




Importance of Melatonin on Poultry

Süleyman ÇALIŞLAR¹ , Beyhan YETER¹ , Ahmet ŞAHİN² 

¹Kahramanmaraş Sütçü İmam Üniversitesi Ziraat Fakültesi Zootekni Bölümü Kahramanmaraş, ²Ahi Evran Üniversitesi Ziraat Fakültesi Zootekni Bölümü Kırşehir

ABSTRACT

Intensive production practices, faulty maintenance and feeding, unsuitable keeping conditions, antinutritional factors in feeds and similar abnormalities lead to irregularities in both hormone and enzyme systems in poultry. Especially, due to disorders in endocrine system, a specific hormone, melatonin, can not be produced or underproduced, and thus its metabolic and physiological functions are negatively affected in the organisms.

Melatonin (ML) is one of the important hormones that prevent metabolic and physiological disorders in poultry but does not attract attention by poultry scientist. ML regulates the brain's biological clock, acts on respiration, circulation, excretion, reproduction and immunity system. ML helps regulate feed consumption, energy metabolism and body heat. It also provides elimination of free radicals in the body. ML stimulates growth hormone secretion and, thus, effects growth performance of poultry positively.

It is considered necessary to focus more effectively on the melatonin hormone, which is a positive contribution to animal welfare by correcting metabolic-physiological disorders in poultry. In this review, the definition of melatonin, its interaction with other hormones, its effect on the physiological and metabolic functions of poultry were examined.

DOI:10.18016/ksutarimdog.vi.433039

Article History

Received : 11.06.2018

Accepted : 16.07.2018

Keywords

Melatonin,
poultry,
physiological,
metabolic,
animal welfare

Review Article

Melatonin'in Kanatlı Hayvanlarda Önemi

ÖZET

Yoğun üretim uygulamaları, hatalı bakım ve besleme, uygun olmayan barındırma koşulları, yemlerde antibesinsel maddelerin bulunması ve buna benzer anormallikler kanatlı hayvanlarının hem hormon hem de enzim sistemlerinde düzensizliklere yol açmaktadır. Özellikle endokrin sistem ile ilgili anormallikler yüzünden spesifik bir hormon olan melatonin üretilmediğinden ya da yetersiz üretildiğinden organizmada metabolik ve fizyolojik fonksiyonlar olumsuz etkilenmektedir.

Melatonin (ML), kanatlı hayvanlarda metabolik ve fizyolojik düzensizlikleri önleyen ancak dikkat çekmeyen önemli hormonlardan birisidir. ML, beynin biyolojik saatini ayarlar, solunum, dolaşım, boşaltım, üreme ve bağışıklık sistemi üzerinde etkili olur. ML, yem tüketimini, enerji metabolizmasını, vücut ısısını düzenler ve vücutta serbest radikallerin yok edilmesine yardım eder. ML, büyüme hormonu salgılanımını uyararak büyüme performansını olumlu etkiler.

Kanatlı hayvanlarda metabolik-fizyolojik bozuklukların düzeltilmesini sağlayan ve hayvan refahına olumlu katkıda bulunan ML hormonu üzerine daha etkili şekilde odaklanmanın gerekli olduğu düşünülmektedir. Bu derlemede, melatonin'in tanıtımı, diğer hormonlarla interaktif ilişkileri, kanatlı hayvanlarının fizyolojik ve metabolik fonksiyonları üzerindeki etkisi incelenmiştir.

Makale Tarihiçesi

Geliş Tarihi : 11.06.2018

Kabul Tarihi : 16.07.2018

Anahtar Kelimeler

Melatonin,
kanatlı,
fizyolojik,
metabolik,
hayvan refahı

Derleme Makale

INTRODUCTION

Birds are diurnal animals when offered light they consume feed. In poultry production, broiler chicks are subjected to 23-24 h continuous lighting while egg type chickens are subjected 14-16 h lighting during all day. These conditions are different than their ancestors in natural ecological condition in which their activities were based on day time lighting, i.e., sunlight. By domestication or intensive production, birds' hormonal system has been under control, causing that they become more sensitive to environmental changes such as temperature, humidity, crowding, dust, etc. Under poorly conditions, free radicals are generated in the body in such a large quantity for the natural antioxidant defence systems of the body. Also, this condition causes some changes in metabolism and increases oxidative damage to cells and decrease in feed intake, live weight, egg production, feed conversion ratio and egg quality traits. In addition, this has been led to some zotechnical problem in poultry house such as sudden death syndrome, alertness to poultry keeper, stress and other illness, causing economical losses in poultry production. If we would offer chickens a sufficient time of darkness, they could produce their own melatonin from their pineal gland to behave naturally, yet this has been not happened.

It is thought that melatonin plays an important role in the neuroendocrine control of some metabolic and physiological actions, sexual maturation, reproductive function and modulate efficiency of nutrient utilisation of poultry. In addition, poultry studies appear that body temperature, physiological actions and seasonal rhythms may affect by melatonin.

Therefore, in this review, melatonin was deeply investigated by literature work to explore its detailed effects on birds in order to produce some suggestions on behalf of poultry welfare.

Circadian rhythm in poultry

Birds have quite complicated behavior and impressive gripping skills (Taylor et al., 2007; Grodzinski and Clayton, 2010) exhibiting biochemical, physiological and behavioral activities specific to their nature in relation to daily and seasonal process (Cassone and Westneat, 2012). For this reason, to observe biological time is very important in poultry production (Cassone, 2014). Behaviors and capabilities are modulated by circadian biological clocks in birds (Cassone and Westneat, 2012).

The circadian rhythm in bird is highly synchronized pineal gland, retina and hypothalamus. ML secretion from pineal gland in the dark is reflection or working sign of circadian rhythm (Stehle et al., 2003; Zawilska et al., 2006; Trivedi and Kumar, 2014). The pineal gland has a complementary role in the regulation of

the rhythmic function of endocrine system (Csernus and Mess, 2003) which controls the circadian patterns of ML biosynthesis and photo-receptors (Natesan et al., 2002). In poultry, circadian behavior is performed by epiphyseal ML (Mishra and Kumar, 2016).

ML provides the frequency of one or more oscillators or the coupling between different oscillators. For this reason, any change in ML profile causes changes in circadian system functions (Kumar et al., 2004).

In birds, the circadian rhythm is controlled by the master clock located in the hypothalamic suprachiasmatic nuclei (SCN) in front of the hypothalamus (Brandstatter and Abraham, 2003). Circadian rhythm shows similarities between all bird species, but it is not true to generalize it for all (Cassone et al., 2017). It was reported that the exogenous ML administration inhibited the metabolic activity of SCN in chickens (Cantwell and Cassone, 2002), but the effect of ML on gene expression of the mSCN clock in quail was minimal (Yasuo et al., 2002).

Melatonin secretion in birds

Birds have a pineal gland that varies in size, shape and localization (Przybylska-Gornowicz et al., 2005; Prusik et al., 2006; Prusik et al., 2015). In the pineal gland, ML, which can be modulated by light, darkness and temperature changes, is produced (Pang et al., 1996). However, ML secretion may, be influenced by additional factors. Heat induced by high ambient temperature and high relative humidity during hot dry season causes heat stress in birds. (Sinkalu et al., 2010). Animal studies have shown that melatonin has a thermoregulatory role. Furthermore, ML has a crucial role in circadian thermoregulatory adjustments of body temperature (Saarela and Reiter, 1994).

