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Role of the Histaminergic System in the Inhibitory Effect of Melatonin on Broiler Chicken Feed Intake

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Abstract

Prior investigations have postulated that melatonin, a prominent hormone produced by the pineal gland, can reduce animal food consumption. This study was designed to evaluate the involvement of central histamine H1 and H2 receptors in regulating melatonin-induced feeding behavior among broiler chickens. The research comprised three distinct experiments: In experiment 1, the four groups of chickens received intracerebroventricular (ICV) injections of the control solution, 2.5, 5, and 10 nmol of melatonin. In experiment 2, ICV administration of drugs in four groups of chickens was conducted as control solution, chlorpheniramine (histamine H1 receptor antagonist, 64 nmol), melatonin (10 nmol) and chlorpheniramine + melatonin. In experiment 3, birds received ICV injections with the same procedure as experiment 2, except they were injected with famotidine (histamine H2 receptor antagonist, 148 nmol), instead of chlorpheniramine. Cumulative feed intake measurements were obtained during the 3 h following the injections. The administration of melatonin (10 nmol) led to a notable reduction in feed intake ($P < 0.05$). Pre-injection of chlorpheniramine (64 nmol) mitigated the inhibitory impact of melatonin on feed intake ($P < 0.05$). In contrast, pre-injection of famotidine (148 nmol) failed to exert any significant influence on melatonin-induced feeding behavior. In conclusion, the findings suggest the presence of an interaction between melatonin and the central histaminergic system, mediated through H1 receptors, in the modulation of feed intake in broiler chickens.

Introduction

The interaction between hormonal and neuronal signaling at the hypothalamic level is well-established in regulating appetite (Austin and Marks, 2008). Previous research has demonstrated that peptide hormones, such as Orexins A and B and ghrelin, exert distinct influences on hypothalamic dopamine, norepinephrine, and serotonin release, potentially contributing to their role in appetite regulation (Miller, 2019). In the brain, histamine (HA) is primarily localized in neurons within the tuberomammillary nucleus (TM) of the posterior hypothalamus, and these neurons project widely to various brain regions (Schneider *et al*., 2014). Central HA receptors and histaminergic neurons have been implicated in regulating feeding behavior. Meade and Denbow (2001) demonstrated that intracerebroventricular (ICV) injection of HA suppresses feed intake in chickens. Similarly, central administration of chloorpheniramine (H1 receptor antagonist) and famotidine (H2 receptor antagonist) in chickens have been shown to influence feeding behavior (Taati *et al*., 2009). Taati *et al*. (2009) demonstrated that thioperamide, a selective H3 receptor antagonist, stimulates the release of neuronal histamine, thereby decreasing feed intake in broiler chickens. Conversely, the central infusion of α-fluoromethylhistidine (FMH), a specific histidine decarboxylase inhibitor, increases feed intake (Yoshimatsu *et al*., 2002).

Numerous pieces of evidence suggest that the histaminergic system regulates feed intake downstream of other feeding-related peptides. For instance, previous research has shown that the anorectic effect of ghrelin in chickens is mediated through histamine H1 receptors (Taati *et al*., 2010).

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Shalikar *et al*. (2021) showed that leptin's hypophagic effect is mediated by H1 and H3 receptors in neonatal layer chickens.

Melatonin (N-acetyl-5-methoxytryptamine), an indolamine, is a neural hormone primarily secreted by the pineal gland during darkness in chickens and other animals. Melatonin regulates the internal biological clock governing various daily and seasonal physiological rhythms in birds (Cassone and Westneat, 2012). In addition to its well-documented role in regulating biological rhythms, melatonin is implicated in several physiological processes, including thermoregulation, reproductive and cardiopulmonary systems, immunoregulation and sleep (Tordjman *et al*., 2017). Two well-characterized G protein-coupled plasma membrane melatonin receptors, MT1 and MT2, regulate multiple cellular and physiological functions (Ekmekcioglu, 2014). Numerous studies strongly support melatonin's involvement in satiety mechanisms (Suriagandhi and Nachiappan, 2022). For example, melatonin is implicated in the regulation of feed intake in rats (Huether, 1994), mice (Bubenik and Pang, 1994), hamsters (Bartness and Wade, 1985), pigs (Bubenik *et al*., 1996), as well as various submammalian species like goldfish (De Pedro *et al*., 2008), rainbow trout (Conde-Sieira *et al*., 2012), and zebrafish (Piccinetti *et al*., 2010, 2013). Large doses of melatonin lead to decreased feed consumption in chickens (Bermudez *et al*., 1983). Moreover, feed consumption significantly increases in young cockerels (Injidi and Forbes, 1983) and hens (Pietras, 1996) after pinealectomy.

