

DOI: <http://dx.doi.org/10.5281/zenodo.15292798>

Effect of lavender (*Lavender angustifolia*) extract on food consumption, melatonin, leptin and reproductive parameters in male Syrian hamsters (*Mesocricetus auratus*)

Emine İnci Balkan ¹, Bülent Gündüz ^{2,*}

¹ Department of Medical Laboratory Techniques, Vocational School of Health Services, Demiroglu Bilim University, Istanbul, 34570 Turkey

² Department of Biology, Faculty of Science, Çanakkale Onsekiz Mart University, Çanakkale, 17020 Turkey

* Corresponding author e-mail: bgunduzbio@comu.edu.tr

Received: 16 December 2024; Revised submission: 14 February 2025; Accepted: 26 March 2025



<https://jbrodka.com/index.php/ejbr>

Copyright: © The Author(s) 2025. Licensee Joanna Bródka, Poland. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>)

ABSTRACT: Lavender (*Lavandula angustifolia*) is a plant of medicinal and economic importance. This study investigated the effects of lavender extract at different doses on metabolism and reproductive physiology in male Syrian hamsters (*Mesocricetus auratus*) under long photoperiod (16L; 16 hours of light, 8 hours of darkness). Male Syrian hamsters aged 6-8 weeks were administered different doses of lavender extract dissolved in saline intraperitoneally every day at the same time (12:00-13:00 h) for 21 days. A significant decrease in food consumption was observed in the group treated with 200 mg/kg of lavender extract ($p < 0.05$). The effects of the 100 mg/kg and 200 mg/kg doses on body weight were also noted. Blood samples for hormone measurement were collected at two different times of the day (12:00 h and 00:00 h) at the end of the experiment. It was shown that melatonin levels significantly increased at the 100 mg/kg dose of lavender extract in both times ($p < 0.05$). However, no significant difference was found between the light and dark phases at the 200 mg/kg dose ($p > 0.05$). A significant decrease in testosterone levels was observed compared to the control group. Similarly, no significant difference was detected between the light and dark phases at the 200 mg/kg dose ($p > 0.05$). No significant differences were observed in testis histology between the control and treatment groups. In conclusion, lavender extract has positive effects on metabolism, but it may have negative effects on the reproductive system at high doses.

Keywords: Hamster; Lavender; Leptin; Metabolism; Plant extract; Reproduction.

1. INTRODUCTION

Plants in nature have been used by humans for various purposes for centuries. While plants are often used in health and beauty, they also hold an important place in nutrition. They are consumed fresh in season or dried as food or drink out of season. Nowadays, with the rapid rise of diseases, interest in organic agricultural products and natural nutrition has also increased. However, the correct use of these plants is crucial for human health. Consuming too much, as well as too little, can sometimes cause health issues. While many plants have therapeutic properties, some of the active ingredients they contain can be potentially carcinogenic, mutagenic, and/or toxic [1]. Studies have shown that many plants contain mutagenic components [2], and findings suggest

that some also have potential natural antigenotoxic effects [3]. Lavender is one of the flowering plants that can be used as a natural antioxidant source and potential food.

The *Lavandula* genus (Lamiaceae) is widespread in the Mediterranean region and is represented by 39 species in Turkey. Lavender (*Lavandula angustifolia*) has been used throughout history in Anatolia for both medicinal and aromatic purposes. Lavender has been used in the treatment of urinary tract infections, heart diseases, relief of rheumatic pain, and conditions such as eczema [4-9]. Lavender essential oils are frequently used in the perfume and cosmetics industries [10-12] and are also known for their antiseptic, disinfectant, and calming properties [13].

Among the essential oil components, linalool and linalyl acetate, which are found in the highest amounts, determine the characteristic odor and therapeutic effects of lavender extract [10]. In addition, components such as 1,8-cineole, β -caryophyllene and terpinen-4-ol also have important biological activities. In addition, lavender extract is rich in flavonoids and phenolic acids, and exhibits antioxidant and neuroprotective effects [14]. Research on the diverse biological impacts of lavender oil has demonstrated its analgesic, antibacterial, genotoxic, and anti-inflammatory properties [10, 15-17]. Additionally, it has been proposed that lavender extracts have anticancer properties and can be utilized to treat a number of illnesses [12, 18]. Also, studies has demonstrated that lavender oil affects the central nervous system, making it very useful in the treatment of anxiety, stress, and sleep issues [19-22]. In addition, lavender tea is frequently used to treat insomnia and lower stress.

Some studies have shown that lavender may have impacts on the reproductive system. Lavender oil has been demonstrated to help regulate reproductive hormones and enhance sperm quality [23, 24]. Lavender was given in different ways, especially by inhalation or ingestion, in different experimental groups. Considering all of this, no research has been done that solely looks at the effects of lavender extracts when they are injected directly into experimental groups. Thus, this study examines how extracts from lavender flowers affect Syrian hamsters' metabolic and reproductive systems.

2. MATERIALS AND METHODS

2.1. Preparation of the *L. angustifolia* extract

Dried flowers of *Lavandula angustifolia* were obtained from a local herbalist in Çanakkale. The dried samples were physically ground using a grinder. A Soxhlet device was used to extract 50 g of powdered *L. angustifolia* flowers in 400 mL of 70% ethanol over the course of eight hours. Ethanol was removed using an evaporater (40 °C). The extract was stored at +4 C⁰ until use. Lavender extract solutions used in the study were prepared using physiological serum.