ML is a neurogenic hormone synthesized in the dark in the epiphysis and in the light in retina (Ambriz-Tututi et al., 2009). Approximately 80% of ML in the bloodstream is produced by the epiphysis (Şener, 2010). It is also secreted from the skin, testes, bone marrow, thrombocytes, lymphocytes and the gastrointestinal tract (Bubenik, 2002). The chemical events that occur in the 24-hour cycle in organism, hormone production and metabolism are regulated by circadian oscillators in the epiphysis (Csernus, 2006). Approximately, 80% of ML in the bloodstream is secreted by the epiphyseal gland (Şener, 2010). ML participates in many physiological processes in the organism (Lamosova et al., 1997) that are rapidly transported to other organs through blood and spinal fluid and can easily pass through biological membranes due to its lipophilic nature. Excess ML is inactivated by hydroxylation in the liver (Lazar et al., 2015) and is excreted in urine (Reppert, 1997). There is a multi-synaptic nerve pathway that connects the pineal gland to the out environment via the retina. ML

production is stimulated in dark periods and is inhibited in the light (Timothy and Birdsall, 1996, Barrenetxe et al., 2004). ML receptors in poultry are not found only in different central nervous systems associated with sensory functions (Cassone et al., 1995), but also in many peripheral organs such as the lung (Pang et al., 1993), spleen (Yu et al., 1991) and gastrointestinal tract (Lee and Pang, 1992).

The physiology of melatonin

ML plays a vital role in regulating neural and endocrine processes that are synchronized with daily changes in light (Lazar et al., 2015). Serum ML concentrations reflect environmental lighting conditions and allow information to be transmitted to the entire organism (Zeman et al., 2001). The circadian rhythm is controlled by light-sensitive ML (Liu et al., 2011; Singh et al., 2012) as reproduction, excretion, blood pressure, immunity, thermoregulation, neuroendocrine and physiological systems, sleep regime, work of such organs heart and lung (Pang et al., 1996; Apeldoorn et al., 1999; Ambriz-Tututi et al., 2009; Schwan-Lardner et al., 2013).

While the ML produced in the pineal gland is secreted in response to darkness, the ML produced by the enterochromaffin cells of the gastrointestinal tract is secreted, in particular in response to the feeding (Bubenik, 2002).

ML stimulates lymphocyte production and antibody formation (Zheng et al., 2013) to improve immunity. It helps remove free radicals from the body (Bubenik, 2001; Zheng et al., 2013) with its antioxidant effect (Ahmed et al., 2005).

The production of ML in poultry is controlled by three main mechanisms: direct light reception, endogenous generator and noradrenergic transmission (Prusik et al., 2015). There are 3 ML receptor subtypes in chickens; Mel1A, Mel1B and Mel1C. Each of these receptors has different affinities for ML. ML receptor subtypes are found at different concentrations and quantities in different parts of the body. Mel1A and Mel1B receptors are found in organs such as the heart, retina, epiphysis, liver and lung. Mel1A is present in the retina of chickens, while Mel1A and Mel1B, Mel1A, Mel1B and Mel1C are in the ovary. Mel1C in the crustacean affects the crustal thickness of the egg. ML receptors in quail egg white are part of the antioxidant system, preventing embryonic oxidative stress during development.

The application of darkness has a positive effect on ML production (Lessons and Summers, 2005). A 4.5 h lighting after 10 h dark period, the serum ML level reached its highest level in chicks (Pablos et al., 1998). There was an 85% decrease in serum ML level of pigeons exposed to light for 80 minutes (Vakkuri et al., 1985). 16 hours light: 8 hours dark or 20 hours light: 4 hours dark; serum ML concentrations of egg hens

varied between 40-100 pg / mL in the light and 150-390 pg / mL in the dark (Liou et al., 1987). Abnormal serum levels of ML may be indicative of metabolic and other disorders (Lazar et al., 2015). It has been reported that pinealectomized chickens decreased production of ML (Wang et al., 1998). They applied pinealectomy at 2-d old. After 8 weeks, the amount of serum ML in the control group was 23.19 pg / mL, but in pinealectomy groups, the serum ML level decreased to 9.17 pg/mL. Pinealectomy caused 58% scoliosis in chickens (Turgut et al., 2003).

In poultry, the synthesis of ML is controlled by genes that produce molecular oscillations under the influence of the negative feedback mechanism (Okano and Fukada 2003, Csernus et al., 2005; Turkowska et al., 2014).

ML has the ability to convert environmental information into appropriate endocrine signals. For this reason, ML allows the physiology, metabolism and behavior of animals to be synchronized with optimum environmental conditions. ML, synchronized with light changes, plays an essential role in the regulation of neuroendocrine processes (Lazar et al., 2015) and in the biology of all cells (Reiter and Robinson, 1995). ML affects growth and health status (Clark and Classen 1995), the concentrations of other hormones in poultry (Zeman et al., 1993). ML and brain SR metabolism are interrelated. For this reason, some of the physiological effects generated by ML are mediated by the modulation of central serotonergic transmission. ML causes an increase in the SR amount of chickens (Zeman et al., 1999).

The central adrenergic pathway present in poultry is involved in the regulation of GH (Harvey et al., 1991) and is modulated by ML. In the regulation of growth, the role of ML emerges through interactions with other hormones. Progesterone administration reduced ML biosynthesis and release, but testosterone injection accelerated ML production (Vacas and Cardinali, 1979). Progesterone production was stimulated by LH and markedly decreased by the effect of ML (Lewis et al., 2006). ML also reduced ovarian activity as it inhibited LH secretion (Rozenboim et al., 2002). ML treatment reduces plasma progesterone and estrogen levels, showing its effect on ovarian function (Guchhait and Haldar, 2000). Testosterone, estrogen and deoxycorticosterone stimulate ML synthesis, but progesterone and corticosterone inhibit ML synthesis (Mahata and Mahata, 1992). ML generally inhibits the production thyroid hormones (Lewinski, 2002, Mogulkoc and Baltaci, 2003). High doses of ML inhibited the response of the thyroid stimulating hormone (Wright et al., 1997). ML directly or indirectly increases the plasma concentration of leptin hormone (Mustonen et al. 2000), elevating serum thyroxine (T4) level (Legradi et al., 1997).

Dietary ML supplementation lowered plasma corticosterone concentrations in chickens (Hassanzadeh et al., 2016) while it has an inhibitory effect on the secretion of luteinizing hormone (LH), FSH, adreno corticotropic hormone (ACTH), prolactin and b-endorphin (Csernus and Mess, 2003). This was evidenced that ML treatment (5, 20 and 80 mg/kg) decreased LH secretion in the castrated leghorn roosters by drop reduction occurred in 10 minutes after ML injection (Rozenboim et al., 2002).

ML regulates bone physiology (Witt-Enderby et al., 2012). In addition, ML plays an important role in the formation of bone by osteoblasts by increasing type I collagen production and osteoblastic proliferation (Nakade et al., 1999). The addition of ML inhibits the natural destruction of the bone by causing an increase in mineral content. Femur and tibia bones have higher fracture strengths in chickens treated with ML.

In birds, ML influences the absorption of calcium in the duodenum (Sjöblom et al., 2003). It has been reported that the lack of ML is partly responsible for malformations in the bones and the rate of bone disease is reduced by ML treatment (Machida et al., 1995). The ML receptor in the eggshell gland (Natesan and Cassone, 2002; Sazanov et al., 2007) limits the storage of calcium in the egg shell and its transport into the shell gland epithelium.