Several experimental investigations have assessed the role of histamine in circadian rhythmicity in the body and its potential interaction with melatonin in regulating feeding behavior (Nowak, 1994; Zawilska *et al*., 1996). Biochemical analyses have shown apparent circadian fluctuations in brain histamine content in rats, rabbits, rhesus monkeys, mice, and guinea pigs (Tuomisto, 1991). Aligning with daily activities in rats, the circadian rhythm of histamine release is characterized by higher values during the dark period and lower values during the light period (von Gall, 2022). Histaminergic fibers richly innervate the SCN and contain high histamine content (Cheng *et al*., 2021). Cote and Harrington (1993) reported that histamine, in hypothalamic slices containing the SCN, which plays a central role in circadian rhythms, resets the circadian clock, mediated via H1 receptors. On the other hand, previous research has also identified histamine and telemethylhistamine in the chick's pineal glands (Zawilska *et al*., 1996). Nowak and Sek (1994) demonstrated that histamine dose-dependently stimulates cAMP formation in the pineal glands of chickens. Based on the findings presented above, and given the similar effects of histamine and melatonin on feeding behavior in birds, it is reasonable to propose that the central histaminergic system may mediate melatonin's control of feed intake. In this study, we investigated the impact of blocking central H1 and H2 histamine receptors on melatonin-induced feeding behavior in broiler chickens.

Materials and Methods

Ethics

The ethical standards were considered during this research. The appropriate approvals from the ethical review committee of Lorestan University were also obtained under the reference number LU.ECRA.2023.42.

Materials

The pharmaceuticals employed in this study, Famotidine, chlorpheniramine maleate, and melatonin, were sourced from Sigma Aldrich Co., St. Louis, USA. Melatonin was dissolved in 0.85% saline (Saito *et al*., 2005).

Birds' husbandry

A total of 70 one-day-old male Ross broiler chickens (Dorbar Hatchery, Borujerd, Iran) with a live body weight of 42 ± 2 g were housed in heated batteries. During the growing phase, chickens had free access to a starter diet (20% crude protein and 2,900 kcal/kg of ME) and then a grower diet (19% crude protein and 2,950 kcal/kg of ME). No coccidiostats, antibiotics and enzymes were included in the diets. Feed and water were provided *ad libitum* during the experiment. Upon reaching 14 d of age, the cockerels were individually transferred to cages, where they were raised until they reached 21 d of age. The birds were subjected to a continuous 24-hour lighting regimen, while the environmental conditions were maintained at a temperature of 22 °C and a humidity level of 50% (Olanrewaju *et al.*, 2006). Each cage was equipped with a bell drinker and a pan feeder. Throughout the experimental period, no indications of illness or mortality were observed among the birds.

Surgical preparation

At the age of 21 d, with an average weight of approximately 750 g, birds were subjected to intramuscular anesthesia using a combination of ketamine (30 mg/kg) and xylazine (1 mg/kg) (Alfasan, Utrecht, Netherlands) (Thurmon *et al*., 1996). Subsequently, they were positioned on a stereotaxic apparatus (RWD Co., Shenzhen, China). A 23-gauge stainless steel cannula was surgically inserted into the lateral cerebral ventricle for ICV injection (Davis *et al*., 1979). The precise location of

the cannula was 6.7 mm anterior to bregma, 0.7 mm lateral to the midline, and 3.7 mm below the skull's outer surface. Three stainless steel screws and dental cement were used to fix the cannula on the skull (Aqua Cem, Dentsply). To prevent the blockage of the cannula, a stainless wire stylet was carefully inserted into the cannula. Lincospectin (Razak Pharma, Tehran, Iran) was used to prevent infection. A recovery period of 5 d was considered before the experimental procedures.