The amount of active substances in the *L. angustifolia* plant varies depending on the soil structure, climatic circumstances, and altitude in the location where it is located, hence GC-MS service was employed. The components were characterized using a variety of electronic libraries.

2.2. Animals and housing

Male Syrian hamsters (*Mesocricetus auratus*) weighing about 120 g and 6–8 weeks of age were used. Four groups of forty male hamsters, each consisting of ten hamsters, were randomly assigned. The animals were obtained from the Hamster and Gerbil unit of the Çanakkale Onsekiz Mart University Research and Application Center for Experimental Animals (COMUDAM). During the 21-day experimental period, the laboratory temperature was maintained at approximately 22±2 °C. The hamsters were housed individually in polycarbonate cages (16 x 31 x 42 cm). The photoperiod was set at 16 hours of light and 8 hours of darkness. Food pellets and

tap water were provided *ad libitum*. All methods were conducted with the approval of the Çanakkale Onsekiz Mart University Animal Ethics Committee (Approval number: 2021/04-10).

2.3. Experimental design

The study was conducted in four groups. During the 21-day experiment, injections were made at the same time every day (12:00-13:00 h). According to the data obtained by Kashani et al. [25] and the effectiveness on the animals, the doses of the extracts were determined as 50 mg/kg, 100 mg/kg, 200 mg/kg.

Group 1 (Control Group; n=10): Since lavender extract was dissolved in physiological serum, the hamsters in this group were injected with physiological serum intraperitoneally between 12:00 and 13:00 for 21 days as the control group. Tissue and blood samples were taken at the end of the experiment.

Group 2 (50 mg/kg; n=10): The animals in this group were injected with 50 mg/kg *L. angustifolia* extract intraperitoneally between 12:00 and 13:00 for 21 days. At the end of the experiment, tissue and blood samples were taken.

Group 3 (100 mg/kg; n=10): The animals in this group were injected intraperitoneally with 100 mg/kg *L. angustifolia* extract between 12:00 and 13:00 for 21 days. At the end of the experiment, tissue and blood samples were taken.

Group 4 (200 mg/kg; n=10): The animals in this group were injected intraperitoneally with 100 mg/kg *L. angustifolia* extract between 12:00 and 13:00 for 21 days. At the end of the experiment, tissue and blood samples were taken.

2.4. Measurement of food intake and body weight

Weighed amounts of food pellets were put in the cages to measure the amount of food consumed. The food scraps and leftovers in the cages were weighed after a day. Possible food pieces were also considered into the consumption calculation because these animals have a tendency to keep food in their mouth. The amount of food consumed each day was assessed, and the average consumption for 21 days was noted. Weekly changes in body weight were recorded.

2.5. Measurement of serum hormones levels

At the end of the 21-day period, blood and testis tissue samples were collected from each group at two different times of day (12:00 and 00:00 h). Five hamsters from each group were decapitated at the specified times for sample collection. Approximately 5 mL of blood was taken for the measurement of melatonin, leptin, and testosterone levels. Blood samples collected during the dark phase were handled under dim red light. The blood samples were centrifuged at 4000 rpm for 30 minutes (Cence L-500), and the serum was stored at -20°C until analysis. Hormones were measured using commercial ELISA kits (BioAssay-Technology Laboratory Rat Melatonin E0601Ra; BioAssay-Technology Laboratory Rat Leptin E051Ra; BioAssay-Technology Laboratory Rat Testosterone EA0023Ra) following the manufacturer's instructions. Optical densities were determined at 450 nm using an ELISA microplate reader (Thermo Scientific Multiskan FC Microplate Reader USA).

2.6. Preparation of histological preparations and examination of sections

Hamster testes that were isolated were preserved in 10% formalin, subjected to standard histological procedures, and then embedded in paraffin. A microtome was used to cut 5 µm thick serial sections from each block. These sections were mounted on slides and stained with hematoxylin-eosin. The prepared slides were examined under an Olympus BX51 phase contrast microscope, and changes in testis composition were evaluated.

