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Effect of Opioid Receptors Agonists on Feeding Behaviour Using Different Diets in *Ad Libitum* Fed Neonatal Chicken

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ABSTRACT

Arva S., Zendehdel M., EbrahimNezhad Y., Ghiasi Ghalehkandi J., Hassanpour S., Aghdam Shahryar H. (2017): **Effect of opioid receptors agonists on feeding behaviour using different diets in *ad libitum* fed neonatal chicken**. Czech J. Anim. Sci., 62, 98–109.

Despite progress in studying the role of opioids in reward, the effect of opioid receptors on feeding behaviour in *ad libitum* fed meat-type chicken offered different diet types is still unclear. So in this study, 12 experiments (each included 4 groups) were designed to determine the role of μ, δ, and κ receptors with different diets on feeding responses in *ad libitum* fed neonatal chicken. In Experiment 1, group A chicken were intracerebroventricularly (ICV) injected with saline, groups B–D chicken were ICV injected with DAMGO (μ-opioid receptor agonist; 125, 250, and 500 pmol), then standard diet without fat was offered. In Experiment 2, group A chicken were ICV injected with saline, groups B–D chicken were ICV injected with DAMGO (125, 250, and 500 pmol) and diet with nutrient energy ratio 20% below standard was provided to the birds. Experiments 3–4 were similar to Experiment 1, except after injection, diets containing nutrient energy ratio 20% above standard and standard diet with fat were provided to the birds, respectively. In Experiment 5, chicken were ICV injected with saline, DPDPE (δ-opioid receptor agonist) at doses of 20, 40, and 80 nmol, and then received standard diet without fat. Experiments 6–8 were similar to Experiment 5 in which diet containing nutrient energy ratio by 20% lower than standard, diet containing nutrient energy ratio by 20% higher than standard, and diet containing fat were provided instead of standard diet without fat to the birds, respectively. In Experiment 9, birds received ICV injection of saline and U-50488H (κ-opioid receptor agonist; 10, 20, and 40 nmol) and were provided standard diet without fat. Experiments 10–12 were similar to Experiment 9 but after ICV injection, birds were fed diet containing by 20% lower nutrient energy ratio, diet containing by 20% higher nutrient energy ratio, and standard diet containing fat, respectively. Then the cumulative food intake was measured until 180 min post injection. According to the results, DAMGO decreased while DPDPE and U-50488H increased the food intake ($P < 0.05$). These findings suggest endogenous governing food preferences via δ- and κ-opioid receptor in *ad libitum* fed neonatal chicken.

Keywords: appetite; food selection; central food intake regulation; meat-type chicken

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The present research does not include any studies with human subjects performed by any of the authors.

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Food intake regulation is associated with central nervous system (CNS) reward, motivation and hedonic mechanisms, and energy-regulatory systems (Figlewicz and Sipols 2010). Animals prefer certain foods and the main common denominator for such foods is their rewarding value (Taha 2010). The appetite in birds is controlled by diverse neurotransmitters via complex neurological pathways (Zendehdel et al. 2015a). Opioids are known to be inhibitory neurotransmitters, and their receptors, classified mainly as μ, δ, and κ subtypes, are widely distributed throughout the central nervous system in vertebrates (Bungo et al. 2005).

Endogenous opiates are frequently distributed in the CNS and interplay with numerous physiologic functions such as pain regulation, respiration, immune system (Le Merrer et al. 2009), and food intake (Bodnar 2014). The intracerebroventricular (ICV) injection of μ- and δ-opioid receptor agonists exerts orexigenic effects in mammals (Kaneko et al. 2012). The ICV injection of μ-opioid receptor agonist decreases while that of δ- and κ-opioid receptor agonists increases food intake in neonatal meat-type (Shiraishi et al. 2008) and layer-type chicken (Shojaei et al. 2015).

Animal model studies revealed that caloric intake and dietary preference modification is a phenomenon when rats are allowed to choose their diet from pure macronutrient sources (Boghossian et al. 2001). This phenomenon is linked to reward behaviour which caused its complex process (Haghighi et al. 2014). Despite considerable progress being made in characterizing the mechanisms and neural pathways underlying opioid-induced feeding behaviour, the role of the opioidergic system in determining macronutrient preference remains unclear (Taha 2010). Opioidergic system plays crucial role in macronutrient selection. ICV administration of morphine amplified carbohydrate intake in the carbohydrate-preferrers and stimulated fat intake in the fat-preferring rats (Gosnell and Levine 2009). For instance, high-fat food is selectively enhanced via nucleus accumbens (NAcc) μ-opioid receptors in rat (Zhang et al. 1998).

Numerous researches suggest many aspects of feeding regulation in avian appear similar to those in mammals but there are some responses that are anomalous in domestic fowls (Bungo et al. 2005). Preference for fat is a complex feeding behaviour regulated by reward-related mechanisms to maintain energy balance and expenditure (Haghighi et al. 2014). Based on the literature review, there is no report on the role of opioidergic receptors in appetite regulation in response to different diet types in avian. On the basis of comparative physiology it is important to determine the mechanisms of food intake control in other species (Zendehdel and Hassanpour 2014).

Because chickens, as a precocial species, recognize and ingest food voluntarily, it is worth knowing about the feeding behaviour of neonatal chicks (Bungo et al. 2004). So, the aim of the current study was to determine the role of central μ-, δ-, and κ-receptors in feeding behaviour in *ad libitum* fed neonatal meat-type chicken in the presence of different diets.

MATERIAL AND METHODS

Animals. A total of 576 one-day-old meat-type chickens (Ross 308) were purchased from a local hatchery (Morghak Co., Tehran, Iran). The chicken were kept as flocks for 2 days, then randomly transferred into individual cages and kept at a temperature of 30 ± 1°C with 50 ± 2% humidity (Olanrewaju et al. 2006). Four experimental diets were used in this study (standard diet without fat, diet containing nutrient energy ratio by 20% higher than standard, diet containing nutrient energy ratio by 20% lower than standard, and standard diet containing fat; Chineh Co., Tehran, Iran) to determine the role of central μ-, δ-, and κ-receptors on feeding behaviour of meat-type chickens. The composition of diets is presented in Table 1. All chicks were offered food *ad libitum* and fresh water during the study. The injections were applied to all birds at 5 days of age.

