Melatonin in Edible and Non-Edible Plants

Yenilebilen ve Yenilemeyen Bitkilerde Melatonin

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ABSTRACT

The concept of melatonin has become more important recently both in plants and in human who utilize plants for nutritional and health purposes. Melatonin, synthesized from L-tryptophan by enzymes, protects plants against difficult conditions. People have consumed these plants for their antioxidant, immunomodulator, antiinflammatory and anticancer effects. In parts of edible and non-edible plants, levels of melatonin are determined by cyclodextrin-modified micellar electrokinetic chromatography, enzyme-linked immuno sorbent assay, radioimmunoassay, high-performance liquid chromatography, liquid chromatography with electrochemical detection, liquid chromatography with fluorimetric detection, liquid chromatography-mass spectrometry, and liquid chromatography-ultraviolet spectrophotometry. In this review, biosynthesis of melatonin in both animal and plants, function of melatonin in plant kingdom, especially in medicinal/edible and nonedible plants, and detection of phytomelatonin content in those plants are presented.

Key words: Melatonin, phytomelatonin, activity of melatonin

INTRODUCTION

Melatonin (N-acetyl-5-methoxytryptamine) means melanophore-contracting hormone (Greek: µαύρος=black; τάσης=tension) firstly was isolated from bovine’s pineal gland in 1958.12 It is a neurohormone secreted by the pineal gland and a derivative of serotonin.3 Serotonin is a monoamine neurotransmitter and one of the precursors (Figure 1), whereas L-tryptophan, like serotonin is the common precursor of melatonin biosynthesis.4,5 Both have many influences on health of animal and human being, such as serotonin is used against depression6 and also affects behaviours and inward.7 Secretion of melatonin increases in the dark on the contrary of light, seasonal and physiological alteration effect levels of melatonin8,9 for that reason that has been studied for its hormone like effects and its biological activities for decades.

Although melatonin was described in organisms such as bacteria, fungi, algae, and vertebrates10 it was notified in plants at the end of 1994.11,12 Increasing number of studies have proved that there was melatonin in different parts (seed, fruit, leaf, root etc.) of plants and in so much as medicinal herbs.13 A major role of melatonin in plants have been discovered that protects plants against damages of changing climate.14

Biosynthesis of melatonin

Melatonin is synthesised not only in bone marrow cells but also in retina.15,16 Thus it is both a hormone and tissue factor.15 The presence of melatonin was detected in egg, biological fluids like plasma, milk, by developed methods, such as liquid chromatography (LC) with fluorimetric detection, and LC-tandem mass spectrometry (LC-MS/MS).17-19 Biosynthesis of melatonin is explained enzymatically from the essential amino acid precursor tryptophan to melatonin. The synthesis includes four different enzymes. The first one is tryptophan hydroxylase (TPH), which forms 5-hydroxytryptophan from tryptophan; the second is aromatic amino acid decarboxylase which forms

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Received: 17.03.2016, Accepted: 09.06.2016
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serotonin from 5-hydroxytryptophan; the third is arylalkylamine N-acetyl-transferase (AANAT), which forms N-acetylserotonin from serotonin; and the last one is N-acetylserotonin O-methyltransferase (ASMT), which forms the final step to melatonin (Figure 2). AANAT and ASMT is considered that they were speed limiting enzymes.4,20

Biological activity of melatonin

A major role of melatonin is the antioxidant function with free radicals (reactive oxygen species) and reactive nitrogen species scavenging activity21-25 thus has protective effect against ultraviolet (UV) radiations induced damages.26 Consequently, melatonin can be used for healing of muscle diseases, Parkinson and Alzheimer’s due to antioxidant and neuroprotective affects.27-31 Melatonin is widely used for sleep disorders such as jetlag and insomnia.32 Its administration can relieve daytime and overnight sleep.33,34 Clinical and in vivo studies showed that melatonin decreased symptoms of depression35-37 moreover has immunomodulator function.38,39 An in vivo study showed that melatonin have potential anticonvulsant activity.43 Melatonin effects vascular system.44 Studies showed that melatonin suppress proliferation of cancer cell line and induces apoptosis tumor cell and also it is promising for the treatment of prostat cancer, and breast cancers.25,45-53 A study has also emitted that melatonin can be effective on malaria.54