The effects of melatonin on performance and health

ML improves feed utilization (Clark and Classen, 1995) by stimulating growth hormone in poultry (Zeman et al., 1999), regulating thermoregulatory mechanisms (Rozenboim et al., 1998; Sahin et al., 2004) and energy metabolism (Apeldoorn et al., 1999). ML administration increased weight gain and energy retention by an average of 19% in male broiler chickens (Osei et al., 1989).

ML improves performance in poultry by stimulating uptake of lipids, proteins and carbohydrates into tissues (Ahmed et al., 2006) and preventing heat stress and salmonella enteritidis infection in chickens (Hassanzadeh et al., 2016; Woodward et al., 2005; Nisbet et al., 2008). ML application compensated egg shell and skeletal defects in chickens (Taylor et al., 2013; Machida et al., 1995).

ML given with drinking water changed the behavior of quails and increased the amount of certain peripheral hormones, especially GH. The stimulation level of GH was 140% when ML was administered alone, whereas the level of GH stimulation was 285% when ML was administered with quipazinin (Zeman et al., 1999). The increased GH concentration by ML stimulation leads to a decrease in abdominal fat in quails (Zeman et al., 1993).

When ML supplementations were given at doses of 10 mg, 20 mg and 30 mg per bird, the optimal ML dose on

egg yield and quality was reported to be 10 mg. The use of ML at a dose of 30 mg per bird adversely affected egg yield and quality (Jia et al., 2016).

Egg weights of chickens treated with ML were significantly higher than those without ML (Taylor et al., 2013). ML is required for early bone growth (Fagan et al., 2009).

ML administration-controlled calcium distribution between the bone and egg shells in chickens by strengthening bone but weakening egg shell (Taylor et al., 2013). However, ML addition (2 mg / kg body weight) also increased egg weight and shell thickness (Archana, 2012). Song birds practiced in ML produced more eggs (Grieves et al., 2012). ML has increased the absorption of zinc (Mocchegiani et al., 1996; Fabris et al., 1997). ML administration is beneficial for bone strengthening in poultry but decreases egg shell strength. This should be taken into account when applying ML to laying poultry.

Depending on intensive breeding conditions and heat stress, deteriorating of the feed efficiency, leg problems, ascites, sudden death syndrome and similar disadvantages occur (Hassanzadeh et al., 2016). Changes in plasma corticosterone levels are an important indicator of the exposure of the poultry to stress. High temperature increases plasma corticosterone levels in pigeons (Barriga et al., 2002). ML can be used in controlling temperature stress (Siegel, 1995) since epiphyseal gland and its metabolites play an important role in the circadian thermoregulation in many animal species (Reiter, 1995). ML administration inhibits the production of ACTH in poultry by performing a hypothalamic-pituitary adrenal axis inhibitory role, showing that ML is effective to control stress at both central and environmental levels (Rasmussen et al., 2003).

ML application decreased feed intake and heat production due to decrease locomotor activity in broiler chickens (Zeman et al., 2001; Brennan et al., 2002), improving feed utilization (Clark and Classen, 1995; Apeldoorn et al., 1999). The fact that ML causes decrease in body basal heat is attributed to its hypothermic effect (George, 1999).

Environmental changes affect the activities of the pineal gland in poultry (Sudhakumari and Haldar, 2001). Quails exposed to cold produced the less amount of ML in epiphysis and retina (Lee et al., 1990). For this reason, poultry require ML supplementation when they are kept on outside. ML application reduced mortality in fast growing and acute heat stressed quails (Hassanzadeh et al., 2016) by restoring their mineral status such as N, Ca, P, Zn, Fe and Cr excretion, and, consequently, healing them against depression associated with heat stress (Sahin et al., 2004).

Environmental rhythms, chemical, biological or behavioral functions that occur in the 24-hour cycle play an important role in the welfare of poultry. ML provides a significant contribution to the welfare of poultry by controlling biological rhythm. Sudden death syndrome, ascites and some skeletal imperfections occur due to daily rhythm impairment.

In quail, ML given to drinking quail alters lipid and protein metabolism (Zeman et al., 1999). ML has significant role in reproductive function in many animal species by managing biological rhythms (Maestroni, 2001) but has little effect on the reproduction of poultry (Rozenboim et al., 2002). After incubation in poultry, light stimulation and ML are effective on the designed of reproduction. ML plays important roles in the photoperiod-related circadian rhythm, embryonic growth and ovary development by altering the synthesis and secretion of follicle-stimulating hormone (FSH) with LH (Chuffa et al., 2011).

ML helps the immune responses in poultry (Moore and Siopes, 2003) by increasing lymphocytes proliferation (Kliger et al., 2000) and antibody formation (Zheng et al., 2013). ML treatment increased the activity of B and T lymphocytes (Brennan et al., 2002) and total leukocyte count and lymphocyte percentage in poultry (Abozahra et al., 1998; Brennan et al., 2002; Hodallah et al., 2011). ML affects bone marrow (Taylor et al., 2013), accelerates leukocyte production (Conti et al., 1992) and protects bone marrow from free radical damage due to antioxidant effect (Ahmed et al., 2005). It also increases the number of leukocytes by decreasing the amount of corticosterone hormone (Anwar et al., 1998). A 50 µg / ml melatonin in drinking water increased total white blood cells and percentages of lymphocytes and heterophiles but decreased the proportion of heterophiles / lymphocytes (H / L) in the quail (Moore and Siopes, 2000).

ML application caused lymphoid hyperplasia in bursa fabricus, spleen and liver in broiler chickens. In poultry, ML receptors in the primer and the secondary lymphoid system were reported by Poon et al. (1994) and its binding sites of ML on thymus, spleen, bursa fabricus indicated that it has a physiological role in lymphocyte regulation (Yu et al., 1991). In chickens, the target organ of ML is bursa fabricus (Lee and Pang, 1992) as evidenced that ML administration increased bursal weight, accelerating the development of humoral immune response and cell communication in the turkeys (Moore and Siopes, 2003). Thymus and bursa fabricus are very important in the development

of immune system. For this reason, dark practice suggests that it may help chickens to be more resistant to diseases. Continuous light exposure negatively affects poultry welfare, as poultry causes significant decreases in serum ML levels (Zheng et al., 2013).

As having high antioxidant potential, ML may be used to reduce the adverse effects of high temperature on quails (Sahin et al., 2004). ML repaired liver damage caused by heavy metals and prevented the accumulation of toxic materials (Ohta et al., 2000; Pal and Chatterjee, 2006). It has also been found that the antioxidant capacity of the liver is increased by dark application (Zheng et al., 2013).

Intensive feeding and management systems in poultry production cause metabolic disorders such as ascites and sudden death syndrome in broiler chickens (Bottje and Wideman 1995). ML reduced ascites and sudden death syndrome by slowing down metabolic rate and oxygen consumption in poultry (Clark and Classen 1995). On the other hand, a high intensity light application inhibited ML production (Mishra and Kumar, 2016), thus, causing an increase in the rate of sudden death syndrome (Clark and Classen 1995). Also, it was reported that dietary 10-40 mg ML/ kg greatly reduced hepatic vacuolar degeneration, necrosis and biliary hyperplasia, which were caused by aflatoxin in chicks (Özen et al., 2009).