Animal handling and experimental procedures were performed according to the Guide for the Care and Use of Laboratory Animals by the National Institutes of Health, USA (publication No. 85-23, revised 1996) and the current laws of the Iranian government for animal care, and were approved by the Institutional Animal Ethics Committee of the Faculty of Veterinary Medicine, University of Tehran.

Experimental drugs. Drugs, D-Ala2-NMe-Phe4-Glyol5-Enkephalin (DAMGO, μ-opioid receptor agonist), [D-Pen^{2,5}]Enkephalin, [D-Pen^{2}, D-Pen^{5}] Enkephalin (DPDPE, δ-opioid receptor agonist), U-50488H (κ-opioid receptor agonist), and Evans

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blue were purchased from Sigma-Aldrich (USA). Drugs were first dissolved in absolute dimethyl sulfoxide (DMSO), then diluted with 0.85% control solution (saline) containing Evans blue at a ratio of 1 : 250.

ICV injection procedures. In this study, 12 experiments were performed to determine the possible role of μ, δ, and κ receptors in feeding responses of meat-type chicken in the presence of different diets (each experiment included 4 groups with 12 replicates in each group; n = 48). Prior to each experiment, the chickens were weighed and based on their body weight (BW) divided into experimental groups, so the average weight between treatment groups was as uniform as possible. The ICV injections were done using a microsyringe (Hamilton, Switzerland) without anesthesia in accordance with the technique described by Davis et al. (1979) and

Table 1. Ingredient and nutrient analysis of experimental diets

Ingredient (%)	Standard diet without fat	Standard diet with fat	Nutrient energy ratio	
			20% above standard	20% below standard
Corn grain	59.78	50.00	66.35	50.81
Soybean meal, 44% crude protein	24.67	40.43	24.53	25.07
Gluten meal	9.70	0.00	4.17	17.13
Soybean oil	0.00	4.00	0.00	0.00
Oyster shell	1.39	1.34	1.21	1.63
Di-calcium phosphate	1.98	1.87	1.62	2.44
Salt	0.23	0.23	0.18	0.27
Sodium bicarbonate	0.26	0.27	0.22	0.31
Mineral permix[1]	0.25	0.25	0.25	0.25
Vitamin permix[2]	0.25	0.25	0.25	0.25
DL-Methionine	0.30	0.39	0.28	0.34
L-Lysine monohydrochloride	0.66	0.28	0.45	0.92
L-Threonine	0.48	0.64	0.44	0.53
Salinomycin	0.05	0.05	0.05	0.05
Nutrient analysis				
Metabolizable energy (kcal/kg)	2970	2970	2970	2970
Crude protein (%)	23.07	23.07	19.97	27.31
Calcium (%)	1.05	1.05	0.90	1.24
Available phosphorus (%)	0.50	0.50	0.42	0.59
Sodium (%)	0.18	0.18	0.15	0.21
Potassium (%)	0.71	0.96	0.70	0.71
Chloride (%)	0.17	0.17	0.15	0.20
Lysine (%)	1.43	1.43	1.23	1.70
Methionine + cysteine (%)	1.07	1.07	0.93	1.27
Tryptophan (%)	0.25	0.32	0.23	0.27
Threonine (%)	0.94	0.94	0.81	1.11
Linoleic acid (%)	1.73	1.79	1.88	1.54

[1]contents per kg of diet: copper 12 mg, iodine 1 mg, iron 40 mg, manganese 120 mg, selenium 0.30 mg, zinc 100 mg

[2]contents per kg of diet: retinol (Vitamin A) 15 000 IU, cholecalciferol (Vitamin D_3) 5 000 IU, tocopherol (Vitamin E) 60 IU, menadione (Vitamin K_3) 3 g, thiamine (Vitamin B_1) 3 mg, riboflavin (Vitamin B_2) 8 mg, nicotinic acid (Vitamin B_3) 70 mg, pantothenic acid (Vitamin B_5) 20 mg, pyridoxine (Vitamin B_6) 3 mg, biotin 1.5 mg, folic acid 1.5 mg, choline chloride 1500 mg

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Furuse et al. (1997) in which the head of the birds was held with an acrylic device while the bill holder was at 45° and calvarium parallel to the surface of table (Van Tienhoven and Juhasz 1962). A hole was drilled in a plate laid over the right lateral ventricle. A microsyringe was inserted into the right ventricle through the hole and the tip of the needle penetrated 4 mm beneath the skin of the skull. There is no injection-induced physiological stress by this technique in neonatal chickens (Saito et al. 2005). All injections were done in a volume of 10 µl (Furuse et al. 1999). The control group received control solution (saline containing 10 µl Evans) (Furuse et al. 1999). At the end of the experiments, to recognize accuracy of injection, chicken were killed by decapitation. Accuracy of placement of the injection in the ventricle was verified by the presence of Evans blue followed by slicing the frozen brain tissue. In each group, 12 birds received injection, but just the data of those individuals where dye was present in their lateral ventricle were used for analysis (9–12 chickens per group). All experimental procedures were done from 8:00 a.m. until 3:30 p.m.

Feeding experiments. Experiments 1–12 were done to investigate specific effects of opioid receptors on feeding behaviour in *ad libitum* fed neonatal meat-type chicken. Experiments 1–4 were designed to investigate the effects of µ-opioid receptors on food consumption of birds to different diets. Each experiment included 4 groups (A–D). In Experiment 1, birds were ICV injected with (A) saline, (B) DAMGO (125 pmol), (C) DAMGO (250 pmol) and (D) DAMGO (500 pmol), then standard diet without fat was offered to the birds. In Experiment 2, chicken were ICV injected with (A) saline, (B) DAMGO (125 pmol), (C) DAMGO (250 pmol) and (D) DAMGO (500 pmol), then fed diet containing nutrient energy ratio by 20% lower than standard. In Experiment 3, the birds received injections of (A) saline, (B) DAMGO (125 pmol), (C) DAMGO (250 pmol) and (D) DAMGO (500 pmol) and were fed diet containing nutrient energy ratio by 20% higher than standard. In Experiment 4, birds were fed standard diet containing fat after ICV injection with (A) saline, (B) DAMGO (125 pmol), (C) DAMGO (250 pmol) and (D) DAMGO (500 pmol).

