biochemical and physiological aspects of melatonin in plants. In the interval 2018-2022, about 120 articles per year related to melatonin in plants were reached. In 2023, the numbers have shoot up if we consider the growing interest not only in plants but in mushrooms, algae, yeasts and bacteria, and also in related foodstuffs such as juices, wines, breads, and other fermented products (7), reaching about 130 articles in the first quarter of this year.

Figure 1 shows the global distribution of articles referring to "plant melatonin" or "phytomelatonin" as keywords for the different areas of study. The quest was carried out in two of the most important scientific databases, Web of Science (WOS) and Scopus. The search in the WOS database found 2148 documents with a total subject count of 3669, while in Scopus database were 2484 documents with a total subject count of 4212. The relevance of the use of "plant melatonin" or "phytomelatonin" in the research carried out from 1995 can be seen in the various scientific subjects in which "plant melatonin" or "phytomelatonin" were involved, being the principal subject of those related to Plant Science or Agriculture with the 21% of the counts in WOS, and the 27% in Scopus, followed by Biochemistry and Molecular Biology with the 8% in WOS, and the 25% in Scopus.

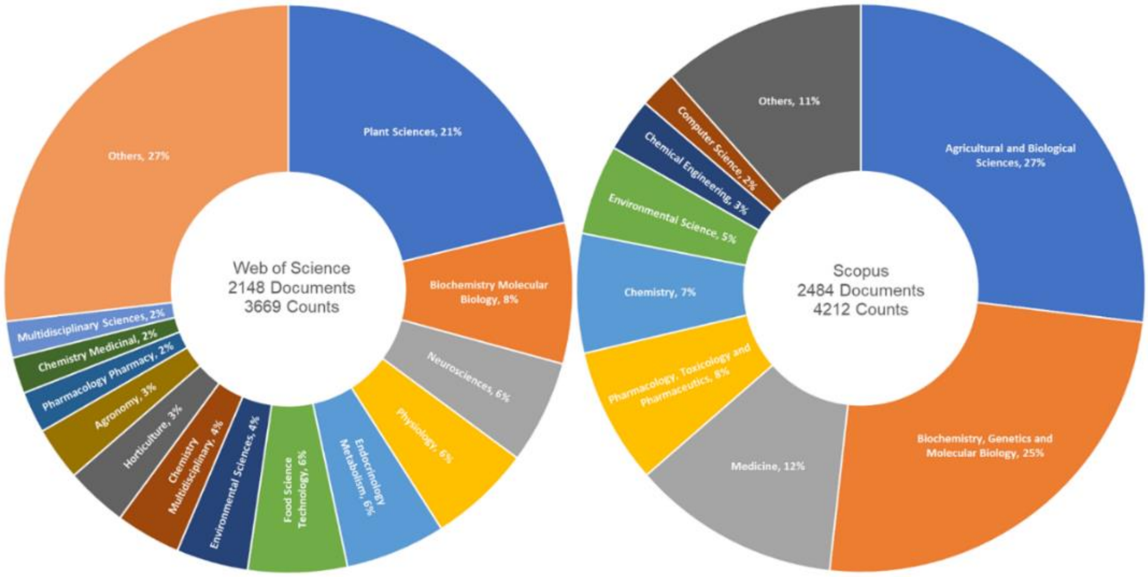

Fig. 1. Scientific subject distribution of articles dealing with "plant melatonin" or "phytomelatonin".

The data were obtained by searching in all years in the Web of Science (www.webofscience.com) and SCOPUS (www.scopus.com) databases. Accessed on 24/4/2023.

Regarding new perspectives on research on phytomelatonin, there are several aspects to highlight and be promoted in the different areas:

1. In Plant Sciences and Agronomy. Botanically, an insignificant part of plant species has been characterized in respect to their phytomelatonin content, requiring more data on phytomelatonin content in medicinal plants. On the other hand, there are numerous plant physiological studies in *Arabidopsis thaliana* and many other species of agronomic interest, mainly horticultural and cereals. Many of the responses in plants have been shown to be modulated by melatonin, which improves processes such as germination, growth, flowering, etc., but the most important action of melatonin is as a mediator in stress situations: biotic, caused by herbivores, fungi, bacteria, parasites and other plants, and abiotic, such as salinity, drought, chemicals, UV-radiation, physical damage, among others (8, 9). Some of these physiological actions mediated by melatonin are beginning to be tested in large-scale crops, obtaining experimental field data that indicate the clear agronomic advantages of treatments with melatonin. Future perspectives point to the need to know new possible phytomelatonin receptors, the relationship of its expression in different tissues and its regulation by environmental factors and the biological clock in plants. Future studies should delve into the possibilities of using (phyto)melatonin as an anti-stress agent in crops, promoting tolerance to both abiotic and biotic stress agents. In the latter case, the co-participation of melatonin with pesticides points to a line of study to reduce the doses of chemical treatments (fungicides, bactericides, acaricides, insecticides, etc.) using melatonin as a safener in an eco-friendly strategy in crops (10). Lately, studies on the control of viruses in plants by melatonin have been successful, with special emphasis on *Tobamovirus* such as mosaic virus of tobacco, potato, tomato, and cucumber, among others, with relevant agroeconomic repercussion (11, 12). Likewise, its relevant role in stomatal regulation should induce more interesting studies on the water economy of crops and the postharvest responses of fruits and vegetables to exogenous

melatonin treatments. All of the above, from an integral point of view, with melatonin as a sustainable agent in a more productive and circular agriculture of the future, ensuring the absence of undesirable environmental effects (7, 13).

2. In Molecular Biology and Genetic studies, great advances have been made. The biosynthetic route of phytomelatonin in plants and the differences with it in mammals are known. However, although many genes and isoforms of some of the biosynthetic enzymes have been determined, in other cases there are hardly any data, such as tryptamine-5-hydroxylase (T5H) and the possible presence or absence of tryptophan hydroxylase (TPH) in plant tissues. Another aspect of interest is the study of phytomelatonin catabolism enzymes and the amazing role of 2-hydroxymelatonin as an anti-stress regulator. The better understanding of the relationship between the expression of phytomelatonin biosynthesis genes and the redox defense mechanisms and detoxification of heavy metals in plants is of great interest in the future. Also, the phylogenetic distribution of phytomelatonin in plants, algae, and fungi, including differences in gene regulation, it is presented as a topic of great interest (8).

3. For Food Chemistry and Nutrition area, melatonin has shown an important role in gastro-intestinal regulation, being massively generated by the cells of the digestive tract. Ingested melatonin, from plant foods or not, is easily assimilated and incorporated into the bloodstream. Therefore, knowing the bio-assimilation rate of phytomelatonin is presented as a relevant objective. Especially considering the great diversity of human diets in the different geographical areas and communities. Also, for the food industry, the presence of melatonin from juice extracts and the appearance of melatonin due to fermentation processes in products such as wine and beer, has meant a new approach in the field of functional foods (14–20).

4. In the Animal Nutrition area, mainly herbivores, ingest huge amounts of herbs and feed made with plant materials (flours, oils, fibers, etc.), being of interest to know the real levels of phytomelatonin intake and its role in the physiology of the animal, and also its repercussions on livestock and its management. For example, melatonin dermal patches are currently used to homogenize ovulation in cattle sheep, and will can be replaced by feeds rich in phytomelatonin (21). Also, it is well known the beneficial effects of melatonin in immunoregulation and other physiological responses, being able through feed to improve those responses. In pets, mainly dogs and cats, several dysfunctions are treated with melatonin, such as some hair problems (alopecia), insomnia and sleep disorders in elderly dogs, and anxiety and nervousness about noise or disorientation, in which symptoms could be improved through pet foods rich in phytomelatonin (22). In addition, the effects of plant melatonin on milk quality and production of cows and goats is an aspect of great interest (23–27).

5. To consider the possibilities of phytomelatonin-rich extracts as therapy, numerous clinical studies must be carried out to define basic pharmacological parameters and their possible interactions with other drugs. Also, their use in cancer therapies as adjuvant should be consider (28).

6. The use of phytomelatonin in cosmetic and dermatological treatments, both in medical and veterinary applications, can also be considered (22).

7. To finish, one of the most requested applications of phytomelatonin we must point out. The manufacture of pills or capsules with phytomelatonin-rich extracts is an application highly demanded by companies of the natural products industry. An extensive exposition and discussion on the obtaining and use of non-synthetic melatonin can be consulted (29).

In overall, the discovery of the presence of melatonin in plants (phytomelatonin) has led to important steps in the research of multiple areas that, coordinated or not, have formed a data body with multidisciplinary applications having as an unavoidable focus agriculture, food technology and medical/veterinary applications within a circular and sustainable economy.

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AUTHORSHIP

All authors contributed equally to the writing of this paper.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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