Melatonin in plants-phytomelatonin

First evidence of the presence of melatonin in organisms was obtained in Lingulodinium polyedrum (syn. Gonyaulax polyedra) and Pyrocystis acuta, which were unicellular organisms. Scientists detected melatonin metabolite 5-methoxytryptamine and the melatonin analogue N,N-dimethyl-5-methoxytryptamine in those living organisms.55-57 By following studies melatonin was determined in the members of alga, bacteria, fungi, plant families. Level of melatonin, although differs from plant to plant, that was observed higher than level of melatonin in animal blood.58-60 Melatonin level varies both from plant to plant and also tissues/organs of same plant, moreover, temperature, pH, effects of present metal ions’s, sensitivity of analytics and extraction methods cause these diversities. For example, melatonin of Datura metel L. (devil’s trumpet) differed from flowers and leaves. In addition, melatonin of Lycopersicon esculentum Mill. varied by region.11,61-64 Presence of melatonin in different plants were shown in Table 1.

Biosynthesis of phytomelatonin

Plant melatonin biosynthesis pathway firstly was determined owing to Hypericum perforatum L. (St John’s wort).4,59 Synthesis in plants is complicated on the contrary in animals (Figure 2). Initial enzyme is tryptophan decarboxylase (TDC) instead of TPH. TDC forms tryptamine from essential amino acid tryptophan. The last enzyme is ASMT (Figure 2).65,66 Plants take melatonin also by their roots apart from biosynthesis.67,68 Although its biosynthetic pathway and metabolic mechanisms are unclear, the presence of melatonin in plants is a wide concept.69