Experiments 5–8 were designed to determine the effects of δ-opioid receptors on feeding behaviour of neonatal meat-type chicken to different diets. In Experiment 5, chicken were ICV injected with (A) saline, (B) DPDPE (20 nmol), (C) DPDPE (40 nmol), and (D) DPDPE (80 nmol), then received standard diet without fat. In Experiment 6, diet containing nutrient energy ratio by 20% lower than standard was provided to the birds which were ICV injected with (A) saline, (B) DPDPE (20 nmol), (C) DPDPE (40 nmol), and (D) DPDPE (80 nmol). In Experiment 7, the ICV injected chicken with (A) saline, (B) DPDPE (20 nmol), (C) DPDPE (40 nmol), and (D) DPDPE (80 nmol) were fed diet containing nutrient energy ratio by 20% higher than standard. In Experiment 8, chickens were fed standard diet containing fat after ICV injection of (A) saline, (B) DPDPE (20 nmol), (C) DPDPE (40 nmol), and (D) DPDPE (80 nmol).

In Experiments 9–12, the effects of κ-opioid receptors on feeding behaviour of neonatal meat-type chicken to different diets was determined. In Experiment 9, chicken were ICV injected with (A) saline, (B) U-50488H (10 nmol), (C) U-50488H (20 nmol), and (D) U-50488H (40 nmol) and were offered a standard diet without fat. In Experiment 10, birds were ICV injected with (A) saline, (B) U-50488H (10 nmol), (C) U-50488H (20 nmol), and (D) U-50488H (40 nmol), then fed diet containing nutrient energy ratio by 20% lower than standard. In Experiment 11, chicken were injected using (A) saline, (B) U-50488H (10 nmol), (C) U-50488H (20 nmol), and (D) U-50488H (40 nmol), then consumed a diet containing nutrient energy ratio by 20% higher than standard. In Experiment 12, injection procedure was (A) saline, (B) U-50488H (10 nmol), (C) U-50488H (20 nmol), and (D) U-50488H (40 nmol) and birds were fed standard diet containing fat. Injection dosages were calculated based on previous (Steinman et al. 1987; Bungo et al. 2004, 2005; Khan et al. 2009; Zendehdel et al. 2015c) and our pilot studies (unpublished). In all groups, immediately after injection, fowls were returned to their individual cages and supplied fresh water and food (pre-weighed). Cumulative food intake (g) was measured at 30, 60, 120, and 180 min post injection. Food consumption (plus any food spillage) was calculated as a percentage of BW weight to minimize the impact of BW on the amount of food intake. Each bird was used just once in each experimental group. The injection procedure is presented in Table 2.

Statistical analysis. Cumulative food intake (% BW) was analyzed by two-way analysis of variance

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Table 2. Treatments procedure in Experiments 1–12 (in each series of experiments birds were injected with the same agonist but were provided different diets)

Treatment groups	ICV injection
Experiments 1–4	
I	CS
II	DAMGO (125 pmol)
III	DAMGO (250 pmol)
IV	DAMGO (500 pmol)
Experiments 5–8	
I	CS
II	DPDPE (20 nmol)
III	DPDPE (40 nmol)
IV	DPDPE (80 nmol)
Experiments 9–12	
I	CS
II	U-50488H (10 nmol)
III	U-50488H (20 nmol)
IV	U-50488H (40 nmol)

CS = control solution, DAMGO = μ-opioid receptor agonist, DPDPE = δ-opioid receptor agonist, U-50488H = κ-opioid receptor agonist

(ANOVA) for repeated measurement using the software SPSS 16.0 for Windows and is presented as mean ± SEM. For treatments showing a main effect by ANOVA, means were compared using *post hoc* Bonferroni test. $P < 0.05$ was considered as significant difference between treatments.

RESULTS

Effects of specific opioid receptors (μ, δ, and κ) on feeding behaviour in *ad libitum* fed neonatal chicken to different diets are shown in Figures 1–12.

In Experiment 1, ICV injection of different levels of DAMGO (μ-opioid receptor agonist; 125, 250, and 500 pmol) significantly decreased birds appetite to intake of standard diet without fat compared to control group (saline injected) ($P < 0.05$) (Figure 1). As seen in Experiment 2, ICV injection of DAMGO (125, 250, and 500 pmol) significantly induced hypophagia to diet containing nutrient energy ratio by 20% lower than standard ($P < 0.05$) (Figure 2). ICV injection of DAMGO in a dose-dependent manner diminished intake of diet containing nutrient energy ratio by 20% higher than standard in comparison to control group (saline injected) in neonatal meat-type chickens ($P < 0.05$) (Figure 3). A significant decrease in appetite to standard diet containing fat was observed in neonatal meat-type birds injected with 125, 250, and 500 pmol of DAMGO ($P < 0.05$) (Figure 4).

As seen in Figure 5, ICV injection of different levels of DPDPE (δ-opioid receptor agonist; 20, 40, and 80 nmol) significantly increased eating behaviour in *ad libitum* fed neonatal meat-type chickens that received standard diet without fat in comparison to control group (saline injected) ($P < 0.05$). The same manner was observed for feeding behaviour of the birds offered diet containing nutrient energy ratio by 20% lower than

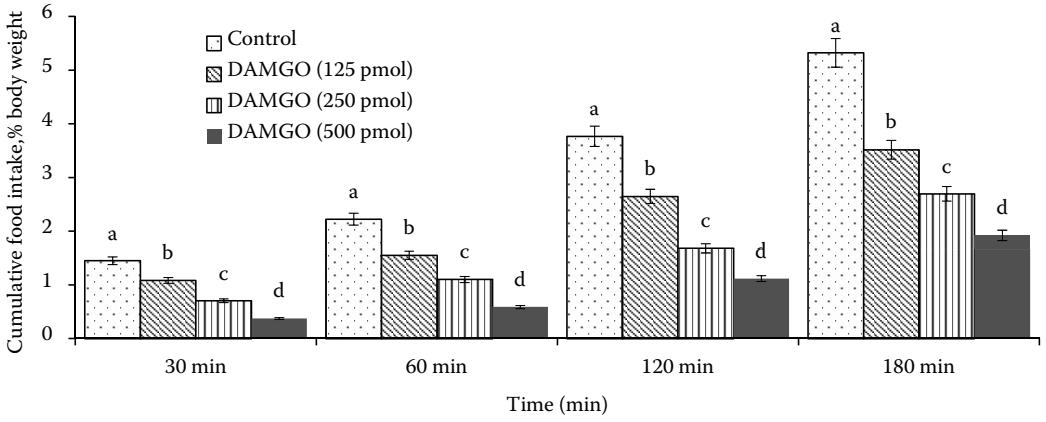

Figure 1. Effect of ICV injection of different levels of DAMGO (μ-opioid receptor agonist; 125, 250, and 500 pmol) in neonatal meat-type chickens fed standard diet without fat
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