Candidate plants for natural feed additives

Poultry feeds such as corn, wheat and barley usually contain low-level tryptophan (Takada and Otsuka, 2007). Tryptophan is required for the synthesis of ML (N-acetyl 5-methoxytryptamine) (El-Slamoney et al., 2010). ML is found in different parts of various plants (leaf, stem, root, flower, fruit, seed etc.). *Festuca arundinacea* is in the first order with 5288.1 pg / g, oat (*Avena sativa*) 1796.1 pg / g, and sweet maize (*Zea mays saccharata* Sturt.) with 1370 pg / g ML content (Hattori et al., 1995). In addition, walnuts, tomatoes, grapes, hazelnuts, strawberries, orange cherries, sour cherries such as cherries contain significant amounts of ML and serotonin (Paredes et al., 2009; Huang and Mazza, 2011). It is thought that the nutrient to be fed with ML-rich foods (Table 1) will positively affect the metabolic and physiological functions of poultry. These information encouraged poultry scientist to compensated commercial birds' poor welfare caused by intense and long-term lighting, by dietary addition of ML by using foods given in Table 1 without causing destruction of ML with food processing.

Table 1. Amounts of melatonin in plants

Name	MT Value or Range	Reference
Cereals and Legumes (raw)		
Corn (different varieties)	1.3-2034 ng/g DW	Hattori et al., 1995; Badria, 2002; Wang et al., 2009; Tan et
Wheat	124.7 ng/g FW	Hernandez-Ruiz et al., 2005
Barley	0.38- 82.3 ng/g FW	Badria, 2002, Hattori et al., 1995, Hernandez-Ruiz et al., 2005
Oats	1.80- 90.6 ng/g FW	Hattori et al., 1995; Hernandez-Ruiz et al., 2005; Hernandez-Ruiz and Arnao, 2008
Rice	0-264 ng/g DW	Wang et al., 2009
Lentil	0.07- 0.5 ng/g DW	Aguilera et al., 2015
Kidney beans	1.0 ng/g DW	Aguilera et al., 2015
Soybean	0.45 ng/g DW	Zielin et al., 2001
Lupin (seed-coat)	37.50 ng/g FW	Hernandez-Ruiz and Arnao, 2008
Strawberry	5.5- 11.26 ng/g FW	Sturtz et al., 2011
Cherry	0.05-20 ng/g FW	Gonzalez-Gomez et al., 2009; Zhao et al., 2013
Grape (skin)	8.9-158.9 ng/g DW	Boccalandro et al., 2011
Pistachio	226.9- 233.0 µg/g	Oladi et al., 2014
Onion	0.03- 0.30 ng/g FW	Badria, 2002; Hattori et al., 1995
Garlic	0.59 ng/g FW	Badria, 2002
Carrot	0.06- 0.49 ng/g FW	Badria, 2002; Hattori et al., 1995
Pepper	4.48 -11.9 ng/g FW	Riga et al., 2014
Tomato	0.03 -23.87 ng/g FW	Hattori et al., 1995; Sturtz et al., 2011; Wang et al., 2014
Sunflower	29 ng/g DW	Manchester et al., 2000; Reiter and Tan, 2002
Refined linseed oil	0.29 ng/g	Venegas et al., 2011
Soybean oil	0.19 ng/g	Venegas et al., 2011
Refined olive oil	0.03-0.08 ng/mL	De La Puerta et al., 2007; Venegas et al., 2011
Refined sunflower oil	0.05 ng/mL	De La Puerta et al., 2007

DW: dry weight, FW: fresh weight, ng: nano gram

CONCLUSION

Poultry can sometimes be exposed to stress conditions at different stages of their life. Stress conditions cause some irregularities in the hormone and enzyme system. These irregularities lead to significant metabolic and physiological dysfunctions in poultry. The methods applied in the correction of metabolic and physiological dysfunctions can sometimes be very expensive and sometimes do not give the desired result.

When medication is required in poultry animals and human health can be negatively affected. For this reason, it is very important to use non-side effects methods for eliminating possible metabolic and physiological disorders in poultry. Research has shown that ML, especially immunity, has positive effects on the health and overall performance of poultry. ML, used in combination with many viral infections, has increased the success rate of treatment. In the 21st

century, where organic animal production and animal welfare are priorities, the use of drugs (antibiotics, etc.) is limited every day. It is thought to be beneficial and necessary to focus more on ML in compensating for economic losses from poultry-specific metabolic and physiological abnormalities.

It is thought that there has been a need for more focus and new research on ML, which is very effective in preventing many metabolic-physiological disorders leading to significant economic losses in poultry industry and ensuring animal welfare.

REFERENCES

- Abozahra AA, El-sayed M, Elshazly KA, Saad MF 1998. The Influence of Melatonin on the Immune Response to IBD Vaccination in Broilers. *J. Zagazig Vet., Med. 4th Vet. Med. Zag. Congress*, 600-608s.
- Aguilera Y, Herrera T, Benitez V, Arribas SM, Lopez De Pablo AL, Esteban RM, Martin-Cabrejas MA