Experimental procedures

This study comprised three experiments exploring the effect of melatonin and its interaction with the histaminergic system concerning feed intake in meat-type chickens. Each experiment encompassed four distinct groups, each consisting of five chickens housed in individual cages. All animals were subjected to 3 h of food deprivation prior to the commencement of the experiments, although ad libitum access to water was maintained.

Experiment 1 aimed to assess the impact of ICV injections of varying melatonin doses on cumulative feed intake in chickens. In this experiment, the four groups of chicks received ICV injections of either a control solution (Group A) or melatonin at 2.5, 5, and 10 nmol doses in groups B, C, and D, respectively. In Experiment 2, the chickens were subjected to ICV injections as follows: Group A received a control solution, Group B received chlorpheniramine (64 nmol), Group C received melatonin (10 nmol), and Group D received a combination of chlorpheniramine (64 nmol) and melatonin (10 nmol). Experiment 3 involved ICV injections where Group A received the control solution, Group B received famotidine (148 nmol), Group C received melatonin (10 nmol), and Group D received a combination of famotidine (148 nmol) and melatonin (10 nmol). The dosages of chlorpheniramine and famotidine were determined based on a previous study by Taati *et al*. (2009).

A 10-µl Hamilton syringe was connected to the cannula through a 60 cm length of PE-20 tubing. Each chick received an ICV injection of drug solutions in a-10-µL volume (Furuse *et al*., 1999). Saline was used as the control solution (Saito *et al*., 2005). After the injections, the chickens were returned to their cages. At 15, 30, 60, 120, and 180 min post-injection, cumulative feed intake was measured. All experimental procedures were conducted from 9:00 AM to 1:00 PM. After the experiments, the accuracy of the injection placement in the ventricle was confirmed by administering an ICV injection of methylene blue (Merck Co., Darmstadt, Germany), followed by brain tissue sectioning.

Statistical analysis

All data are presented as mean ± *SEM*. Statistical analysis was performed to elucidate the interaction between groups and times after injection by conducting a two-way analysis of variance (ANOVA) for repeated measurements using SPSS 16.0 for Windows (SPSS, Inc., Chicago, IL, USA). *Tukey* post hoc test was performed for comparisons between means. A p-value less than 0.05 was considered statistically significant.

Results

The effect of ICV injection of melatonin, chloorpheniramine (H1 receptor antagonist), famotidine (H2 receptor antagonist) and their combinations on cumulative food intake in neonatal chickens are presented in Figure 1, 2 and 3. The effect of ICV injection of different doses of melatonin on cumulative food intake in neonatal chickens is shown in Figure 1. According to the results, ICV injection of the melatonin at a dose of 10 nmol significantly decreased cumulative food intake in food-deprived chickens compared to control group at all timepoints after injection ($P < 0.05$). Melatonin at a dose of 2.5 nmol did not have a significant effect on feed intake in the 180-min food-deprived chickens after injection. In contrast, 5 nmol melatonin significantly decreased feed consumption during the first hour after injection ($P \leq 0.05$) (Figure 1). Effect of ICV injection of melatonin, chlorpheniramine and their combination on cumulative food intake in neonatal chickens is shown in Figure 2. ICV injection of sub effective dose of the chlorpheniramine (64 nmol) had no significant effect on food intake in food deprived birds compared to control group ($P > 0.05$). Co-injection of the melatonin + chlorpheniramine significantly attenuated melatonin-induced hypophagia until 120 min after injections ($P < 0.05$) (Figure 1). Results obtained from experiment 3 are depicted in Fig 3. In this experiment, the effects of ICV injection of melatonin, famotidine and their combination on cumulative food intake in neonatal chickens were evaluated. ICV injection of the effective dose of melatonin significantly decreased cumulative food intake in FD3 compared to the control group ($P < 0.05$). ICV injection of the sub-effective dose of the famotidine (148 nmol) had no significant effect on food intake in food-deprived birds compared to control group ($P > 0.05$). Co-injection of the ghrelin + famotidine had no ameliorative impact on melatonin-induced hypophagic effects on feed intake ($P < 0.05$) (Figure 3).