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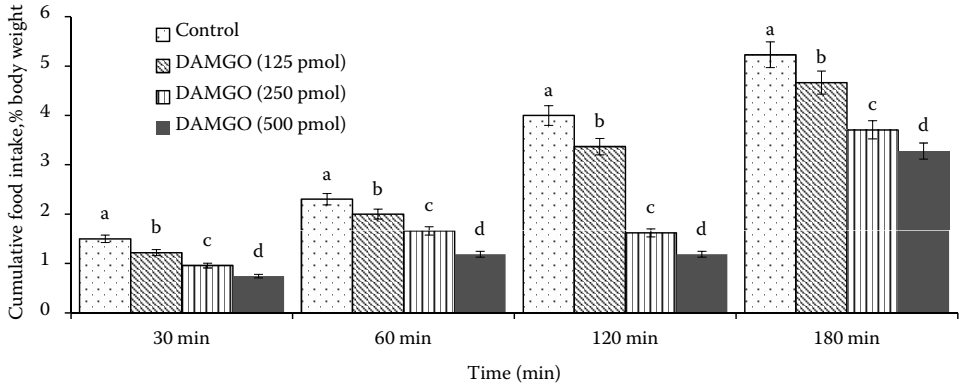

Figure 2. Effect of ICV injection of different levels of DAMGO (μ-opioid receptor agonist; 125, 250, and 500 pmol) in neonatal meat-type chickens fed diet containing nutrient energy ratio by 20% lower than standard
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

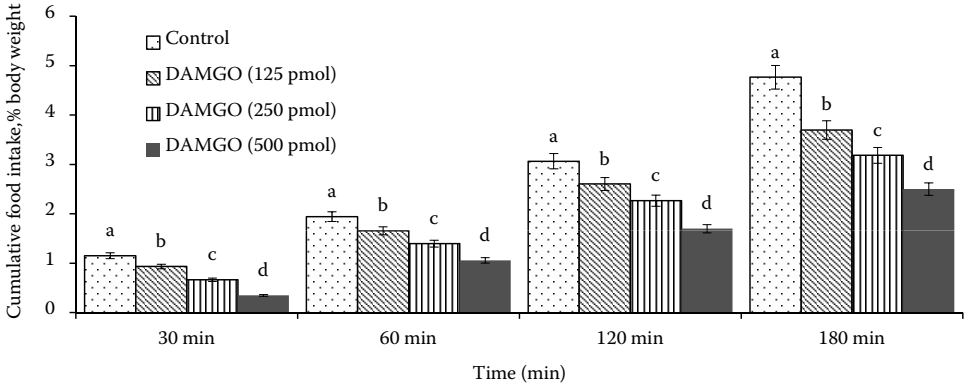

Figure 3. Effect of ICV injection of different levels of DAMGO (μ-opioid receptor agonist; 125, 250, and 500 pmol) in neonatal meat-type chickens fed diet containing nutrient energy ratio by 20% higher than standard
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

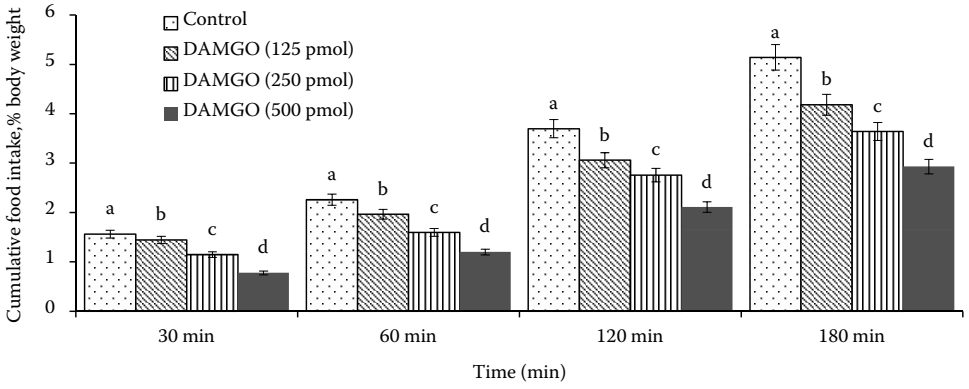

Figure 4. Effect of ICV injection of different levels of DAMGO (μ-opioid receptor agonist; 125, 250, and 500 pmol) in neonatal meat-type chickens fed standard diet containing fat
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

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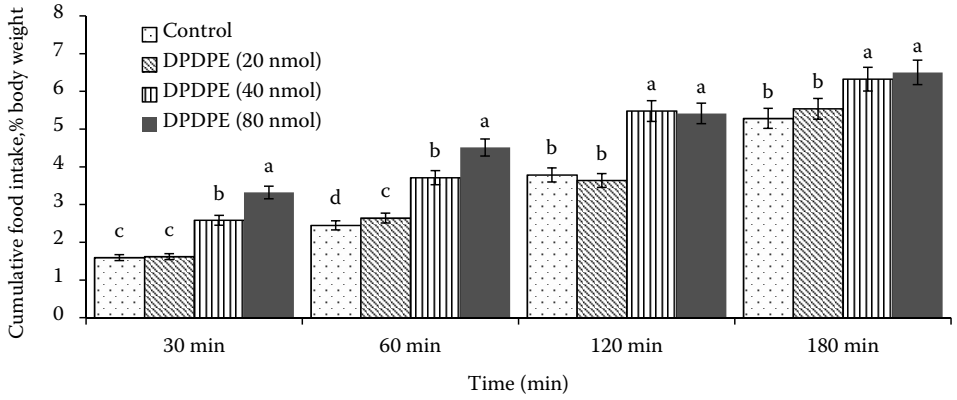

Figure 5. Effect of ICV injection of different levels of DPDPE (δ-opioid receptor agonist; 20, 40, and 80 nmol) in neonatal meat-type chickens fed standard diet without fat
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