2015. Estimation of Scavenging Capacity of Melatonin and Other Antioxidants: Contribution and Evaluation in Germinated Seeds. *Food Chem.*, 170(1): 203-211.
- Ahmed HH, Essawy GS, Salem HA, Abdel Daim MA 2005. Melatonin has a Strong Antioxidant Activity and Improves Liver and Kidney Functions in Broiler Chicks. Egypt. *J. Basic and Appl. Physiol.*, 4(1): 77-92.
- Ahmed HH, Essawy GS, Salem HA, Abdel Daim MA 2006. Effect of Melatonin on Productive Performance and Some Biochemical Parameters in Broiler Chicks. *Egyptian Journal of Basic and Applied Physiology*. 5(2): 365-380.
- Ambriz-Tututi M, Rocha-Gonzalez HI, Cruz SL, Granados-Soto V 2009. Melatonin: a Hormone that Modulates Pain. *Life Sci.*, 84(15-16): 489-498.
- Anwar MM, Mahfouz HA, Sayed AS 1998. Potential Protective Effects of Melatonin on Bone Marrow of Rats Exposed to Cytotoxic Drugs. *Com. Biochem. Physiol. A. Mol. Integr. Physiol.*, 199 (2): 49-501.
- Apeldoorn EJ, Schrama JW, Mashaly MM, Parmentier HK 1999. Effect of Melatonin and Lighting Schedule on Energy Metabolism in Broiler Chickens. *Poultry Sci.*, 78(2): 223-229.
- Archana J 2012. Studies on Production Performance of Layers Supplemented with Dietary Melatonin. *Indian Journal of Poultry Science*, 47(3): 345-347.
- Badria FA 2002. Melatonin, Serotonin, and Tryptamine in Some Egyptian Food and Medicinal Plants. *J. Med. Food.*, 5(3): 153-157.
- Barrenetxe J, Delagrangre P, Martinez JA 2004. Physiological and Metabolic Functions of Melatonin. *J. Physiologic. Biochem.*, 60 (1): 61-72.
- Barriga C, Marchena JM, Lea RW, Harvey S, Rodriguez AB 2002. Effect of Stress and Dexamethasone Treatment on Circadian Rhythms of Melatonin and Corticosterone in Ring Dove (*Streptopelia risoria*). *Molecular and Cellular Biochemistry*, 232(1-2): 27-31.
- Boccalandro HE, Gonzalez CV, Wunderlin DA, Silva MF 2011. Melatonin Levels, Determined By Lc-Esi-MS/MS, Luctuate During The Day/Night Cycle in Vitis Vinifera cv. Malbec: Evidence of Its Antioxidant Role in Fruits. *J. Pineal Res.*, 51(2): 226-232.
- Bottje WG, Wideman RF 1995. Potential Role of Free Radicals in the Pathogenesis of Pulmonary Hypertension Syndrome. *Poult. Avian Biol. Rev.*, 6(3): 211-231.
- Brandstatter R, Abraham U 2003. Hypothalamic Circadian Organization in Birds. I. Anatomy, Functional Morphology, and Terminology of the Suprachiasmatic Region. *Chronobiol. Int.*, 20(4): 637-655.
- Brennan CP, Hendricks III GL, El-Sheikh TM, Mashaly MM 2002. Melatonin and the Enhancement of Immune Responses in Immature Male Chickens. *Poultry Science*, 81(3): 371-375.
- Bubenik GA 2001. Localization, physiological significance and possible clinical implication of gastrointestinal melatonin. *Biol Signals Recept.*, 10(6) 350-366.
- Bubenik GA 2002. Gastrointestinal Melatonin: Localization, Function, and Clinical Relevance. *Dig. Dis. Sci.*, 47(10): 2336-2348.
- Cantwell EL, Cassone VM 2002. Daily and Circadian Fluctuation in 2-deoxy [(14)C]-Glucose Uptake in Circadian and Visual System Structures of the Chick Brain: Effects of Exogenous Melatonin. *Brain Res Bull.*, 57(5): 603-611.
- Cassone VM, Brooks DS, Kelm TA 1995. Comparative Distribution of 2[125] Iodomelatonin Binding in the Brains of Diurnal Birds: outgroup analysis with turtles. *Brain Behav. Evol.*, 45(5): 241-256.
- Cassone VM, Westneat DF 2012. The Bird of Time: Cognition and the Avian Biological Clock. *Front Mol. Neurosci.*, 22(5): 32.
- Cassone VM 2014. Avian Circadian Organization: A Chorus of Clocks. *Front Neuroendocrinol.*, 35(1): 76-88.
- Cassone VM, Paulose JK, Harpole CE, Li Y, Whitfield-Rucker M 2017. Avian Circadian Organization. Department of Biology, University of Kentucky, Lexington, KY 40506, USA. V. Kumar (ed.), Biological Timekeeping: Clocks, Rhythms and Behaviour, pp 241-246.
- Chuffa LG, Seiva FR, Fávoro WJ, Teixeira GR, Amorim JP, Mendes LO, Fioruci BA, Pinheiro PF, Fernandes AA, Franci JA, Delella FK, Martinez M, Martinez FE 2011. Melatonin Reduces LH, 17 Beta-Estradiol and Induces Differential Regulation of Sex Steroid Receptors in Reproductive Tissues During Rat Ovulation. *Reproductive Biology and Endocrinology*, 9(1): 108.
- Clark WD, Classen HL 1995. The Effects of Continuously or Diurnally Fed Melatonin on Broiler Performance and Health. *Poultry Sci.*, 74 (11): 1900-1904.
- Conti A, Gattera NH, Maestroni G 1992. Role of Pineal Melatonin and Melatonin-Induced Immuno-Opioids in Murine Leukemogenesis. *Med. Oncol. Tumor Pharmacother.*, 19 (2): 87-92.
- Csernus V, Mess B 2003. Biorhythms and Pineal Gland. *Neuroendocrinol. Letters*, 24(6): 404-411.
- Csernus V, Faluhelyi N, Nagy AD 2005. Features of the Circadian Clock in the Avian Pineal Gland. *Ann N.Y. Acad Sci.*, 1040(1): 281-287.
- Csernus V 2006. The Avian Pineal Gland. *Chronobiol Int.*, 23(1-2): 329-339.
- De La Puerta C, Carrascosa-Salmoral MP, García-Luna PP, Lardone PJ, Herrera JL, Fernández-Montesinos R, Guerrero JM, Pozo D 2007. Melatonin is A Phytochemical in Olive Oil. *Food Chem.*, 104(2): 609-612.

- El-Slamoney AE, Battaa A, Hassaan SF, Raga EAEK, Abdulla EH 2010. Effect of Photoperiod and Tryptophan Amino Acid Supplementation on Pineal Gland Hormone (Melatonin) and Its Relation to Performance in Local Strain. 1- Effect on laying hen performance. *Egypt. Poult. Sci.*, 30(4): 927-960.
- Fabris N, Mocchegiani E, Provinciali M 1997. Plasticity of Neuron-Endocrine-Thymus Interactions During Aging-A Minireview. *Cell. Mol. Biol.*, 43(1): 529-541.
- Fagan AB, Kennaway DJ, Oakley AP 2009. Pinelectomy in the Chicken: A Good Model of Scoliosis? *Eur Spine J.*, 18(8): 1154-1159.
- George JC 1999. Muscle, metabolism and melatonin. In: Melatonin in the promotion of health (R. R. Watson, Ed.) CRC Press, Boca Raton, pp. 69-97.
- González-Gómez D, Lozano M, Fernández-León MF, Ayuso MC, Bernalte MJ, Rodríguez AB 2009. Detection and Quantification of Melatonin and Serotonin in Eight Sweet Cherry Cultivars (*Prunus avium* L.). *Eur. Food Res. Technol.*, 229(2): 223-229.
- Grievess TJ, Kingma SA, Beltrami G, Hau M 2012. Melatonin Delays Clutch Initiation in a Wild Songbird. *Biol Lett.*, 8(3): 330-332.
- Grodzinski U, Clayton NS 2010. Problems Faced by Food-Caching Corvids and the Evolution of Cognitive Solutions. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.*, 365(1542): 977-987.
- Guchhait P, Haldar C 2000. Time and Reproductive Phase-Dependent Effects of Exogenous Melatonin on The Pineal Gland and Ovary of a Nocturnal Bird, The Indian Spotted Owlet, *Athene brama*. *Folia Biol.*, 48(3-4): 91-96.
- Harvey S, Decuyper E, Darras VM, Berghman L 1991. Differential Effects of T4 and T3 on TRH- and GRF-Induced GH Secretion in the Domestic Fowl. *Reprod. Nutr. Dev.*, 31(4): 451-460.
- Hassanzadeh M, Moghimi Niaki AA, Babapour V, Mohit A, Mirzaie S 2016. A Study of The Employment of Melatonin Supplementation and Darkness Regime on Reducing the Negative Effects of Acute Heat Stress and Mortality in Broiler Chickens. *Iranian Journal of Veterinary Medicine.*, 10(1): 7-17.
- Hattori A, Migitaka H, Iigo M, Itoh M, Yamamoto K, Ohtani-Kaneko R, Hara M, Suzuki T, Reiter RJ 1995. Identification of Melatonin in Plants and its Effects on Plasma Melatonin Levels and Binding to Melatonin Receptors in Vertebrates. *Biochem. Mol. Biol. Int.*, 35(3): 627-634.
- Hernandez-Ruiz J, Cano A, Arnao MB 2005. Melatonin Acts as a Growth-Stimulating Compound in Some Monocot Species. *J. Pineal Res.*, 39(2): 137-142.
- Hernandez-Ruiz J, Arnao MB 2008. Distribution of Melatonin in Different Zones of Lupin and Barley Plants at Different Ages in the Presence and Absence of Light. *J. Agric. Food Chem.*, 56(22): 10567-10573.
- Hodallah H, Ahmed Gamal S, Essawy Hamdy A, Salem Mabrouk A, Abd el-Daim 2011. Effect of Melatonin on Some Hematological Parameters and Immune Status of Broiler Chicks. *Journal of Agricultural Science*, 3(2): 243-254.
- Huang X, Mazza G 2011. Application of LC and LC-MS to the Analysis of Melatonin and Serotonin in Edible Plants. *Crit. Rev. in Food Sci. Nutr.*, 51(4): 269-284.
- Jia Y, Yang M, Zhu K, Wang L, Song Y, Wang J, Qin W, Xu Z, Chen Y, Liu G 2016. Melatonin Implantation Improved the Egg-Laying Rate and Quality in Hens Past their Peak Egg-Laying Age. *Sci Rep.*, 23(6): 39799.
- Kliger CA, Gehad AE, Hulet, RM, Roush WB, Lillehoj HS, Mashaly MM 2000. Effects of Photoperiod and Melatonin on Lymphocyte Activities in Male Broiler Chickens. *Poultry Sci.*, 79(1):18-25.
- Kumar V, Singh BP, Rani S 2004. The Bird Clock. A Complex Multi-Oscillatory and Highly Diversified System, *Biol. Rhythm Res.*, 35(1-2): 121-144.
- Lamosova D, Zeman M, Jurani M 1997. Influence of Melatonin on Chick Skeletal Muscle Cell Growth. *Comp. Biochem. Physiol.*, 118(3): 375-379.
- Lazar R, Solcan C, Creta C, Laser M, Muntean C, Boisteanu PC 2015. Characterization of the Relations Between Morphology and Physiological Status of the Pineal Gland in Connection with the Somatic Development Level in Turkeys Reared in Romania. *Brazilian Journal of Veterinary and Animal Science*, 67(3):763-770.
- Lee PP, Allen AE, Pang SF 1990. Cold Stress Duringscotophase Elicited Differential Responses in Quail Pineal, Retinal and Serum Melatonin Levels. *Acta Endocrinol.*, 122(4): 535-539.
- Lee PP, Pang SF 1992. Identification and Characterization of Melatonin Binding Sites in the Gastrointestinal Tract of Ducks. *Life Sci.*, 50(2): 117-125.
- Legradi G, Emerson CH, Ahima RS, Flier JS, Lechan RM 1997. Leptin Prevents Fasting-Induced Suppression of Prothyrotropin-Releasing Hormone Messenger Ribonucleic Acid in Neurons of the Hypothalamic Paraventricular Nucleus. *Endocrinology*, 138(6): 2569-2576.
- Lessons S, Summers JD 2005. Feeding Programs for Broiler Chickens. In: Commercial Poultry Nutrition. 3rd edition, Nottingham University Press. Manor Farm, Church Lane, Thrumpton, Nottingham, NG11 0AX, England, pp 230-293.
- Lewinski A 2002. The Problem of Goiter with Particular Consideration of Goiter Resulting from Iodine Deficiency. II. Management of Non-Toxic Nodular Goiter and of Thyroid Nodules. *Neuro Endocrinol. Lett.*, 23(4): 356-364.
- Lewis PD, Middleton BA, Gous RM 2006. Exogenous Melatonin Modifies Rate of Sexual Maturation in Domestic Pullets. *Poult Sci.*, 85(1): 117-122.