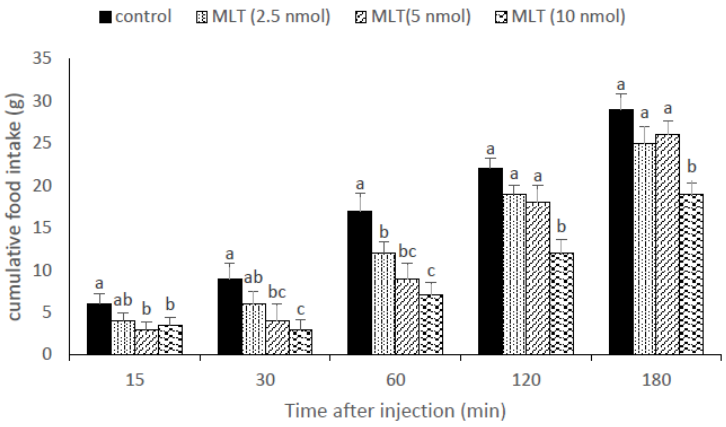

Figure 1. Effect of intracerebroventricular (ICV) injection of melatonin at different doses on feed intake in chickens. Columns with different superscripts in each time are significantly different ($P < 0.05$). Data are expressed as means ± *SEM*.

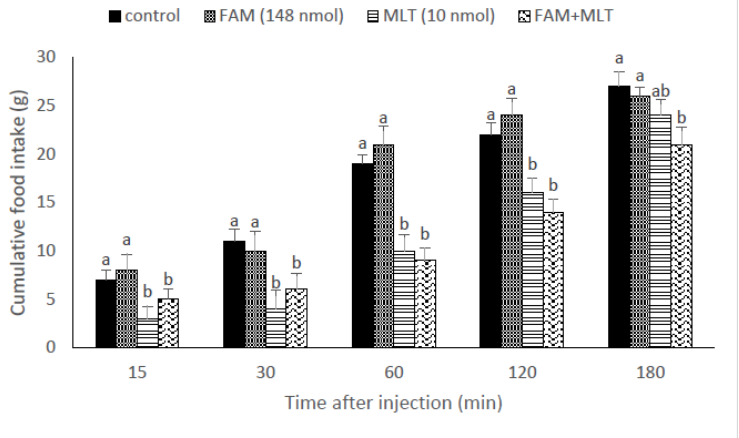

Figure 2. Effect of ICV injection of CHL (64 nmol), MLT melatonin (10 nmol) and their combination on cumulative feed intake in chickens. CHL: chlorpheniramine, selective histamine H1 receptors antagonist. MLT: melatonin. Columns with different superscripts in each time are significantly different (a, b and c; $P < 0.05$). Data are expressed as means ± *SEM*.

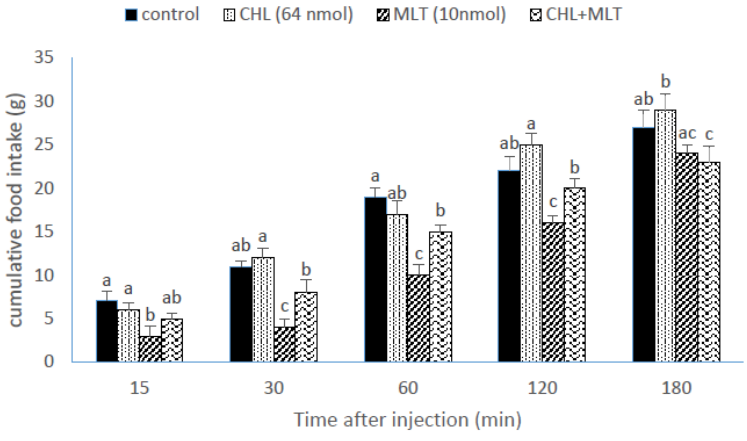

Figure 3. Effect of ICV injection of FAM (148 nmol), MLT melatonin (10 nmol) and their combination on cumulative feed intake in chickens. FAM: famotidine, selective histamine H2 receptors antagonist. MLT: melatonin. Columns with different superscripts in each time are significantly different (a and b; $P < 0.05$). Data are expressed as means ± *SEM*.