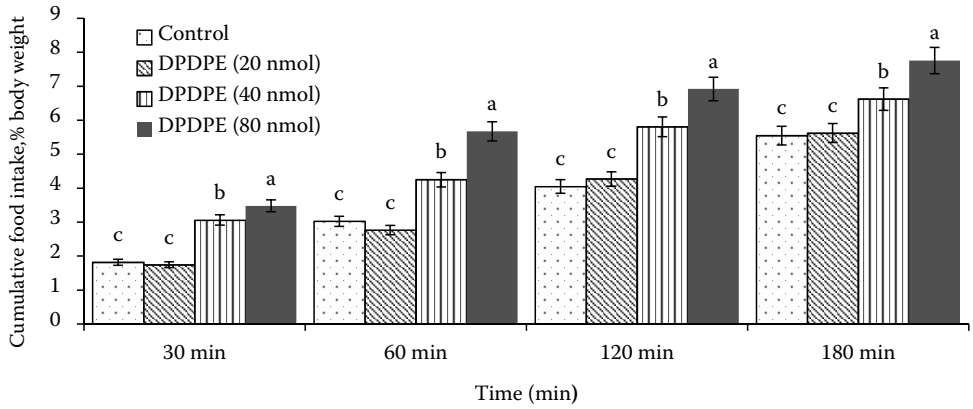

Figure 6. Effect of ICV injection of different levels of DPDPE (δ-opioid receptor agonist; 20, 40, and 80 nmol) in neonatal meat-type chickens fed diet containing nutrient energy ratio by 20% lower than standard
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

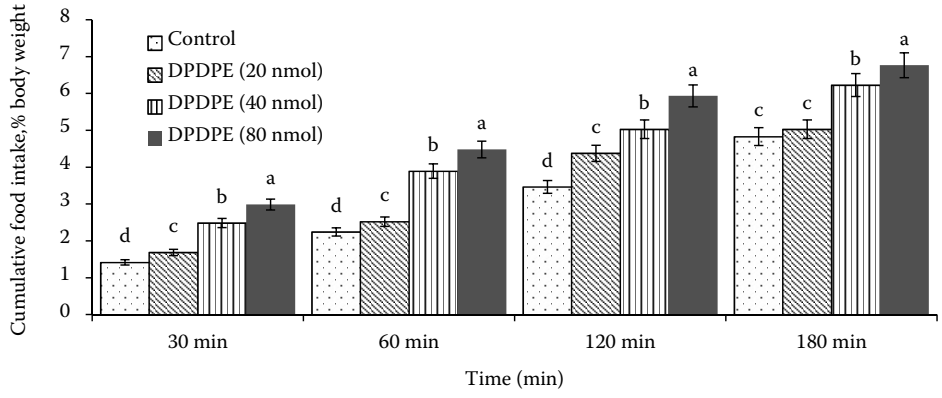

Figure 7. Effect of ICV injection of different levels of DPDPE (δ-opioid receptor agonist; 20, 40, and 80 nmol) in neonatal meat-type chickens fed diet containing nutrient energy ratio by 20% higher than standard
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

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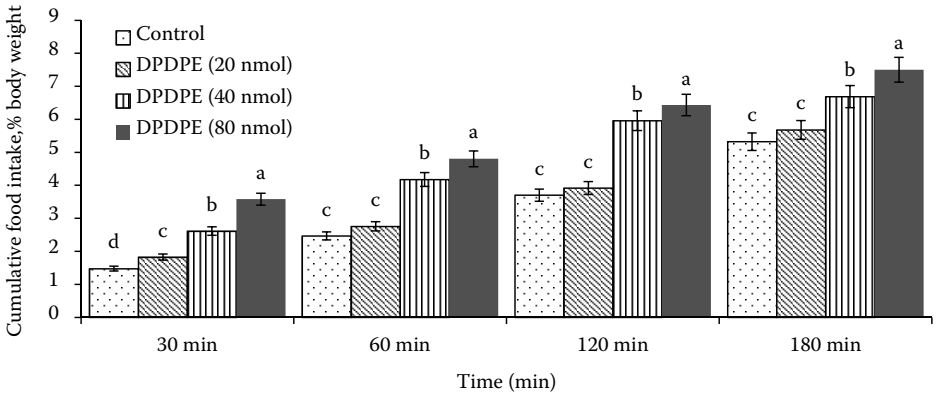

Figure 8. Effect of ICV injection of different levels of DPDPE (δ-opioid receptor agonist; 20, 40, and 80 nmol) in neonatal meat-type chickens fed standard diet containing fat
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

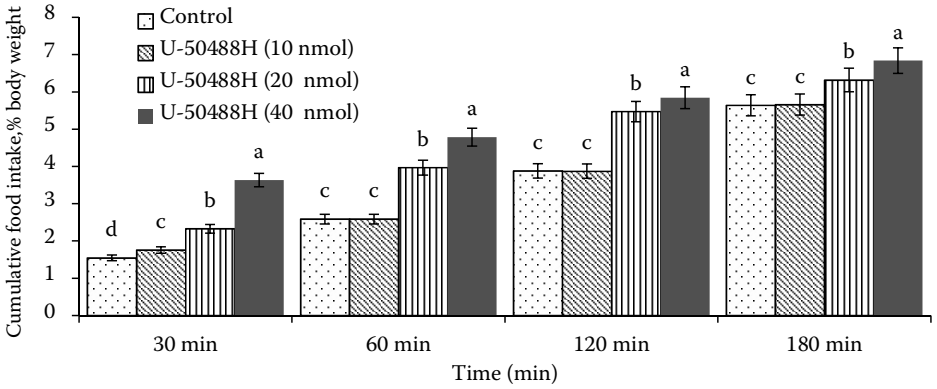

Figure 9. Effect of ICV injection of different levels of U-50488H (κ-opioid receptor agonist; 10, 20, and 40 nmol) in neonatal meat-type chickens fed standard diet without fat
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

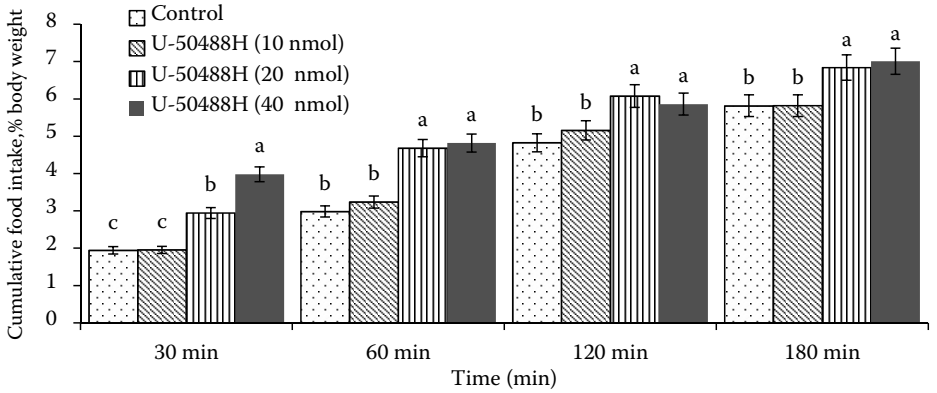

Figure 10. Effect of ICV injection of different levels of U-50488H (κ-opioid receptor agonist; 10, 20, and 40 nmol) in neonatal meat-type chickens fed diet containing nutrient energy ratio by 20% lower than standard
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