- Liou SS, Cogburn LA, Biellier HV 1987. Photoperiodic Regulation of Plasma Melatonin Levels in the Laying Chicken (*Gallus domesticus*). *Gen. Comp. Endocrinol.*, 67(2): 221-226.
- Liu J, Wu F, Liu Y, Zhang T, Tang Z 2011. The Effect of Melatonin on Mitochondrial Function in Endotoxemia Induced by Lipopolysaccharide. *Asian-Aust J Anim Sci.*, 24(6): 857-866.
- Machida M, Dubousset J, Imamura Y, Iwaya T, Yamada T 1995. Role of Melatonin Deficiency in the Development of Scoliosis in Pinealectomised Chickens. *J. Bone Joint Surg. Br.*, 77(1): 134-138.
- Maestroni GJM 2001. The Immunotherapeutic Potential of Melatonin. *Exp. Opin. Invest. Drugs*, 10(3): 467-476.
- Mahata-Mahapatra M, Mahata SK 1992. Circannual Pineal Rhythms in the Soft-Shell Turtle (*Lissemys punctata punctata*). *J. Interdiscipl. Cycle Res.*, 23(1): 9-16.
- Manchester LC, Tan DX, Reiter RJ, Park W, Monis K, Qi W 2000. High Levels of Melatonin in the Seeds of Edible Plants: Possible Function In Germ Tissue Protection. *Life Sci.*, 67(25): 3023-3029.
- Mishra I, Kumar V 2016. Role of Pineal and Melatonin in the Avian Circadian and Photoperiodic Systems. *Journal of Endocrinology and Reproduction*, 20(1): 38-45.
- Mocchegiani E, Bulian D, Santarelli L, Tibaldi A, Muzzioli M, Lesnikov V, Pierpaoli W, Fabris N 1996. The Zinc Pool is Involved in the Immune-Reconstituting Effect of Melatonin in Pinealectomized Mice. *J. Pharmacol. Exp. Ther.*, 277(3): 1200-1208.
- Mogulkoc R, Baltaci AK 2003. The Effect of Intraperitoneal Melatonin Supplementation on the Release of Thyroid Hormones and Testosterone in Rats with Hyperthyroid. *Neuro Endocrinol. Lett.*, 24(5): 345-347.
- Moore CB, Siopes TD 2000. Effects of Light Conditions and Melatonin Supplementation on The Cellular and Humoral Immune Responses in Japanese Quail *Coturnix coturnix japonica*. *Gen. Comp. Endocrinol.*, 119(1): 95-104.
- Moore CB, Siopes TD 2003. Melatonin Enhances Cellular and Humoral Immune Responses in the Japanese quail (*Coturnix coturnix japonica*) Via an Opiatergic Mechanism. *Gen. Comp. Endocrinol.*, 131(3): 258-263.
- Mustonen AM, Nieminen P, Hyvarinen H, Asikainen J 2000. Exogenous Melatonin Elevates the Plasma Leptin and Thyroxine Concentrations of the Mink (*Mustela vison*). *Z. Naturforsch., [C]* 55(9-10): 806-813.
- Nakade O, Koyoma H, Arijii H, Yajima A, Kaku T 1999. Melatonin Stimulates Proliferation and Type I Collagen Synthesis in Human Bone Cells in Vitro. *J. Pineal Res.*, 27(2): 106-110.
- Natesan A, Geetha L, Zatz M 2002. Rhythm and Soul in the Avian Pineal. *Cell Tissue Res.*, 309(1):35-45.
- Natesan AK, Cassone VM 2002. Melatonin Receptor mRNA Localization and Rhythmicity in the Retina of the Domestic Chick, *Gallus Domesticus*. *Vis Neurosci.*, 19(3): 265-274.
- Nisbet DJ, Edrington TS, McReynolds JL, Callaway TR, Byrd JA 2008. Influence of Exogenous Melatonin Administration on Salmonella Enteritidis Colonisation in Molted Layers. *Poult Sci.*, 87(6): 1083-1088.
- Ohta Y, Kongo M, Sasaki E, Nishida K, Ishiguro I 2000. Therapeutic Effect of Melatonin on Carbon Tetrachloride-Induced Acute Liver Injury In Rats. *J Pineal Res.*, 28(2): 119-126.
- Okano T, Fukada Y 2003. Chicktacking Pineal Clock. *J. Biochem.*, 134(6): 791-797.
- Oladi E, Mohamadi M, Shamspur T, Mostafavi A 2014. Spectrofluorimetric Determination of Melatonin in Kernels of Four Different Pistacia Varieties After Ultrasound-Assisted Solid-Liquid Extraction. *Spectrochim. Acta A Mol. Biomol. Spectrosc.*, 132(1): 326-329.
- Ozturk G, Coskun S, Erbas G 2002. Effect of Melatonin Treatment on Serum and Tissue Zinc Levels in Rats. *J. Trace Elem Exp Med.*, 15(1): 1-8.
- Özen H, Karaman M, Çigremis Y, Tuzcu M, Özcan K, Erdag D 2009. Effectiveness of Melatonin on Aflatoxicosis in Chicks. *Research in Veterinary Science*, 86(3): 485-489.
- Pablos MI, Reiter RJ, Ortiz GG, Guerrero JM, Agapito MT, Chuang JI, Seweynek E 1998. Rhythms of Glutathione Peroxidase and Glutathione Reductase in Brain of Chick and their Inhibition by Light. *Neurochemistry International.*, 32(1): 69-75.
- Pal S, Chatterjee AK 2006. Possible Beneficial Effects of Melatonin Supplementation on Arsenic-Induced Oxidative Stress in Wistar rats. *Drug Chem Toxicol.*, 29(4): 423-433.
- Pang CS, Brown GM, Tang PL, Cheng KM, Pang SF 1993. 2-[125]Iodomelatonin Binding Sites in the Lung and Heart: A Link Between the Photoperiodic Signal, Melatonin and the Cardiopulmonary System. *Biol. Signals*, 2(1):228-236.
- Pang SF, Pang CS, Poon AMS, Wan Q, Song Y, Brown GM 1996. An Overview of Melatonin and Melatonin Receptors in Birds. *Poult. Avian Biol. Rev.*, 7(4):217-228.
- Paredes SD, Korkmaz A, Manchester LC, Tan DX, Reiter RJ 2009. Phytomelatonin: A Review. *J. Exp. Bot.*, 60(1): 57-69.
- Poon AM, Liu ZM, Tang F, Pang SF 1994. Evidence for a Direct Action of Melatonin on the Immune System. *Biol. Signals*, 3(2): 107-117.
- Prusik M, Lewczuk B, Nowicki M, Przybylska-Gornowicz B 2006. Histology and Ultrastructure of the Pineal Organ in the Domestic Goose. *Histol. Histopathol.*, 21(10): 1075-1090.