Discussion

Our findings indicate that central administration of melatonin inhibits food intake in broiler chickens. To the best of my knowledge, this is the first report addressing the impact of ICV administration of melatonin on feeding behavior in broiler chickens. Effects of melatonin on food intake have been described in different mammalian species, including humans (Schneider *et al*., 2014; Meade and Denbow, 2001). However, limited information is available regarding the influence of melatonin ICV injection on food intake in avian species. Research has revealed that both intraperitoneal and oral administration of melatonin lead to reduced chicken feed consumption (Bermudez *et al*., 1983). Injidi and Forbes (1983) also demonstrated that exogenously administered melatonin hampers growth and food intake in chickens. Moreover, studies have shown that removing the primary source of endogenous melatonin through pinealectomy stimulates growth and food intake (Pietras, 1996). Pinealectomized birds eat little food during the night, while intact birds do not consume food at night (Injidi and Forbes, 1983; Pietras, 1996). It has been suggested that elevated melatonin levels during the dark period correlate with decreased nocturnal feed intake. Chickens predominantly consume feed during daylight hours, leading to the assumption that feed intake and growth peak in broilers raised under nearly continuous illumination (Apeldoorn *et al*., 1999). The lighting duration significantly impacts melatonin synthesis, as well as the growth and overall health of chickens (Zheng *et al*., 2013). Broilers exposed to continuous lighting are expected to have decreased melatonin levels in their serum, whereas performance and health improve in those subjected to intermittent lighting (Apeldoorn *et al*., 1999). Sun *et al*. (2017) found significantly higher melatonin levels in broilers exposed to a 16L:8D lighting regime compared to chickens exposed to continuous or intermittent lighting with shorter periods of darkness.

The precise mechanism underlying melatonin-induced hypophagia remains incompletely understood. The pineal gland has been reported to exert a stimulatory effect on the ventromedial hypothalamic nucleus, a satiety center in the hypothalamus (Hardeland *et al*., 2012). Additionally, the pineal gland and melatonin influence various metabolic functions through the suprachiasmatic nuclei, which regulate feeding behavior (Van Drunen and Eckel-Mahan, 2021). Given melatonin's rapid and pronounced effect on feeding behavior, Bermudez *et al*. (1983) strongly propose that its site of action lies within the central nervous system. Physiological control of animal feeding behavior is regulated by a complex interplay of hormones, neurotransmitters, and neuropeptides (Zendehdel and Hassanpour, 2014). Melatonin can directly or indirectly modulate the secretion of other hormones involved in feed intake regulation, as previously reported (Tordjman *et al*., 2017). Molecular studies suggest that melatonin may regulate appetite through an intricate network of signals (Guan *et al*., 2021; Ríos-Lugo *et al*., 2015). Piccinetti *et al*. (2010) demonstrated that oral administration of melatonin significantly increases the expression of genes responsible for feeding inhibition, such as MC4R, while significantly reducing significant orexigenic signals, including NPY and CB1 in zebrafish.

The anatomical and functional connection between the pineal gland and the histaminergic system has been revealed. Histaminergic nerve fibers innervating the pineal gland in rats have been previously described (Mikkelsen *et al*., 1992). Moreover, it has been observed that histamine can reset the circadian clock in the hamster suprachiasmatic nucleus (SCN) (Cote and Harrington, 1993). Accumulating data indicate that the chicken pineal gland contains a complete functional histaminergic system, encompassing amine synthesis, inactivation and receptors (Zawilska *et al*., 1996; Nowak and Sek, 1994). Nowak and Sek (1994) demonstrated that histamine strongly stimulates cAMP generation in the chicken pineal gland, leading to the activation of cationic channels in acutely isolated and cultured pineal cells. The chicken pineal gland exhibits relatively high histamine levels (Zawilska *et al*., 1996). On the other hand, the peripheral administration of L-histidine, the precursor of histamine, to chickens has significantly elevated pineal levels of histamine (Zawilska *et al*., 1996).