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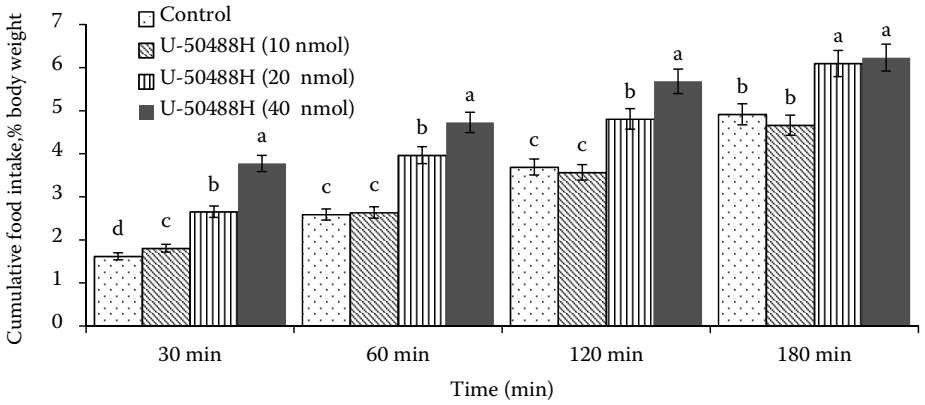

Figure 11. Effect of ICV injection of different levels of U-50488H (κ-opioid receptor agonist; 10, 20, and 40 nmol) in neonatal meat-type chickens fed diet containing nutrient energy ratio by 20% higher than standard
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

standard ($P < 0.05$) (Figure 6). The administration of DPDPE at the levels of 20, 40, and 80 nmol significantly increased intake of diet containing nutrient energy ratio by 20% higher than standard compared to control group (saline injected) ($P < 0.05$) (Figure 7). In this study, ICV injection of different doses of DPDPE (20, 40, and 80 nmol) showed the hyperphagic effect to the standard diet containing fat ($P < 0.05$) (Figure 8).

The effects of ICV injection of different levels of κ-opioid receptor agonist (U-50488H) are presented in Figures 9–12. As observed, ICV administration of U-50488H (10, 20, and 40 nmol) significantly increased intake of diet without fat compared to control group (saline injected) in *ad libitum* fed neonatal meat-type chickens ($P < 0.05$) (Figure 9). In this study, ICV injection of 10, 20, and 40 nmol of U-50488H increased feeding behaviour to diets containing nutrient energy ratio by 20% lower than standard ($P < 0.05$) (Figure 10). In Experiment 11, a hyperphagic response to a diet containing nutrient energy ratio by 20% higher than standard in *ad libitum* fed neonatal meat-type chickens injected with different doses of U-50488H (10, 20, and 40 nmol) in comparison to control group (saline injected) ($P < 0.05$) was observed. The same response was observed for standard diet containing fat in neonatal meat-type chickens injected with U-50488H (10, 20, and 40 nmol) ($P < 0.05$) (Figure 12).

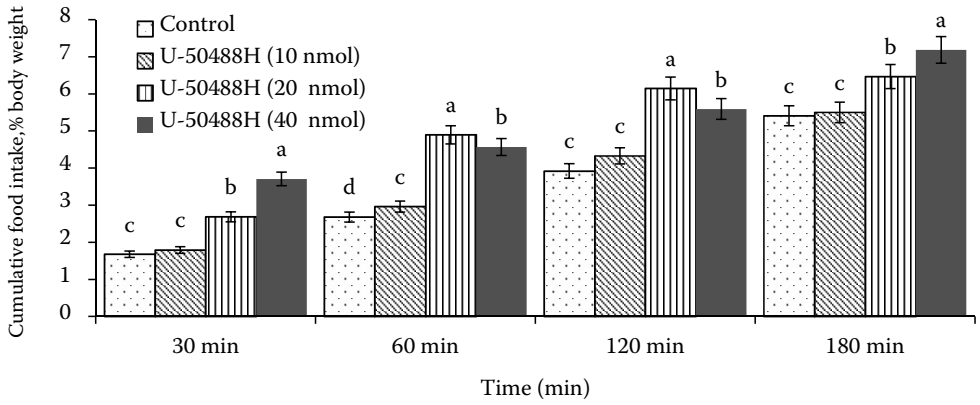

Figure 12. Effect of ICV injection of different levels of U-50488H (κ-opioid receptor agonist; 10, 20, and 40 nmol) in neonatal meat-type chickens fed standard diet containing fat
results are presented as mean ± SEM
[a–d]differences between groups with different superscripts are significant ($P \leq 0.05$)

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DISCUSSION

So far, frequent researches have been done to investigate the role of the opioidergic system in reward in mammals, but aspects of food intake regulation in avian are still unclear (Hassanpour et al. 2015). To the best of our knowledge, despite the researches done to determine the role of the μ-, δ-, and κ-receptors in appetite regulation, limited studies exist on the role of the μ-, δ-, and κ-opioid receptors in appetite regulation in response to different diet types. According to the results, ICV injection of DAMGO diminished while DPDPE and U-50488H increased food intake in *ad libitum* fed neonatal meat-type chicken. Central mechanisms for appetite regulation in chicken are somewhat dissimilar from those in mammals. It is reported that ICV injection of DAMGO (125, 250, and 500 pmol) inhibited while DPDPE (20, 40, and 80 nmol) and U-50488H (10, 20, and 40 nmol) increased food intake in layer-type chicken (Shojaei et al. 2015). However, μ-, δ-, and κ-opioid receptors are known as an orexigenic neurotransmitters (Kaneko et al. 2012; Kozlov et al. 2013).