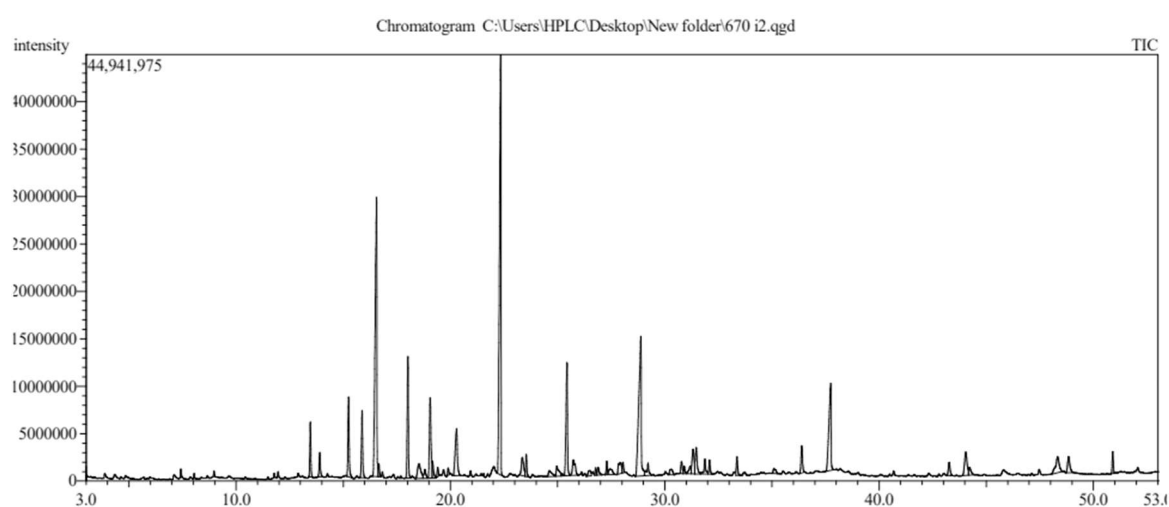
2.7. Statistical analysis

Statistical analysis was performed using SPSS 22.0 and Sigma Plot 14.0. Data were analyzed using SPSS v.11.0. One-way ANOVA was used to analyze hormone levels, followed by Duncan's multiple range test. t-tests were used to determine whether there were differences in means within or between groups. At $p < 0.05$, values were considered statistically significant. The data is presented as mean $\pm$ SEM.

3. RESULTS

3.1. GC-MS analysis

GC-MS analysis was performed to determine the active ingredients in the lavender plant. Figure 1 shows the levels of the active ingredients.



Peak Report TIC

Peak#	R.Time	Area%	Name
1	13.461	1.60	Eucalyptol
2	13.902	0.90	2(3H)-Furanone, 5-ethenyldihydro-5-methyl-
3	15.249	2.84	LINALOOL OXIDE CIS
4	15.877	2.42	Linalool oxide <cis->
5	16.551	14.02	Linalool
6	16.664	0.41	1,5,7-Octatrien-3-ol, 3,7-dimethyl-
7	18.016	4.09	Camphor
8	18.537	1.41	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-
9	18.805	0.53	Acetic acid, 3-methyl-6-oxo-hex-2-enyl ester
10	19.051	3.81	BORNEOL L
11	19.165	0.62	Epoxylinolol
12	19.403	0.36	Epoxylinolol
13	19.893	0.25	Isobutyrate <hexyl->
14	20.287	3.01	3,7-dimethyl-1,5-octadien-3,7-diol
15	22.343	18.56	Linalyl acetate
16	23.359	1.25	1,7-Octadiene-3,6-diol, 2,6-dimethyl-
17	23.538	0.76	Lavandulyl acetate
18	24.605	0.59	2-Methoxy-4-vinylphenol
19	24.968	0.77	Cyclobutanecarboxylic acid, octyl ester
20	25.441	4.91	8-ACETOXYLINALOOL

Peak#	R.Time	Area%	Name
21	25.743	1.28	2-Oxabicyclo[2.2.2]octan-6-ol, 1,3,3-trimethyl-, acetate
22	26.513	0.42	Bicyclo[2.2.1]heptan-2-ol, 7,7-dimethyl-, acetate (CAS)
23	26.775	0.24	Geranyl acetate
24	26.892	0.42	Coumarin <3,4-dihydro->
25	27.296	0.45	3,7-Nonadien-2-ol, 4,8-dimethyl-
26	27.425	0.61	LINALOOL OXIDE CIS
27	27.926	1.05	8-ACETOXYLINALOOL
28	28.051	0.39	Caryophyllene
29	28.883	10.38	Coumarin
30	29.222	0.77	Farnesene <(E)-, beta->
31	30.316	0.46	6,7-Dioxabicyclo[3.2.1]octane, 1-methyl-
32	30.784	0.55	8-ACETOXYLINALOOL
33	30.910	0.28	Neryl (S)-2-methylbutanoate
34	31.175	0.49	(+)-Aromadendrene
35	31.320	1.50	trans-Linalool oxide
36	31.468	1.47	Linalool oxide <trans->
37	31.873	0.79	Octanal, 7-methoxy-3,7-dimethyl-
38	32.088	0.55	Octanal, 7-methoxy-3,7-dimethyl-
39	33.369	0.72	Caryophyllene oxide
40	35.096	0.37	3-(2'-Hydroxy-4'-methoxyphenyl)propanoic acid
41	36.390	1.24	Bisabolol <alpha->
42	37.742	5.53	2H-1-Benzopyran-2-one, 7-methoxy-
43	43.274	0.72	Ascaridole
44	44.041	1.79	Palmitic acid
45	44.235	0.55	LIMONENE DIOXIDE 1
46	48.333	1.73	(Z,Z)-6,9-cis-3,4-epoxy-nonadecadiene
47	48.843	1.10	Octadecanoic acid
48	50.902	0.74	Tributyl acetylcitrate
49	53.381	0.28	Palmitate <isopropyl->
		100.00	

Figure 1. GC-MS analysis results.

3.2. Food intake

Figure 2 displays the amount of food consumed by the experimental and control groups. There was no significant difference in food intake, except for the 200 mg/kg group ($p > 0.05$). Compared to the control group, food intake in the 200 mg/kg lavender extract group showed a significant decrease ($p < 0.05$). This suggests that the 200 mg/kg concentration may have had an influence on the feeding habits of the animals, leading to a decrease in overall food consumption.