Histamine in the brain has been shown to inhibit feeding behavior through H1 receptors in mammals (Tabarean, 2016) and chickens (Taati *et al*., 2009; Taati *et al*., 2010). Given histamine's anorectic effect in chickens, it is conceivable that melatonin's anorexic effect may be mediated by histamine. Our study assessed the potential involvement of the central histaminergic system in melatonin-induced feeding behavior in broiler cockerels for the first time. The results demonstrated that pre-administration of chlorpheniramine, an H1 receptor antagonist, mitigated the inhibitory effect of melatonin on feed intake. However, blocking central H2 receptors did not reduce melatonin's inhibitory effect on feed intake in the study. We utilized sub-effective doses of chloorpheniramine (H1 receptor antagonist) and famotidine (H2 receptor antagonist) obtained from our previous study (Taati *et al*., 2009) to investigate the potential interaction between melatonin and histamine on food intake. Sub-effective doses of the drugs block histamine receptors without affecting food intake (Jaefari-Anari *et al*., 2018). Therefore, any effect of combination of chlorpheniramine (H1 receptor antagonist) and famotidine (H2 receptor antagonist) and melatonin on

food intake would be related to the interaction of these two systems.

Conclusion

In summary, we examined the involvement of central histamine H1 and H2 receptors in regulating melatonin-induced feeding behavior among broiler chickens. ICV injection of melatonin induced a reduction in feed intake. Co-injection of chlorpheniramine and melatonin attenuated the inhibitory impact of melatonin on feed intake. However, the use of famotidine with melatonin had not any significant effect on melatonin-induced feeding behavior. Our findings highlight the role of central histamine H1 receptors in the anorectic effect of melatonin in chickens.

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References

Apeldoorn EJ, Schrama JW, Mashaly MM & Parmentier HK. 1999. Effect of melatonin and lighting schedule on energy metabolism in broiler chickens. Poultry Science, 78(2): 223-229. DOI: 10.1093/ps/78.2.223

Austin J & Marks D., 2008. Hormonal regulators of appetite. International Journal of Pediatric Endocrinology, 2009: 1-9. DOI: 10.1155/2009/141753

Bartness TJ & Wade GN. 1985. Body weight, food intake and energy regulation in exercising and melatonin-treated Siberian hamsters. Physiology & Behavior, 35(5): 805-808. DOI: 10.1016/0031-9384(85)90415-9

Bermudez FF, Forbes JM & Injidi MH. 1983. Involvement of melatonin and thyroid hormones in the control of sleep, food intake and energy metabolism in the domestic fowl. The Journal of Physiology, 337(1): 19-27. DOI: 10.1113/jphysiol.1983.sp014608

Bubenik GA & Pang SF. 1994. The role of serotonin and melatonin in gastrointestinal physiology: Ontogeny, regulation of food intake, and mutual serotonin-melatonin feedback. Journal of Pineal Research, 16(2): 91-99. DOI: 10.1111/j.1600-079x.1994.tb00088.x

Bubenik GA, Pang SF, Hacker RR & Smith PS. 1996. Melatonin concentrations in serum and tissues of porcine gastrointestinal tract and their relationship to the intake and passage of food. Journal of Pineal Research, 21(4): 251-256. DOI: 10.1111/j.1600-079x.1996.tb00294.x

Cassone VM & Westneat DF. 2012. The bird of time: cognition and the avian biological clock. Frontiers in Molecular Neuroscience, 5: 32. DOI: 10.3389/fnmol.2012.00032

Cheng L, Liu J & Chen Z. 2021. The histaminergic system in neuropsychiatric disorders. Biomolecules, 11(9): 1345. DOI: 10.3390/biom11091345

Conde-Sieira M, Librán-Pérez M, Patiño MAL, Soengas JL & Míguez JM. 2012. Melatonin treatment alters glucosensing capacity and mRNA expression levels of peptides related to food intake control in rainbow trout hypothalamus. General and Comparative Endocrinology, 178(1): 131-138. DOI: 10.1016/j.ygcen.2012.04.011

Cote NK & Harrington ME. 1993. Histamine phase shifts the circadian clock in a manner similar to light. Brain Research, 613(1): 149-151. DOI: 10.1016/0006-8993(93)90465-y

Davis JL, Masuoka DT, Gerbrandt LK & Cherkin A. 1979. Autoradiographic distribution of L-proline in chicks after intracerebral injection. Physiology & Behavior, 22(4): 693-695. DOI: 10.1016/0031-9384(79)90233-6

De Pedro N, Martínez-Álvarez RM & Delgado MJ. 2008. Melatonin reduces body weight in goldfish (Carassius auratus): effects on metabolic resources and some feeding regulators. Journal of Pineal Research, 45(1): 32-39. DOI: 10.1111/j.1600-079X.2007.00553.x