Functions of phytomelatonin

Melatonin has roles in plants similar to animals, that protects plants against extreme conditions such as temperature change, UV exposure, environmental pollution, toxins, drought oxidative and (a) biotic stress. Exogenous melatonin applied to Arabidopsis (thale cress) leaves has demostrated preservative potency against high salinity, cold and dryness, additionally plant has developed tolerance biotic and abiotic stresses.70 Corn embryo proteome was improved due to exogenous melatonin.71 Moreover, harmful effects of salt diminished by melatonin in faba bean.72 Conservation aspects of melatonin were studied in a variety of plants such as wheat, oat, barley, canary grass, tobacco, Chinese liquorice, soybean, cucumber, tomato.14,67,73-79 The studies also has shown that melatonin has regulatory role in growth of thale cress, specially growth of flowers and fruits.80 Reports, which investigated effect of exogenous melatonin on both tomato’s and maize’s seeds, have confirmed this case too.79,81 Melatonin plays an important role to maintain the vitality of the plants.82
| Family      | Latin name                      | Part               | Quantity | Method       | Ref. |
|------------|---------------------------------|--------------------|----------|--------------|------|
| Actinidiaceae | Actinidia chinensis Planch.      | Fruit              | 24       | RIA          | 61   |
| Amaranthaceae | Basella alba L.                 | Leaf               | 39       | RIA          | 61   |
| Amaryllidaceae | Allium cepa L.                 | Bulb               | 32       | RIA          | 61   |
| Amaryllidaceae | Allium fistulosum L.          | Bulb               | 86       | RIA          | 61   |
| Anacardiaceae | Pistacia lentiscus L.          | Leaf               | 581      | ELISA        | 96   |
| Anacardiaceae | Pistacia lentiscus L.          | Whole fruit        | 536±129  | ELISA        | 96   |
| Anacardiaceae | Pistacia palaestina Boiss.     | Leaf               | 498      | ELISA        | 96   |
| Apiaceae     | Angelica keiskei Koidz.        | Leaf and stem of leaf | 624     | RIA          | 61   |
| Apiaceae     | Apium graveolens L.            | Seed               | 7        | HPLC-ECD     | 97   |
| Apiaceae     | Coriandrum sativum L.          | Seed               | 7        | HPLC-ECD     | 97   |
| Apiaceae     | Daucus carota L.               | Root               | 55       | RIA          | 61   |
| Apiaceae     | Foeniculum vulgare Mill.       | Seed               | 28       | HPLC-ECD     | 97   |
| Apiaceae     | Pimpinella anisum L.           | Seed               | 7        | HPLC-ECD     | 97   |
| Arecaceae    | Phoenix dactylifera L.         | Whole fruit        | 469      | ELISA        | 96   |
| Asparagaceae | Asparagus officinalis L.        | Shoot              | 10       | RIA          | 61   |
| Asparagaceae | Ophiopogon japonicus (L.f.) Ker Gawl. | Whole plant  | 198 | HPLC-FD-MS | 90 |
| Asteraceae   | Glebionis coronari (L.) Cass. ex Spach | Leaf       | 417      | RIA          | 61   |
| Asteraceae   | Dendranthera morifolium (Ramat.) Tzvelev | Whole plant  | 160 | HPLC-FD-MS | 90 |
| Asteraceae   | Helianthus annuus L.           | Seed               | 29       | HPLC-ECD     | 97   |
| Asteraceae   | Petasites japonicus F. Schmidt | Shoot              | 50       | RIA          | 61   |
| Asteraceae   | Silybum marianum (L.) Gaertn.  | Seed               | 2        | HPLC-ECD     | 97   |
| Araceae      | Colocasia esculenta (L.) Schott | Tuber              | 55       | RIA          | 61   |
| Araceae      | Peltandra virginica (L.) Raf. ex Schott | Whole plant  | 585 | HPLC-FD-MS | 90 |
| Brassicaceae | Arabidopsis spp.               | Leaf               | 548±26   | SPE, CD-ME-KC | 98 |
| Brassicaceae | Brassica campestris L.         | Leaf               | 657      | RIA          | 61   |
| Brassicaceae | Brassica hirta Moench         | Seed               | 189      | HPLC-ECD     | 97   |
| Brassicaceae | Brassica nigra (L.) W. D. J. Koch | Seed            | 129      | HPLC-ECD     | 97   |
| Brassicaceae | Brassica oleracea L.          | Leaf               | 107      | RIA          | 61   |
| Brassicaceae | Raphanus sativus L.           | Whole plant        | 485      | HPLC-FD-MS   | 90   |
| Brassicaceae | Raphanus sativus L.           | Root               | 113      | RIA          | 61   |
| Bromeliaceae | Ananas comosus (L.) Merr.     | Fruit              | 36       | RIA          | 61   |