- Prusik M, Lewczuk B, Ziolkowska N, Przybylska-Gornowicz B 2015. Regulation of Melatonin Secretion in the Pineal Organ of the Domestic Duck - An In Vitro Study. *Polish Journal of Veterinary Sciences*, 18(3): 635-644.
- Przybylska-Gornowicz B, Lewczuk B, Prusik M, Nowicki M 2005. Post-Hatching Development of the Turkey Pineal Organ: Histological and Immunohistochemical Studies. *Neuro Endocrinol. Lett.*, 26(4): 383-392.
- Rasmussen DD, Marck BT, Boldt BM, Yellon SM, Matsumoto AM 2003. Suppression of Hypothalamic Pro-Opiomelanocortin (POMC) Gene Expression by Daily Melatonin Supplementation in Aging Rats. *J. Pineal Res.*, 34(2): 127-133.
- Reiter RJ 1995. The role of the Neurohormone Melatonin as a Buffer Against Macromolecular Oxidative Damage. *Neurochem Int.*, 27(6): 453-460.
- Reiter RJ, Robinson JO 1995. Melatonin: Your Body's Natural Wonder Drug. In Reiter, R.J. and Robinson (Eds), Bantam Books, 1540 Broadway, New York, New York 10036.
- Reppert SM 1997. Melatonin receptors: Molecular biology of a new family of G protein-coupled receptors. *J. Biol. Rhythms*. 12(6): 528-531.
- Riga P, Medina S, Garcia-Flores LA, Gil-Izquierdo A 2014. Melatonin Content of Pepper and Tomato Fruits: Effects of Cultivar and Solar Radiation. *Food Chem.*, 156(1): 347-352.
- Rozenboim I, Miara L, Wolfenson D 1998. The Thermoregulatory Mechanisms of Melatonin-Induced Hypothermia in Chicken. *Am. J. Physiol.*, 274(43): R232-R236.
- Rozenboim I, Aharony T, Yahav S 2002. The Effect of Melatonin Administration on Circulating Plasma Luteinizing Hormone Concentration in Castrated White Leghorn Roosters. *Poult Sci.*, 81(9): 1354-1359.
- Saarela, S. and Reiter, R.J. (1994) Function of melatonin in thermoregulatory processes. *Life. Sci.* 54: 295-311.
- Sahin N, Oderci M, Sahin K, Gursu MF, Smith MO 2004. Ascorbic Acid and Melatonin Reduce Heat-Induced Performance Inhibition and Oxidative Stress in Japanese Quails. *Br. Poult. Sci.*, 45(1): 116-122.
- Sazanov AA, Stekol'nikova VA, Korczak M, Sazanova AL, Jaszczak K, Zieba G, Malewski T 2007. Expression of Positional Candidates for Shell Thickness in the Chicken. *Poult Sci.*, 86(1): 202-205.
- Schwean-Lardner K, Fancher BI, Gomis S, Van Kessel A, Dalal S, Classen HL 2013. Effect of Day Length on Cause of Mortality, Leg Health, and Ocular Health in Broilers. *Poult. Sci.*, 92(1):1-11.
- Siegel HS 1995. Stress, Strains, and Resistance. *Br. Poult. Sci.*, 36(1): 3-22.
- Singh R, Singh AK, Tripathi M 2012. Melatonin Induced Changes in Specific Growth Rate, Gonadal Maturity, Lipid and Protein Production in Nile Tilapia *Oreochromis niloticus* (Linnaeus 1758). *Asian-Australas J Anim Sci.*, 25(1): 37-43.
- Sinkalu VO, Ayo JO, Abimbola AA, Ibrahim JE 2015. Effects of melatonin on cloacal temperature and erythrocyte osmotic fragility in layer hens during the hot-dry season. *Journal of Applied Animal Research Volume* 43(1): 52-60.
- Sjöblom M, Säfsten B, Flemström G 2003. Melatonin-Induced Calcium Signaling in Clusters of Human and Rat Duodenal Enterocytes. *Am. J. Physiol. Gastrointest. Liver Physiol.*, 284(6): G1034-1044.
- Stehle JH, Von Gall C, Korf HV 2003. Melatonin: A Clock-Output, A Clock-Input. *Journal of Neuroendocrinology*, 15(4): 383-389.
- Sturtz M, Cerezo AB, Cantos-Villar E, Garcia-Parrilla MC 2011. Determination of the Melatonin Content of Different Varieties of Tomatoes (*Lycopersicon esculentum*) and strawberries (*Fragaria ananassa*). *Food Chem.*, 127(3): 1329-1334.
- Sudhakumari CC, Haldar C 2001. Effects of Photoperiod Alteration on Adrenocortical, Pineal and Gonadal Activity in a Nocturnal Bird, *Athene Brama* and Diurnal Bird, *Perdicula sciatica*. *Zool. Sci.*, 18(1): 71-80.
- Sener G 2010. Karanlığın Hormonu: Melatonin. *Marmara Eczacılık Dergisi*, 14(1): 112-120.
- Takada R, Otsuka M 2007. Effects of Feeding High Tryptophan GM-Rice on Growth Performance of Chickens. *International Journal of Poultry Science*, 6(7): 524-526.
- Tan DX, Zanghi BM, Manchester LC, Reiter RJ 2014. Melatonin Identified in Meats and Other Food Stuffs: Potentially nutritional impact. *J. Pineal Res.*, 57(2): 213-218.
- Taylor AH, Hunt GR, Holzhaider JC, Gray RD 2007. Spontaneous Metatool Use by New Caledonian Crows. *Curr. Biol.*, 17(17): 1504-1507.
- Taylor AC, Horvat-Gordon M, Moore A, Bartel PA 2013. The Effects of Melatonin on the Physical Properties of Bones and Egg Shells in the Laying Hen. *PLoS one*. 8(2): 556-563.
- Timothy C, Birdsall ND 1996. The Biological Effects and Clinical Uses of the Pineal Hormone Melatonin. *Alternative Medicine Review*. 1(2): 94-102.
- Trivedi AK, Kumar V 2014. Melatonin: An Internal Signal for Daily and Seasonal Timing. *Indian J Exp Biol.*, 52(5): 425-37.
- Turgut M, Uysal AL, Bozkurt M, Yurtseven ME 2003. The Effects of Pineal Gland Transplantation on the Production of Spinal Deformity and Serum Melatonin Level Following Pinelectomy in the Chicken. *Eur. Spine J.*, 12(5):487-494.
- Turkowska E, Majewski PM, Rai S, Skwarło-Sońta K 2014. Pineal Oscillator Functioning in the Chicken - Effect of Photoperiod and Melatonin. *Chronobiol Int.*, 31(1): 134-143.