3.3. Body weights

Figure 3 presents the body weight changes observed in the experimental groups compared to the control group. No significant difference in body weight was detected between the control group and the 50 mg/kg dose group, indicating that this concentration of lavender extract did not have a noticeable effect on the animals' weight. However, significant decreases in body weight were observed in the 100 mg/kg and 200 mg/kg dose groups ($p < 0.05$), suggesting that higher concentrations of lavender extract may exert a more pronounced effect on body weight regulation. These findings imply that lavender extract, particularly at these higher doses, could influence metabolic processes or induce appetite suppression, leading to the observed reduction in body weight.

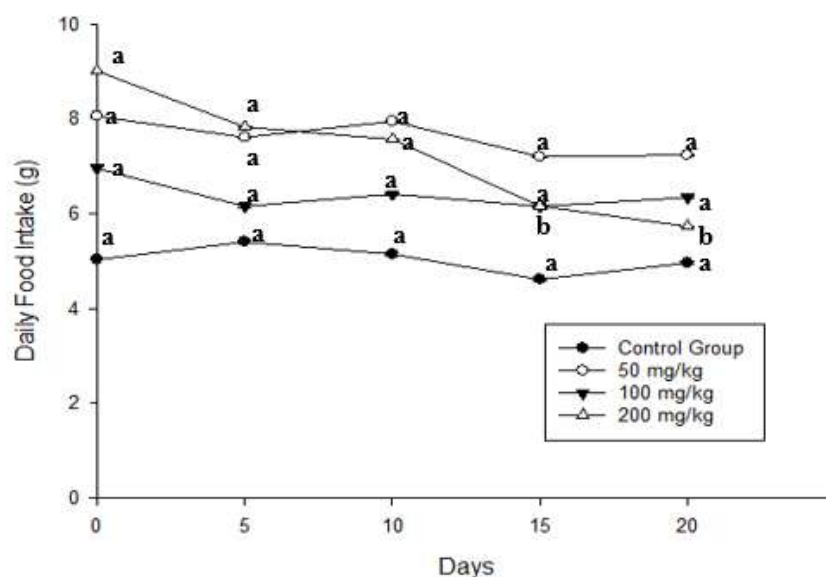


Figure 2. Effects of lavender extract injections on food intake in ad libitum-fed adult male Syrian hamsters. Values are expressed as mean $\pm$ SE. Different letters indicate statistical differences (Dunn's post hoc test, $p < 0.05$). Daily average values are presented every five days. Evaluations were made within groups.

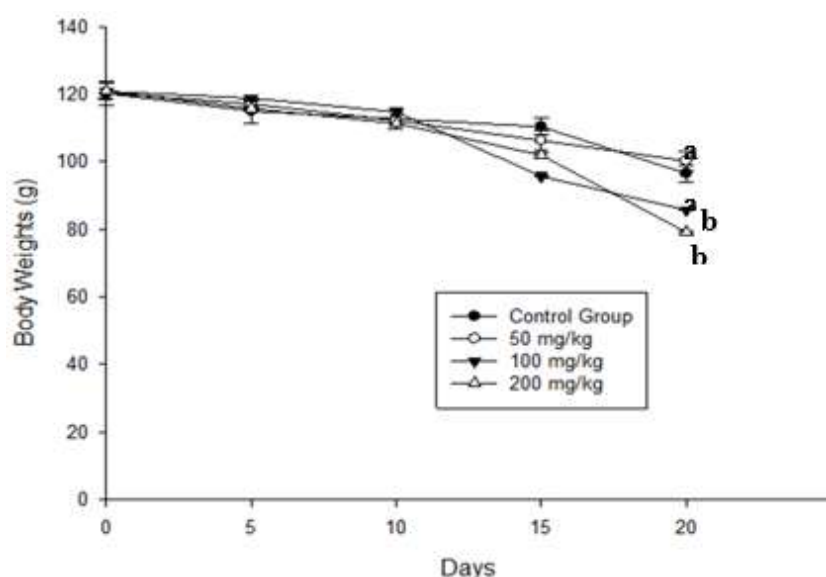


Figure 3. Effects of lavender extract injections on body weight of adult male Syrian hamsters. Values are expressed as means $\pm$ SE. Different letters indicate statistical differences (Dunn's post hoc test, $p < 0.05$). Daily mean values are given every five days. Only the last week was statistically compared.

3.4. Serum melatonin levels

Melatonin levels in the control group were high during the dark phase (00:00 h) and low during the light phase (12:00 h). In the 50 mg/kg group, melatonin levels at night were high but lower than those of the control group ($p < 0.05$), whereas melatonin levels during the day were comparable to the control group. The dosage of 100 mg/kg lavender extract significantly raised melatonin levels. Melatonin levels were higher throughout the day and at night than in the control group, with the highest levels occurring at night. In the 200 mg/kg dosage group, both light and dark phase melatonin levels increased, although dark phase melatonin levels remained similar to those of the control group ($p < 0.05$) (Figure 4). The increase in melatonin levels supports the idea that lavender positively affects sleep patterns and circadian rhythms.