Ekmekcioglu C. 2014. Expression and putative functions of melatonin receptors in malignant cells and tissues. Wiener Medizinische Wochenschrift, 164(21-22): 472-478. DOI: 10.1007/s10354-014-0289-6

Furuse M, Ando R, Bungo T, Shimojo M & Masuda Y. 1999. Intracerebroventricular injection of orexins does not stimulate food intake in neonatal chicks. British Poultry Science, 40(5): 698-700. DOI:10.1080/00071669987115

Guan Q, Wang Z, Cao J, Dong Y & Chen Y. 2021. Mechanisms of melatonin in obesity: a review. International Journal of Molecular Sciences, 23(1): 218. DOI: 10.3390/ijms23010218

Hardeland R, Madrid JA, Tan DX & Reiter RJ. 2012. Melatonin, the circadian multioscillator system and health: the need for detailed analyses of peripheral melatonin signaling. Journal of Pineal Research, 52(2): 139-166. DOI: 10.1111/j.1600-079X.2011.00934.x

Huether G. 1994. Melatonin synthesis in the gastrointestinal tract and the impact of nutritional factors on circulating melatonin. Annals of the New York Academy of Sciences, 719(1): 146-158. DOI: 10.1111/j.1749-6632.1994.tb56826.x

Injidi MH & Forbes JM. 1983. Growth and food intake of intact and pinealectomised chickens treated with melatonin and

triiodothyronine. British Poultry Science, 24(4): 463-469. DOI: 10.1080/00071668308416762

Jaefari-Anari M, Zendehdel M, Gilanpour H, Asghari A & Babapour V. 2018. Central opioidergic system interplay with histamine on food intake in neonatal chicks: role of μ-opioid and H1/H3 receptors. Brazilian Journal of Poultry Science, 20: 595-604. DOI: 10.1590/1806-9061-2018-0785

Meade S & Denbow DM. 2001. Feeding, drinking, and temperature responses of chickens to intracerebroventricular histamine. Physiology & Behavior, 73(1-2): 65-73. DOI: 10.1016/s0031-9384(01)00438-3

Mikkelsen JD, Panula P & Møller M. 1992. Histamine-immunoreactive nerve fibers in the rat pineal gland: evidence for a histaminergic central innervation. Brain Research, 597(2): 200-208. DOI: 10.1016/0006-8993(92)91475-t

Miller GD. 2019. Appetite regulation: hormones, peptides, and neurotransmitters and their role in obesity. American Journal of Lifestyle Medicine, 13(6): 586-601. DOI: 10.1177/1559827617716376

Nowak J. 1994. Histamine in the central nervous system: its role in circadian rhythmicity. Acta Neurobiologiae Experimentalis, 54(Suppl): 65-82.

Nowak JZ & Sek B. 1994. Stimulatory effect of histamine on cyclic AMP formation in chick pineal gland. Journal of Neurochemistry, 63(4): 1338-1345. DOI: 10.1046/j.1471-4159.1994.63041338.x

Olanrewaju HA, Thaxton JP, Dozier WA, Purswell J, Roush WB & Branton SL. 2006. A review of lighting programs for broiler production. International Journal of Poultry Science, 5(4): 301-308. DOI: 10.3923/ijps.2006.301.308

Piccinetti CC, Migliarini B, Olivotto I, Coletti G, Amici A & Carnevali O. 2010. Appetite regulation: the central role of melatonin in Danio rerio. Hormones and Behavior, 58(5): 780-785. DOI: 10.1016/j.yhbeh.2010.07.013. DOI: 10.1089/zeb.2012.0844

Piccinetti CC, Migliarini B, Olivotto I, Simoniello MP, Giorgini E & Carnevali O. 2013. Melatonin and peripheral circuitries: insights on appetite and metabolism in Danio rerio. Zebrafish, 10(3): .275-282. DOI: 10.1089/zeb.2012.0844

Pietras M. 1996. The effect of pinealectomy on oxygen consumption and rectal temperature of adult hens. Journal of Animal and Feed Sciences, 5(3): 289-295. DOI:10.22358/jafs/69608/1996