Herein, despite μ-opioid receptor being hypophagic and δ- and κ-opioid receptors having hyperphagic effects, only the μ-opioid receptor increased the desire to eat the fat containing standard diet in the *ad libitum* fed neonatal meat-type chicken. Several reports from the earlier studies revealed modification in caloric intake and dietary preferences as a function when animals were allowed to choose their diet from pure macronutrient sources. Among the neuropeptides, endogenous opioids play a role in diet selection and the rewarding properties of palatable foods in rat (Boghossian et al. 2001). For example, morphine increases fat consumption while it either decreases or has no effect on carbohydrate or protein intake (Gosnell and Levine 2009). A fascinating aspect of opioid-induced ingestion is that μ-opioid receptors have a potent role in highly palatable foods, mainly sweet or fatty diets (Taha 2010). However, the exact mechanism of how opiates interact on macronutrient preference remains unclear. Perhaps opioid signalling increases consumption of preferred foods and/or preferentially increases consumption of fat (Taha 2010). Infusions of DAMGO into the nucleus accumbens (NAcc) stimulate high-fat diet intake in rats (Olszewski et al. 2011). Peripheral injection of opioid antagonist reduced food intake of the only diet preferred in rats (Woolley et al. 2006).

Feeding behaviour is modulated in several parts of the brain, such as striatum, hypothalamus, amygdala, orbitofrontal cortex, nucleus ventral tegmental area, NAcc, nucleus tractus solitaries, and arcuate nucleus (ARC) (Parker et al. 2014). Pharmacological and neuroanatomical researches revealed that the concept of opioid-driven feeding reward was facilitated only by reward sites. μ-Opioids signalling exert their rewarding effects via NAcc (Pecina 2008). Also, hypothalamic paraventricular opioids alter the intake of high-fat, but not high-sucrose diet, depending on diet preference in rats. Perhaps activation of opioid receptors in the paraventricular nucleus and NAcc is necessary for fat intake (Naleid et al. 2007). Signalling through opioid receptors at both sites increased after eating fat containing diet (Naleid et al. 2007). Complex mechanisms are responsible for feeding regulation, so it becomes clear that reward is in fact a dynamic and individual-specific state (Olszewski et al. 2011).

An interconnection between the opioidergic system and neuropeptide Y (NPY) and the agouti related protein neurons in the ARC has been reported (Woolley et al. 2006). μ-Opioid receptor shows high affinity for endogenous (β-endorphin and enkephalin) opioids. In rats, NPY-producing neurons are synaptically linked with β-endorphin producing neurons in the ARC (Barnes et al. 2006). However, the neural pathway between NPY and opioidergic system is not identified in poultry's hypothalamus (Dodo et al. 2005). These centers directly and indirectly mediate orexigenic properties of opioid receptors (Olszewski et al. 2011). The anorexic effect of μ-opioid receptor on NPY-induced food intake of carbohydrates and fats was dependent on diet preference (Zhang et al. 1998). ICV injection of morphine or DAMGO into the ARC increased μ-opioid receptor mRNA expression in rodents (Zheng et al. 2007).

On the basis of these results, however, the role of μ-opioid receptors in feeding behaviour is different in avian compared to mammals, but the increased desire to eat fat containing diet caused by these receptors was similar to mammalian (Le Merrer et al. 2009; Kaneko et al. 2012). Given the estimated 300 million years of evolutionary distance between mammals and avian, it is not surprising that significant differences have been found in the activity of neurotransmitters such as ghrelin involved in the regulation of energy homeostasis

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(Novoseletsky et al. 2011; Zendehdel et al. 2015b). To the best of our knowledge, there has been no previous study on the role of opioid receptors in feeding response of avian species in the presence of different diets. So, our results are incomparable.

As observed in this study, the effect of μ-opioid receptors on feeding behaviour is different in avian compared to mammals (Le Merrer et al. 2009; Kaneko et al. 2012). For instance, the ICV injection of μ- and δ- (but not κ-) opioid receptors agonists exerts orexigenic effects in mammals (Taha 2010; Kaneko et al. 2012). The ICV injection of μ-opioid receptors agonist decreases while that of δ- and κ-opioid receptors agonists increases food intake in neonatal meat-type chicks (Bungo et al. 2005). In conclusion, these findings suggest endogenous governing food preferences via δ- and κ-opioid receptor in *ad libitum* fed neonatal chicken. Also, endogenous opioids promoted preferences for fat rich diet in *ad libitum* fed neonatal meat-type chicken. Despite frequent research done to determine how the opioidergic system interplays with food preference, the nature of this effect remains unclear (Gosnell and Levine 2009). Further investigations are needed to identify direct cellular and molecular signalling pathways of the opioidergic system in the control of feeding behaviour and macronutrient selection in poultry.

REFERENCES

Barnes M.J., Holmes G., Primeaux S.D., York D.A., Bray G.A. (2006): Increased expression of mu opioid receptors in animals susceptible to diet induced obesity. Peptides, 27, 3292–3298.

Bodnar R.J. (2014): Endogenous opiates and behaviour: 2013. Peptides, 62, 67–136.

Boghossian S., Jourdan D., Dacher M., Alliot J. (2001): Effect of morphine on caloric intake and macronutrient selection in male and female Lou/c/jall rats during ageing. Mechanisms of Ageing and Development, 122, 1825–1839.

Bungo T., Kawamura K., Izumi T., Dodo K., Ueda H. (2004): Feeding responses to μ-, δ- and κ-opioid receptor agonists in the meat-type chick. Pharmacology Biochemistry and Behavior, 78, 707–710.

Bungo T., Dodo K.I., Kawamura K., Izumi T., Ueda H. (2005): Effects of various μ- and δ-opioid ligands on food intake in the meat-type chick. Physiology and Behavior, 85, 519–523.

Davis J.L., Masuoka D.T., Gerbrandt L.K., Cherkin A. (1979): Autoradiographic distribution of L-proline in chicks after intracerebral injection. Physiology and Behavior, 22, 693–695.

Dodo K., Izumi T.H., Ueda H., Bungo T. (2005): Response of neuropeptide Y-induced feeding to μ-, δ- and κ-opioid receptor antagonists in the neonatal chick. Neuroscience Letters, 373, 85–88.

Figlewicz D.P., Sipols A.J. (2010): Energy regulatory signals and food reward. Pharmacology Biochemistry and Behavior, 97, 15–24.

Furuse M., Matsumoto M., Saito N., Sugahara K., Hasegawa S. (1997): The central corticotropin-releasing factor and glucagon-like peptide-1 in food intake of the neonatal chick. European Journal of Pharmacology, 339, 211–214.