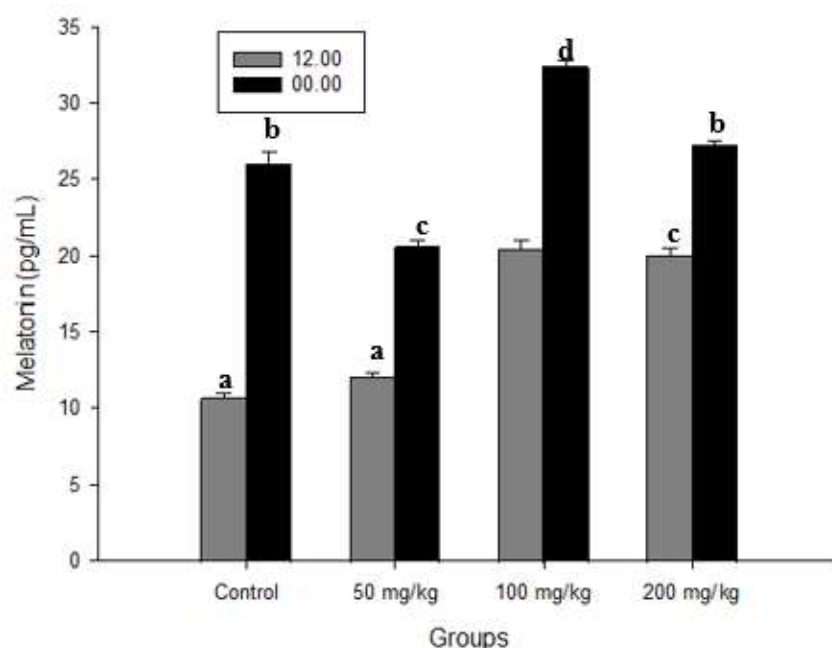


Figure 4. Effect of lavender extracts on melatonin levels in adult male Syrian hamsters. Values are expressed as mean $\pm$ SE. Different letters indicate statistical differences ($p < 0.05$).

3.5. Serum leptin levels

The control group had higher leptin levels during the light phase than the dark phase ($p < 0.05$). In the 50 mg/kg dose group, leptin levels were highest during the light phase, and the dark phase leptin levels matched those of the control group during the light phase. Leptin levels dropped in both the light and dark phases in the 100 and 200 mg/kg dosing groups, with the 200 mg/kg group showing the biggest drop ($p < 0.05$) (Figure 5). Large dosages of lavender (200 mg/kg) decreased food intake and blood leptin levels, raise the possibility that this extract could help lower leptin resistance.

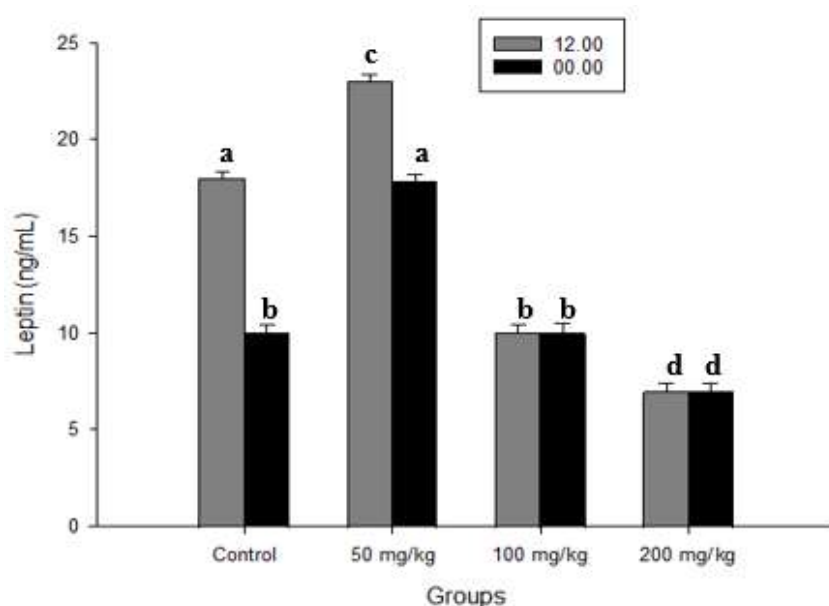


Figure 5. Effect of lavender extracts on leptin levels in adult male Syrian hamsters. Values are expressed as mean $\pm$ SE. Different letters indicate statistical differences ($p < 0.05$).

3.5. Serum testosterone levels

Testosterone levels were highest in the control group during the light phase (12:00 h). Despite staying low, the dark phase testosterone level was higher than that of the extraction groups. None of the experimental groups (50 mg/kg, 100 mg/kg, and 200 mg/kg) showed any noticeable differences ($p>0.05$) (Figure 6). All groups treated with extract experienced a suppression of testosterone levels. Certain components of lavender oil can exhibit estrogenic (estrogen-like) properties and anti-androgenic (testosterone-inhibiting) activities. This means they can mimic estrogen and potentially suppress the effects of testosterone in the body.