| Caprifoliaceae | Lonicera etrusca hort. ex Tausch | Leaf       | 521      | ELISA        | 96   |
| Caprifoliaceae | Lonicera etrusca hort. ex Tausch | Seed           | 403      | ELISA        | 96   |
| Caprifoliaceae | Lonicera japonica Thunb.     | Whole plant        | 140      | HPLC-FD-MS   | 90   |
| Caprifoliaceae | Viburnum tinus L.            | Leaf               | 613      | ELISA        | 96   |
| Cucurbitaceae | Cucumis sativus L.            | Fruit              | 25       | RIA          | 61   |
| Ephedraceae  | Ephedra campylopoda C. A. Mey. | Leaf               | 178      | ELISA        | 96   |
| Ephedraceae  | Ephedra campylopoda C.A.Mey.  | Seed               | 379      | ELISA        | 96   |
| Fabaceae     | Glycyrrhiza uralensis Fisch. ex DC. | Whole plant  | 112     | HPLC-FD-MS   | 90   |
| Fabaceae     | Lupinus albus L.              | Seed (Cotyledone)  | 1.28±0.06 | HPLC-FD   | 99, 100 |
| Fabaceae     | Medicago sativa L.            | Seed               | 16       | HPLC-ECD     | 97   |
| Fabaceae     | Trigonella foenum-graceum L.  | Seed               | 43       | HPLC-ECD     | 97   |
| Juglandaceae | Juglans nigra L.              | Fruit              | 3.5±1.0  | HPLC-ECD     | 101  |
| Family       | Species                          | Part     | Melatonin Content | Method       | RIA       |
|--------------|----------------------------------|----------|-------------------|--------------|-----------|
| Lamiaceae    | *Salvia miltiorrhiza* Bunge       | Whole plant | 187               | HPLC-FD-MS   | 90        |
| Lauraceae    | *Laurus nobilis* L.              | Leaf     | 833               | ELISA        | 96        |
| Lauraceae    | *Laurus nobilis* L.              | Whole fruit | 3710              | ELISA        | 96        |
| Lauraceae    | *Laurus nobilis* L.              | Seed     | 6060              | ELISA        | 96        |
| Lauraceae    | *Laurus nobilis* L.              | Pulp     | 1820              | ELISA        | 96        |
| Liliaceae    | *Asparagus aphyllus* L.          | Leaf     | 142               | ELISA        | 96        |
| Liliaceae    | *Ruscus aculeatus* L.           | Leaf     | 954               | ELISA        | 96        |
| Liliaceae    | *Smilax aspera* L.               | Leaf     | 443               | ELISA        | 96        |
| Linaceae     | *Linum usitatissimum* L.         | Seed     | 12                | HPLC-ECD     | 97        |
| Meliaceae    | *Melia azedarach* L.             | Leaf     | 1579              | ELISA        | 96        |
| Meliaceae    | *Melia azedarach* L.             | Whole fruit | 585              | ELISA        | 96        |
| Moraceae     | *Morus alba* L.                  | Leaf     | 1510              | HPLC-FD-MS   | 90        |
| Moraceae     | *Morus spp.*                     | Leaf     | 990               | ELISA        | 96        |
| Moraceae     | *Ficus carica* L.                | Leaf     | 12,915            | ELISA        | 96        |
| Moraceae     | *Ficus carica* L.                | Whole fruit | 3963             | ELISA        | 96        |
| Myrtaceae    | *Feijoa sellowiana* (O. Berg) O. Berg | Leaf       | 1529              | ELISA        | 96        |
| Myrtaceae    | *Myrtus communis* L.             | Leaf     | 291               | ELISA        | 96        |
| Myrtaceae    | *Myrtus spp.*                    | Leaf     | 490               | ELISA        | 96        |
| Oleaceae     | *Olea europaea* L.               | Leaf     | 4306              | ELISA        | 96        |
| Oleaceae     | *Olea europaea* L.               | Pulp     | 532               | ELISA        | 96        |
| Oleaceae     | *Phillyrea latifolia* L.         | Leaf     | 6337              | ELISA        | 96        |
| Oleaceae     | *Phillyrea latifolia* L.         | Seed     | 439               | ELISA        | 96        |
| Oleaceae     | *Phillyrea latifolia* L.         | Pulp     | 589               | ELISA        | 96        |
| Papaveraceae | *Papaver somniferum* L.          | Seed     | 6                 | HPLC-ECD     | 97        |
| Poaceae      | *Avena sativa* L.                | Seed     | 1796              | RIA          | 61        |
| Poaceae      | *Avena sativa* L.                | Seed     | 90.6±7.7          | HPLC-ECD     | 102       |
| Poaceae      | *Hordeum vulgare* L.             | Seed     | 378               | RIA          | 61        |
| Poaceae      | *Hordeum vulgare* L.             | Seed     | 82.3±6.0          | HPLC-ECD     | 102       |