- Vacas MI, Cardinali DP 1979. Diurnal Changes in Melatonin Binding Sites of Hamster and Rat Brains. Correlation with Neuroendocrine Responsiveness to Melatonin. *Neurosci. Letters* 15(2-3): 259-263.
- Vakkuri O, Rintamäki H, Leppaluoto J 1985. Plasma and Tissue Concentrations of Melatonin after Midnight Light Exposure and Pinealectomy in the Pigeon. *Journal of Endocrinology*, 105(2): 263-268.
- Venegas C, Cabrera-Vique C, Garcia-Corzo L, Escames G, Acuna-Castroviejo D, Lopez LC 2011. Determination of Coenzyme Q10, Coenzyme Q9, and Melatonin Contents in Virgin Argan Oils: Comparison with other edible vegetable oils. *J. Agric. Food Chem.*, 59(22): 12102-12108.
- Wang X, Moreau M Raso VJ, Zhao JI, Jiang H, Mahood J, Bagnall KM 1998. Changes in Serum Melatonin Levels in Response to Pinealectomy in the Chicken and its Correlation with Development of Scoliosis. *Spine*, 23 (22): 2377-2381.
- Wang M, Yokotani K, Nakamura K, Murakami Y, Okada S, Osumi Y 1999. Melatonin Inhibits the Central Sympatho-Adrenomedullary Outflow in Rats. *Jpn. J. Pharmacol.*, 81(1): 28- 33.
- Wang J, Liang C, Li S, Zheng J 2009. Study on Analysis Method of Melatonin and Melatonin Content In Corn and Rice Seeds. *Chin. Agric. Sci. Bull.*, 25(1): 20-24.
- Wang L, Zhao Y, Reiter RJ, He C, Liu G, Lei Q, Zuo B, Zheng XD, Li Q, Kong J 2014. Changes in Melatonin Levels in Transgenic 'Micro-Tom' Tomato Overexpressing Ovine AANAT and Ovine HIOMT Genes. *J. Pineal Res.*, 56(2): 134-142.
- Witt-Enderby PA, Slater JP, Johnson NA, Bondi CD, Dodda BR, Kotlarczyk MP, Clafshenkel WP, Sethi S, Higginbotham S, Rutkowski JL 2012. Effects on Bone by the Light/Dark Cycle and Chronic Treatment with Melatonin and/or Hormone Replacement Therapy in Intact Female Mice. *J. Pineal Res.*, 53(4): 374-384.
- Woodward CL, Kwon YM, Kubena LF, Byrd JA, Moore RW, Nisbet DJ, Rieke SC 2005. Reduction of Salmonella Enterica Serovar Enteritidis Colonization and Invasion by an Alfalfa Diet During Molt in Leghorn Hens. *Poult. Sci.*, 84(2):185-193.
- Wright ML, Pikul A, Babski AM, Labieniec KE, Wolan RB 1997. Effect of Melatonin on the Response of the Thyroid to Thyrotropin Stimulation In Vitro. *Gen. Comp. Endocrinol.*, 108(2): 298-305.
- Yasuo S, Yoshimura T, Bartell PA, Iigo M, Makino E, Okabayashi N, Ebihara S 2002. Effect of Melatonin Administration on qPer2, qPer3, and qClock Gene Expression in the Suprachiasmatic Nucleus of Japanese quail. *Eur. J. Neurosci.*, 16(8): 1541-1546.
- Yu ZH, Lu Y, Pang SF 1991. [125] Iodomelatonin Binding Sites in Spleens of Birds and Mammals. *Neurosci Let.*, 125(2): 175-178.
- Zawilska JB, Lorenc A, Berezinska M, Vivien-Roels B, Pe'vet P, Skene DJ 2006. Diurnal and Circadian Rhythms in Melatonin Synthesis in the Turkey Pineal Gland and Retina. *Gen. Comp. Endocrinol.*, 145(2): 162-168.
- Zeman M, Vyboh P, Jurani M, Lamosova D, Kotsal L, Bilcik B, Blazicek P, Juraniova E 1993. Effects of Exogenous Melatonin on Some Endocrine, Behavioral and Metabolic Parameters in Japanese Quail *Coturnix coturnix japonica*. *Comp. Biochem. Physiol.*, 105(2): 323-328.
- Zeman M, Buyse J, Lamosova D, Herichova I, Decuypere E 1999. Role of Melatonin in the Control of Growth and Growth Hormone Secretion in Poultry. *Domestic Animal Endocrinology*, 17(2-3): 199-207.
- Zeman M, Buyse J, Herichová I, Decuypere E 2001. Melatonin Decreases Heat Production in Female Broiler Chickens. *Acta Vet. Brno.*, 70(1): 15-18.
- Zhao Y, Tan DX, Lei Q, Chen H, Wang L, Li QT, Gao Y, Kong J 2013. Melatonin and its Potential Biological Functions in the Fruits of Sweet Cherry. *J. Pineal Res.*, 55(1): 79-88.
- Zheng L, Ma YE, Gu LY, Yuan D, Shi ML, Guo XY, Zhan XA 2013. Growth Performance, Antioxidant Status, and Nonspecific Immunity in Broilers Under Different Lighting Regimens. *Journal of Applied Poultry Research*, 22(4): 798-807.
- Zielin Ski H, Lewczuk B, Przybylska-Gornowicz B, Kozłowska H 2001. Melatonin in Germinated Legume Seeds as a Potentially Significant Agent for Health in Biologically-Active Phytochemicals in Food: Analysis, Metabolism, Bioavailability and Function, Norwich, UK, Pfannhauser, W., Fenwick, G.R., Khokhar, S.R., Eds.; Royal Society of Chemistry: Cambridge, UK, pp. 110-117.