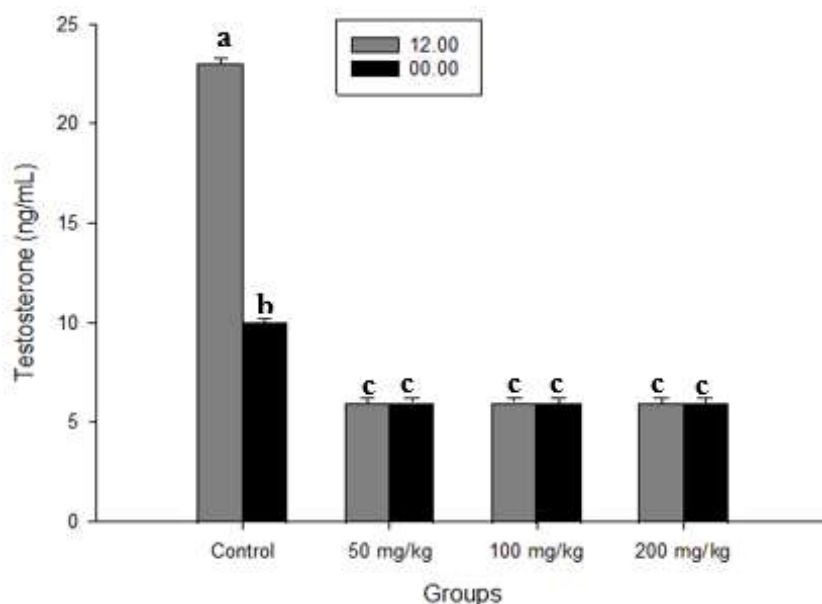


Figure 6. Effect of lavender extracts on testosterone levels in adult male Syrian hamsters. Values are expressed as mean $\pm$ SE. Different letters indicate statistical differences ($p<0.05$).

3.7. Histology of the testis

Figure 7 shows the histological examination of testes across all experimental groups, including the 50 mg/kg, 100 mg/kg, and 200 mg/kg lavender extract treatments. Upon analysis, no significant differences in testicular histology were observed between the treatment groups and the control group. All groups exhibited similar testicular structures, with intact seminiferous tubules, normal interstitial tissues, and active spermatogenesis processes. These findings suggest that lavender extract, at the doses tested, does not appear to have a detrimental effect on testicular morphology or the spermatogenic process. The lack of observable differences in histological features implies that the extract's impact on reproductive organs may not be significant at these concentrations, although further studies are needed to assess its long-term effects on fertility and reproductive health.

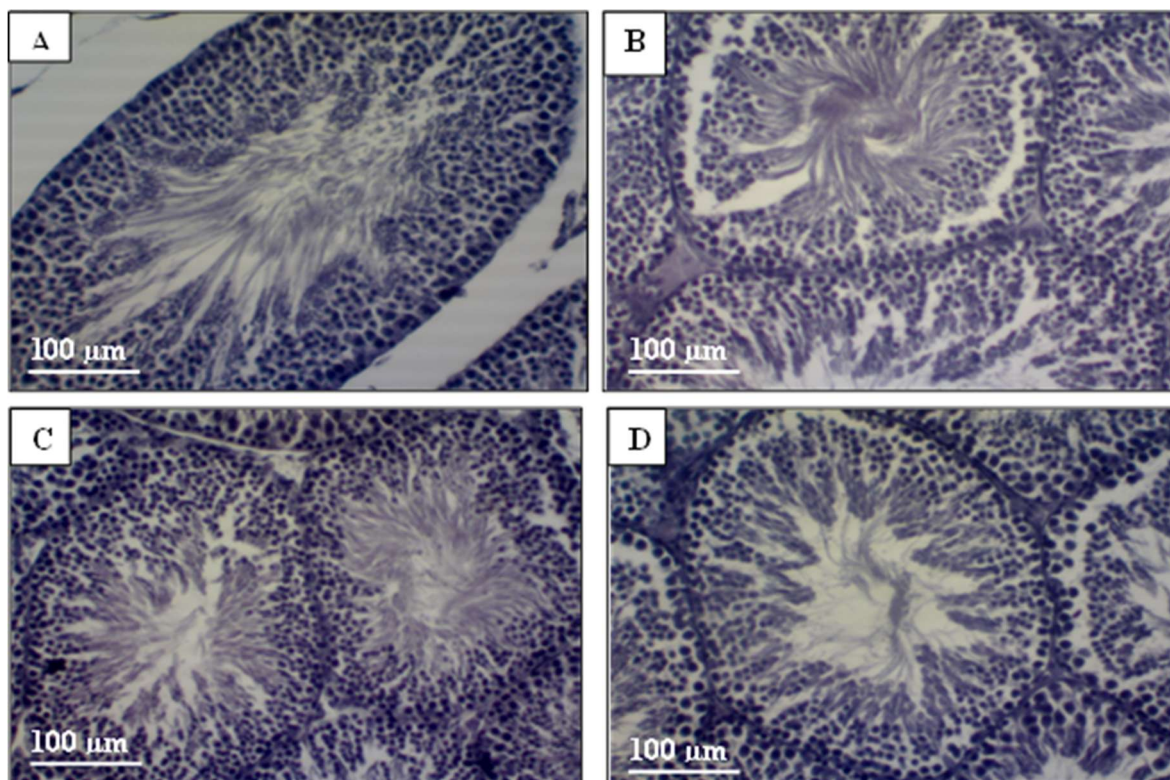


Figure 7. Testicular histology (10X) of control (A), 50 mg/kg (B), 100 mg/kg (C), and 200 mg/kg (D) experimental groups (10X).

4. DISCUSSION

We measured physiological parameters by administering different doses of the lavender plant extract to hamsters in saline solution. In research, physiological saline is often chosen to administer plant extracts to animals. Physiological saline is very biocompatible and has few harmful effects on cells. The biological effects of lavender extract alone can be better observed when isotonic saline is used as an application agent since it reduces the effect of the solvent. Although organic solvents like ethanol, methanol or DMSO may dissolve lavender extract more readily, they may also have harmful effects on tissues. Using such solvents could mask the true effects of the lavender extract and alter its bioavailability by negatively affecting the health of experimental animals. Therefore, physiological saline is widely preferred as a safe application agent.