| Poaceae      | *Hordeum vulgare* L.             | Seed     | 0.09±0.01         | HPLC-FD      | 99        |
| Poaceae      | *Hordeum vulgare* L.             | Seed     | 0.58±0.05         | HPLC-FD      | 99        |
| Poaceae      | *Oryza sativa* L. subsp. japonica Shig. Kato | Seed       | 1006              | RIA          | 61        |
| Poaceae      | *Phalaris canariensis* L.        | Seed     | 26.7±2.2          | HPLC-ECD     | 102       |
| Poaceae      | *Triticum spp.*                  | Seed     | 124.7±14.9        | HPLC-ECD     | 102       |
| Poaceae      | *Triticum spp.*                  | Seed     | 2                 | HPLC-UV      | 102       |
| Poaceae      | *Triticum spp.*                  | Seed     | 4                 | HPLC-UV      | 102       |
| Poaceae      | *Zea mays* L.                    | Seed     | 1366              | RIA          | 61        |
| Poaceae      | *Zea mays* L.                    | Seed     | 0.011*10^-9-2.034*10^-9 | HPLC      | 103       |
| Resedaceae   | *Ochradenus baccatus* Delile     | Leaf     | 474               | ELISA        | 96        |
| Resedaceae   | *Ochradenus baccatus* Delile     | Whole fruit | 488              | ELISA        | 96        |
| Rhamnaceae   | *Rhamnus alaternus* L.           | Leaf     | 306±75            | ELISA        | 96        |
| Rhamnaceae   | *Rhamnus palaestina* Boiss.      | Whole fruit | 907              | ELISA        | 96        |
| Rhamnaceae   | *Rhamnus palaestina* Boiss.      | Seed     | 547               | ELISA        | 96        |
| Table 1. Continue |
|------------------|
| Rhamnaceae       | Rhamnus palustrina Boiss. | Pulp | 409 | ELISA | 96 |
| Rhamnaceae       | Ziziphus jujuba Lam.      | Whole plant | 146 | HPLC-FD-MS | 90 |
| Rhamnaceae       | Ziziphus jujuba Mill. var. spinosa (Bunge) Hu ex H. F. Chou | Whole plant | 256 | HPLC-FD-MS | 90 |
| Rhamnaceae       | Ziziphus spina-christi (L.) Wild. | Leaf | 1324 | ELISA | 96 |
| Rosaceae         | Crataegus aronia (Wild.) Bosc | Leaf | 341 | ELISA | 96 |
| Rosaceae         | Crataegus azarolus L.     | Leaf | 435 | ELISA | 96 |
| Rosaceae         | Fragaria magna Thuill.    | Fruit | 12 | RIA | 61 |
| Rosaceae         | Malus domestica Borkh.    | Fruit | 48 | RIA | 61 |
| Rosaceae         | Prunus amygdalus Stokes   | Seed | 39 | HPLC-ECD | 97 |
| Rosaceae         | Prunus avium L.           | Fruit (harvested around middle May-'Burlat') | 0.224±0.012 | HPLC-MS | 104 |
| Rosaceae         | Prunus avium L.           | Fruit (harvested 6 days after 'Burlat') | 0.027±0.024 | HPLC-MS | 104 |
| Rosaceae         | Prunus avium L.           | Fruit (harvested 31 days after 'Burlat') | 0.006±0.007 | HPLC-MS | 104 |
| Rosaceae         | Prunus avium L.           | Fruit (harvested 33 days after 'Burlat') | 0.06±0.02 | HPLC-MS | 104 |
| Rosaceae         | Prunus avium L.           | Fruit (harvested 37 days after 'Burlat') | 0.115±0.033 | HPLC-MS | 104 |
| Rosaceae         | Prunus avium L.           | Fruit (harvested 44 days after 'Burlat') | 0.048±0.022 | HPLC-MS | 104 |
| Rosaceae         | Prunus cerasus L.          | Fruit | 1.07±0.35-2.18±0.26 | HPLC-ECD | 105 |
| Rosaceae         | Prunus cerasus L.          | Fruit | 5.57±0.38-19.59±2.76 | HPLC-ECD | 105 |
| Rosaceae         | Prunus cerasus L.          | Fruit (Montmorency frozen) | 12.3±2 | HPLC-MS | 106 |
| Rosaceae         | Prunus cerasus L.          | Fruit (Balaton frozen) | 2.9±0.6 | HPLC-MS | 106 |
| Rosaceae         | Prunus cerasus L.          | Fruit (Balaton individually quick frozen powder) | 1.7±0.5 | HPLC-MS | 106 |
| Rosaceae         | Prunus cerasus L.          | Fruit (Montmorency individually quick frozen powder) | 7.5±0.9 | HPLC-MS | 106 |
| Rosaceae         | Rubus idaeus L.            | Whole plant | 387 | HPLC-FD-MS | 90 |
| Rosaceae         | Rubus sanctus Schrebl.     | Leaf | 805 | ELISA | 96 |
| Rubiaceae        | Rubia tenuifolia d’Urv.    | Leaf | 905 | ELISA | 96 |
| Rubiaceae        | Rubia tenuifolia d’Urv.    | Whole fruit | 339 | ELISA | 96 |
| Rubiaceae        | Rubia tenuifolia d’Urv.    | Seed | 539 | ELISA | 96 |
| Santalaceae      | Osyris alba L.             | Leaf | 844 | ELISA | 96 |
| Schisandraceae   | Schisandra chinensis (Turcz.) K. Koch | Whole plant | 86 | HPLC-FD-MS | 90 |
| Scrophulariaceae | Scrophularia nodosa L.      | Whole plant | 342 | HPLC-FD-MS | 90 |
| Solanaceae       | Lycium barbarum L.         | Seed | 103 | HPLC-ECD | 97 |
Phytomelatonin in diets