Furuse M., Ando R., Bungo T., Ao R., Shimojo M., Masuda Y. (1999): Intracerebroventricular injection of orexins does not stimulate food intake in neonatal chicks. British Poultry Science, 40, 698–700.

Gosnell B.A., Levine A.S. (2009): Reward systems and food intake: role of opioids. International Journal of Obesity, 33, S54–S58.

Haghighi A., Melka M.G., Bernard M., Abrahamowicz M., Leonard G.T., Richer L., Perron M., Veillette S., Xu C.J., Greenwood C.M.T., Dias A., El-Sohemy A., Gaudet D., Paus T., Pausova Z. (2014): Opioid receptor mu 1 gene, fat intake and obesity in adolescence. Molecular Psychiatry, 19, 63–68.

Hassanpour S., Zendehdel M., Babapour V., Charkhkar S. (2015): Endocannabinoid and nitric oxide interaction mediates food intake in neonatal chicken. British Poultry Science, 56, 443–451.

Kaneko K., Yoshikawa M., Ohinata K. (2012): Novel orexigenic pathway prostaglandin D2–NPY system – involvement in orally active orexigenic δ opioid peptide. Neuropeptides, 46, 353–357.

Khan M.S.I., Ohkubo T., Masuda N., Tachibana T., Ueda H. (2009): Central administration of metastin increases food intake through opioid neurons in chicks. Comparative Biochemistry and Physiology – Part A, 153, 209–212.

Kozlov A.P., Nizhnikov M., Kramskaya T.A., Varlinskaya E.I., Spear N.E. (2013): μ-Opioid blockade reduces ethanol effects on intake and behaviour of the infant rat during short-term but not long-term social isolation. Pharmacology Biochemistry and Behavior, 103, 773–782.

Le Merrer J., Becker J.A.J., Befort K., Kieffer B.L. (2009): Reward processing by the opioid system in the brain. Physiology and Behavior, 89, 1379–1412.

Naleid A.M., Grace M.K., Chimukangara M., Billington C.J., Levine A.S. (2007): Paraventricular opioids alter intake of high-fat but not high-sucrose diet depending on diet preference in a binge model of feeding. American Journal of Physiology – Regulatory, Integrative and Comparative Physiology, 293, R99–R105.

doi: 10.17221/2/2016-CJAS

Novoseletsky N., Nussinovitch A., Friedman-Einat M. (2011): Attenuation of food intake in chicks by an inverse agonist of cannabinoid receptor1 administered by either injection or ingestion in hydrocolloid carriers. General and Comparative Endocrinology, 170, 522–527.

Olanrewaju H.A., Thaxton J.P., Dozier W.A., Purswell J., Roush W.B., Branton S.L. (2006): A review of lighting programs for broiler production. International Journal of Poultry Science, 5, 301–308.

Olszewski P.K., Alsio J., Schioth H.B., Levine A.S. (2011): Opioids as facilitators of feeding: Can any food be rewarding? Physiology and Behavior, 104, 105–110.

Parker K.E., Johns H.W., Floros T.G., Will M.J. (2014): Central amygdala opioid transmission is necessary for increased high-fat intake following 24-h food deprivation, but not following intraaccumbens opioid administration. Behavioural Brain Research, 260, 131–138.

Pecina S. (2008): Opioid reward 'liking' and 'wanting' in the nucleus accumbens. Physiology and Behavior, 94, 675–680.

Saito E.S, Kaiya H., Tachibana T., Tomonaga S., Denbow D.M., Kangawa K., Furuse M. (2005): Inhibitory effect of ghrelin on food intake is mediated by the corticotropin-releasing factor system in neonatal chicks. Regulatory Peptides, 125, 201–208.

Shiraishi J., Yanagita K., Fujita M., Bungo T. (2008): μ-Opioid receptor agonist diminishes POMC gene expression and anorexia by central insulin in neonatal chicks. Neuroscience Letters, 439, 227–229.

Shojaei M., Zendehdel M., Babapour V., Charkhkar S., Hassanpour S. (2015): Opioid-induced hypophagia is mediated by 5-HT_2c receptors in neonatal layer-type chicken. Czech Journal of Animal Science, 60, 400–410.

Steinman J.L., Fujikawa D.G., Wasterlain C.G., Cherkin A., Morley J.E. (1987): The effects of adrenergic, opioid and pancreatic polypeptidergic compounds on feeding and other behaviours in neonatal leghorn chicks. Peptides, 8, 585–592.

Taha S.A. (2010): Preference or fat? Revisiting opioid effects on food intake. Physiology and Behavior, 100, 429–437.

Van Tienhoven A., Juhasz L.P. (1962): The chicken telencephalon, diencephalon and mesencephalon in sterotaxic coordinates. Journal of Comparative Neurology, 118, 185–197.

Woolley J.D., Lee B.S., Fields H.L. (2006): Nucleus accumbens opioids regulate flavor-based preferences in food consumption. Neuroscience, 143, 309–317.

Zendehdel M., Hassanpour S. (2014): Ghrelin-induced hypophagia is mediated by the β_2 adrenergic receptor in chicken. The Journal of Physiological Sciences, 64, 383–391.

Zendehdel M., Baghbanzadeh A., Yeganeh B., Hassanpour S. (2015a): The role of cyclooxygenase inhibitors in lipopolysaccharide-induced hypophagia in chicken. Czech Journal of Animal Science, 60, 342–350.

Zendehdel M., Ghashghayi E., Hassanpour S., Baghbanzadeh A., Jonaidi H. (2015b): Interaction between opioidergic and dopaminergic systems on food intake in neonatal layer type chicken. International Journal of Peptide Research and Therapeutics, 22, 83–92.

Zendehdel M., Hassanpour S., Babapour V., Charkhkar S., Mahdavi M. (2015c): Interaction between endocannabinoid and opioidergic systems regulates food intake in neonatal chicken. International Journal of Peptide Research and Therapeutics, 21, 289–297.

Zhang M., Gosnell B.A., Kelley A.E. (1998): Intake of high-fat food is selectively enhanced by mu opioid receptor stimulation within the nucleus accumbens. Journal of Pharmacology and Experimental Therapeutics, 285, 908–914.

Zheng H., Patterson L.M., Berthoud H.R. (2007): Orexin signaling in the ventral tegmental area is required for high-fat appetite induced by opioid stimulation of the nucleus accumbens. Journal of Neuroscience, 27, 11075–11082.

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