Ethanol is a widely used solvent in plant extraction and we chose to use ethanol for the following reasons; Ethanol is a polar solvent, which makes it effective for extracting a wide range of polar and semi-polar compounds, including many phytochemicals such as flavonoids, alkaloids, and phenolic compounds. Many bioactive compounds in plants are soluble in ethanol, allowing for efficient extraction of desired substances. Ethanol is generally regarded as safe for human consumption (in food-grade form) and is less toxic compared to other organic solvents like methanol or chloroform, making it a preferred choice for food and pharmaceutical applications. Ethanol has a relatively low boiling point, which allows for easy removal of the solvent after extraction, helping to concentrate the extracted compounds without degrading them. Ethanol can be used in various extraction methods, including maceration, percolation, and Soxhlet extraction, making it adaptable to different extraction needs. These properties make ethanol an effective and popular solvent for extracting valuable compounds from plant materials [26].

Another problem when working with plant extracts is deciding how to deliver the extract to the living organism. In this investigation, we used a known technique: intraperitoneal injection. However, depending on

how it is administered, different outcomes in terms of food intake and body weight could be achieved. For example, it has been demonstrated that giving rats and mice different plant extracts orally or by inhalation reduces their body weight and food intake. For example, five weeks of inhaling 1% β -sitronellol significantly reduced food intake in Sprague-Dawley rats fed a high-fat diet (HFD) [27]. Similarly, 30-minute inhalation of 0.3% patchouli (*Pogostemon cablin* Benth.) essential oil over 12 weeks reduced food intake and body weight in HFD-fed rats [28]. The oral administration of *Arq Zeera* and its main component thymol for four weeks significantly reversed the increase in food intake and body weight gain caused by HFD in Wistar rats [29]. Additionally, citrus (*Citrus aurantifolia*) essential oils suppressed food consumption and reduced body weight in both normal and ketotifen-induced weight gain mice [30]. Different routes of administration may lead to varying effects on food consumption for the same compounds (extracts). Such substances are most likely to be more effective at regulating appetite when inhaled than when administered through other methods. For instance, inhaling benzolacetone, eugenol, and vanillin increases food intake, while intraperitoneal injection does not [31, 32]. Likewise, lavender compounds that are inhaled enhance appetite, but when taken orally, they do not [33-35]. Drugs given orally must pass through the gastrointestinal system, which might decrease their bioavailability and reduce their effectiveness [36]. In animal research, injections of various dosages or concentrations of test medications or plant extracts are frequently used. One way to deliver medicinal medications and plant extracts into the peritoneum is by intraperitoneal injections (body cavity). Understanding when and where intraperitoneal injections can be used may assist develop present drug administration strategies and create options for future study. The benefit of intraperitoneal injections is that the peritoneal cavity can quickly absorb large doses of medication. Some therapeutic plants' active metabolites can have potent tastes or smells, which leads to reduced food intake [37]. Essential oils or metabolites with appetite-regulating properties can be utilized as complementary and alternative medicine in the treatment of eating and hunger disorders because they are associated with diseases including obesity, type 2 diabetes, and anorexia nervosa.

In particular, the hypothalamic arcuate nucleus (ARC) controls the appetite-stimulating (orexigenic) and appetite-suppressing (anorexigenic) pathways required to regulate food intake. ARC neurons express orexigenic peptides (NPY and AgRP) and anorexigenic peptides (POMC and CART). According to some studies, the effects of *Osmanthus* essential oil, trans-cinnamaldehyde, benzylacetone, and 1-phenyl-2-butanone on appetite control are in line with the general idea of these two neuron populations: increased appetite is caused by activated NPY/AgRP neurons or suppressed CART/POMC neurons, and vice versa [33, 31]. Nevertheless, conflicting outcomes for 2,5-dimethyl-4-hydroxy-3(2H)-furanone (DMHF) treatment have been shown, including increased food consumption due to enhanced CART gene expression [38]. Although no compelling explanation has been offered, the location of the target gene after treatment should help to clarify this problem.

Additionally, ARC neurons use certain receptors to detect peripheral metabolic signals like leptin, insulin, ghrelin, GLP-1, and CCK [39, 40]. One important hormone, leptin, reduces food intake and regulates energy balance over the long term. Leptin, which is normally secreted by fat cells, stimulates POMC neurons and suppresses AgRP/NPY neurons, leading to decreased food intake [41]. Interestingly, leptin did not cause obese rats to consume less food [28, 29]. The phenomenon known as leptin resistance occurs when the brain does not react to leptin as it should, leading to sustained food consumption in spite of elevated leptin levels [42]. Our results, which indicate that large dosages of lavender (200 mg/kg) decreased food intake and blood leptin levels, raise the possibility that this extract could help lower leptin resistance. The increased daytime leptin level shown with the low dosage of lavender extract (50 mg/kg) was an unexpected finding in our investigation. Given that melatonin and leptin have an inverse release pattern in these animals [43], this is especially intriguing

when evaluated in respect to melatonin. One theory is that the low melatonin level during the light phase at the 50 mg/kg dose can be the cause of the elevated leptin level during this period. Comparing the control to the 100 mg/kg and 200 mg/kg doses, similar patterns are shown, with leptin levels being low when melatonin levels are high. The decrease in food intake and body weight with high-dose lavender administration is particularly intriguing when considering its relationship with leptin. While food intake and body weight decreased with high doses, no change was observed in the 50 mg/kg dose group, where leptin levels were higher. Considering that these animals are nocturnal, meaning they are active and consume food during the dark phase, further investigation is required to understand this phenomenon better.