The most popular drinks, which are tea, coffee, beer and wine contain melatonin. Not only melatonin but also its isomers (tryptophan-ethylester) were determined in wine and bread. A study reported that regular coffee consumption remarkably decreases the prevalence of human prostate cancer. Scientists introduced that melatonin in wine besides the other secondary metabolites, had protective effect against heart injury. Melatonin was determined high amount in Chinese medicinal herbs. Some of them were Viola philippica Cav., Uncaria rhynchophylla Miq., Morus alba L. and Phellodendron amurense Rupr. In Mediterranean diet, melatonin was found in some foods. It’s thought that melatonin can have positive effects on health via synergic effects with other compounds. Dietary supplement/melatonin supplement preparations have been consumed for different purposes by people mostly in Europe and the United States than the other countries.

Determination of phytomelatonin levels in plants

Melatonin has been detected in fruits, leaves, roots, and seeds of a considerable variety of plant species. Various methods, such as cyclodextrin-modified micellar electrokinetic chromatography, enzyme-linked immunosorbent assay, radioimmunoassay (RIA), high-performance LC (HPLC), HPLC-electrochemical detection, HPLC-fluorescence detector, HPLC-MS and HPLC-UV spectrophotometry (UV) can be applied in order to determine melatonin levels in plants. The first step in determining the levels of melatonin in plants is to find the right extraction method, which have been tried by different authors. The first identification method of melatonin in plants was described by Van Tassel et al. in a congress communication in 1993. The authors had detected melatonin in tomato fruits (Solanum lycopersicum L.) by using RIA and gas chromatography attached with MS, but the results were not published extensively until 1995.

Nowadays, most of the researchers have been utilizing liquid nitrogen treated-plant tissue, which were extracted with organic solvents such as methanol, chloroform, or ethyl acetate. Analysis of these extracts by LC and identification by MS are the most used and recommended techniques for the detection and quantification of melatonin in plants. Due to the developed technology of LC coupled to time-of-flight/MS has also been applied for the melatonin detection in recent years.