Ríos-Lugo MJ, Jiménez-Ortega V, Cano-Barquilla P, Mateos PF, Spinedi EJ, Cardinali DP & Esquifino AI. 2015. Melatonin counteracts changes in hypothalamic gene expression of signals regulating feeding behavior in high-fat fed rats. Hormone Molecular Biology and Clinical Investigation, 21(3): 175-183. DOI: 10.1515/hmbci-2014-0041

Saito S, Tachibana T, Choi YH, Denbow DM & Furuse M. 2005. ICV melatonin reduces acute stress responses in neonatal chicks. Behavioural Brain Research, 165(2): 197-203. DOI: 10.1016/j.bbr.2005.06.045

Schneider EH, Neumann D & Seifert R. 2014. Modulation of behavior by the histaminergic system: lessons from HDC-, H3R-and H4R-deficient mice. Neuroscience & Biobehavioral Reviews, 47: 101-121. DOI: 10.1016/j.neubiorev.2014.07.020

Shalikar M, Zendehdel M, Vazir B & Asghari A. 2021. Impact of the Central Histaminergic and Melanocortin Systems on Leptin-Induced Hypophagia in Neonatal Layer Chicken. Archives of Razi Institute, 76(6): 1735. DOI: 10.22092/ari.2021.354188.1626

Sun YY, Li YL, Li DL, Chen C, Bai H, Xue FG & Chen JL. 2017. Responses of broilers to the near-continuous lighting, constant 16-h lighting, and constant 16-h lighting with a 2-h night interruption. Livestock Science, 206: 135-140. DOI: 10.1016/j.livsci.2017.10.019

Suriagandhi V & Nachiappan V. 2022. Therapeutic target analysis and molecular mechanism of melatonin-treated leptin resistance induced obesity: A Systematic Study of Network Pharmacology. Frontiers in Endocrinology, 13: 927576. DOI: 10.3389/fendo.2022.927576

Taati M, Babapour V, Kheradmand A & TARAHI M. 2009. The role of central endogenous histamine and H1, H2 and H3 receptors on food intake in broiler chickens. Iranian Journal of Veterinary Research. 10(1): 54-60. DOI:10.22099/ijvr.2009.1090

Taati M, Nayebzadeh H, Khosravinia H & Cheraghi J. 2010. The role of the histaminergic system on the inhibitory effect of ghrelin on feed intake in broiler chickens. Iranian Journal of Veterinary Research, 11(1): 38-45. DOI: 10.22099/ijvr.2010.173

Tabarean IV. 2016. Histamine receptor signaling in energy homeostasis. Neuropharmacology, 106: 13-19. DOI: 10.1016/j.neuropharm.2015.04.011

Tordjman S, Chokron S, Delorme R, Charrier A, Bellissant E, Jaafari N & Fougerou C. 2017. Melatonin: pharmacology, functions and therapeutic benefits. Current Neuropharmacology, 15(3): 434-443. DOI: 10.2174/1570159X14666161228122115

Tuomisto L. 1991. Involvement of histamine in circadian and other rhythms. In: Histaminergic neurons: morphology and function (Eds T

Watanabe and H Wada). CRC Press, Boca Raton, 283-295.

Van Drunen R & Eckel-Mahan K. 2021. Circadian rhythms of the hypothalamus: from function to physiology. Clocks & sleep, 3(1): 189-226. DOI: 10.3390/clockssleep3010012

von Gall C. 2022. The effects of light and the circadian system on rhythmic brain function. International Journal of Molecular Sciences, 23(5): 2778. DOI: 10.3390/ijms23052778

Yoshimatsu H, Chiba S, Tajima D, Akehi Y & Sakata T. 2002. Histidine suppresses food intake through its conversion into neuronal histamine. Experimental Biology and Medicine, 227(1): 63-68. DOI: 10.1177/153537020222700111

Zawilska J, Sęk A, Orszulak-Michalak D, Mackova M & Nowak J. 1996. The presence of histamine and tele-methylhistamine in the pineal gland of chick. Acta Neurobiologiae Experimentalis, 56(3): 691-695. DOI: 10.55782/ane-1996-1173

Zendehdel M & Hassanpour S. 2014. Central regulation of food intake in mammals and birds: a review. Neurotransmitter, 1: 1-7. DOI: 10.14800/nt.251

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. DOI: 10.3382/japr.2012-00713