Biotechnology

A biotechnologic study showed that transgenic plant rich on account of melatonin had more antioxidative activity and higer yield than regular plants. When activity of ASMT enzyme-catalyzed from N-acetylserotonin to melatonin and isolated firstly from rice in plants- was increased by overexpression, the level of melatonin has also increased. A study demonstrated that since 6-hydroxymelatonin was not determined in rice, melatonin 2-hydroxylase has been dominant enzyme in melatonin production.

CONCLUSION

Melatonin has been studied to treat some symptoms and diseases in human over the years. Melatonin supplements have proven significant results for treating insomnia and other circadian rhythms caused sleep disorders, moreover, jet lag and shift work, headache, various cancers, gallbladder stones, tinnitus, rheumatoid arthritis, Alzheimer’s disease, and psychiatric disorders have also tried to be eased with melatonin. Besides, it is known that melatonin is a powerful antioxidant and it improves the immune system. According to recent research, melatonin has also a great anti-aging effect.

Melatonin is a hormone that naturally produced by pineal glad in human brain especially at night-time, however, smoking, using

Table 1. Continue

| Family     | Genus                  | Part of plant | Melatonin level | Method/Technology |
|------------|------------------------|---------------|-----------------|-------------------|
| Solanaceae | Lycium barbarum L.     | Whole plant   | 530             | HPLC-FD-MS 90     |
| Solanaceae | Lycopersicon esculentum Mill. | Fruit | 32              | RIA 61           |
| Solanaceae | Solanum elaeagnifolium Cav. | Whole fruit  | 7895            | ELISA 96         |
| Solanaceae | Solanum elaeagnifolium Cav. | Seed         | 5604            | ELISA 96         |
| Solanaceae | Solanum elaeagnifolium Cav. | Pulp         | 7392            | ELISA 96         |
| Solanaceae | Solanum nigrum L.      | Whole fruit   | 323±46          | ELISA 96         |
| Styrraceae | Styrax officinalis L.   | Leaf          | 4069            | ELISA 96         |
| Theaceae   | Camellia sinensis (L.) Kuntze | Leaf | 386±21          | CD-MEKC 98       |
| Tiliaceae  | Tilia cordata L.        | Leaf          | 410±16          | CD-MEKC 98       |
| Verbenaceae| Lantana camara L.       | Leaf          | 389             | ELISA 96         |
| Xanthorrhoeaceae| Aloe vera (L.) Burm. f. | Whole plant  | 516             | HPLC-FD-MS 90    |
| Zingiberaceae| Elettaria cardamomum Maton | Seed         | 15              | HPLC-ECD 97      |
| Zingiberaceae| Zingiber officinale Roscoe | Rhizome    | 584             | RIA 61           |

RIA: Radioimmunoassay, ELISA: Enzyme linked immunosorbent assay, HPLC: High performance liquid chromatography, ECD: Electrochemical detection, FD: Fluorescence detector, MS: Mass spectrometry, SPE: Solid phase extraction, CD: Cyclodextrin, MEKC: Micellar electrokinetic chromatography, UV: Ultraviolet
alcohol, excessive coffee consumption, some medications and disorders can suppress the production of the melatonin. Therefore melatonin should be taken externally such as synthetic melatonin supplements, or from natural resources which produce or contain melatonin. Furthermore, taking nutrients, which contain tryptophan, can increase the secretion of melatonin in the body. For instance, eating strawberries, apples, cherry/juice, rice, pistachios, almonds, spinach, cabbage, onions, tomatoes, cucumber, linsedee and sunflower seeds, thistle, fenugreek and mustard; drinking teas such as fennel and anise tea.

In this study, our aim was to bring attention to melatonin in plants, which has important roles in plants as well as in animals. Many scientists have laboured to identify and quantify the levels of melatonin in plants. Although there are numbers of studies were completed in plants still more studies have been needed to analyse the levels and their absorption and efficiency of melatonin directly from plants, teas and pharmaceutical preparations.

Conflict of Interest: No conflict of interest was declared by the authors.

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