Melatonin hormone, commonly known as the "sleep hormone", is secreted rhythmically from the pineal gland in the brain and provides homeostasis by regulating the circadian cycle. Studies have reported an increase in melatonin levels with lavender use, especially in elderly individuals suffering from sleep problems [22]. The increase in melatonin levels supports the idea that lavender positively affects sleep patterns and circadian rhythms. Melatonin not only plays a critical role in regulating the sleep-wake cycle but also functions as a natural regulator in situations of stress and anxiety [20]. The increase in melatonin levels observed in our study supports lavender's calming and sleep-regulating effects on the nervous system. Especially at high doses (100 and 200 mg/kg), lavender extract caused a greater release of melatonin during the dark phase. The primary components of lavender essential oil, linalool and linalyl acetate, are responsible for the oil's well-known sedative and relaxing effects. These substances are found in considerable quantities. Both linalyl acetate and linalool have narcotic properties and are well-known for their calming effects, which help to lessen pain. These substances are quickly absorbed through the skin when administered topically with massage; they reach peak plasma levels in roughly 19 minutes. It is thought that these compounds cause central nervous system depression, which results in sleepiness and relaxation. It has been demonstrated that inhaling lavender oil raises blood melatonin levels, which may be one way that it promotes sleep. This suggests that by affecting the production of melatonin, lavender oil, which is high in linalool and linalyl acetate, may improve sleep quality.

The primary constituent of lavender essential oil, linalool, has been shown in studies to have sedative and anxiolytic effects on the nervous system and is used as a treatment for anxiety and stress disorders [44]. Similarly, linalyl acetate is an important pharmacological component due to its muscle relaxant and antispasmodic properties. However, lavender extract is not limited to volatile components; non-volatile compounds such as phenolic acids and flavonoids also exhibit significant antioxidant and anti-inflammatory properties. Phenolic acids, in particular, has positive effects on the immune system and neuroprotective mechanisms, supporting the potential role of lavender extract in neurological diseases [14].

In recent years, there has been a growing body of research on the inhibitory effects of lavender on male reproductive hormones, particularly testosterone [45]. Our research demonstrated that lavender, at all administered doses, decreased testosterone levels. As seen in the histological examination of testis tissue, this reduction in testosterone levels did not result from damage to Leydig cells. Thus, the inhibitory effect of lavender extract on testosterone in male hamsters may occur either directly through the testes or indirectly through the hypothalamus.

5. CONCLUSION

This study aimed to contribute to the literature by examining the effects of low and high doses of lavender on metabolic/physiological parameters (body weight, food intake, and melatonin and leptin hormones) and reproductive parameters (testosterone and testis histology) in adult male hamsters. Considering the antioxidant, anti-inflammatory, and antimicrobial effects of lavender extract, this plant is thought to have a wide

range of uses in pharmacological treatments. However, given its potential adverse effects on reproductive health, caution should be exercised, particularly with high doses in males. There are few studies on lavender plant extracts, and the available findings show some inconsistencies. These partial inconsistencies in the findings can be explained by factors such as the animals used and management conditions (e.g., the route of extract administration, species, and environmental conditions) or plant factors (e.g., genotype, environment, processing and extraction methods, harvest time, storage method and duration, product diversity, and dosage and procedures of extract application), which affect the effectiveness of various products, making comparisons and explanations complex.

Author Contributions: EİB and BG conceived and designed the study and performed the experiments. All authors contributed to the writing and approved the final version.

Conflict of Interest: The authors of this work declare that they have no conflicts of interest.

Source of Funding: This work has not received any financial support.

Ethical Approval: Adult male Syrian hamsters were obtained from the hamster colony housed in the Hamster and Gerbil Unit at the Çanakkale Onsekiz Mart University Research and Application Center for Experimental Animals (COMUDAM). All methods were conducted with the approval of the Çanakkale Onsekiz Mart University Animal Ethics Committee (Approval number: 2021/04-10).

REFERENCES

1. Gadano AB, Gurni AA, Carballo MA. Argentine folk medicine: genotoxic effects of Chenopodiaceae family. J Ethnopharmacol. 2006; 103(2): 246-251.
2. Santos FV, Tubaldini F, Cólus IMS, Andreo MA, Bauab TM, Leite CQ, et al. Mutagenicity of mouriri pusa gardner and mouriri elliptica martius. Food Chem Toxicol. 2008; 46: 2721-2727.
3. Ballı M. Sideritis trojana bornm ve sideritis athoa papanikolaou & kokkini bitkilerinden elde edilen ekstraktların ames testi ile mutajenik ve antimutajenik aktivitelerinin araştırılması. Yüksek Lisans Tezi. Çanakkale Onsekiz Mart Üniversitesi, Çanakkale (Türkiye), 2012.
4. Ceylan AA, Vömel NK, Çelik N, Niğdeli E. Bitki sıklığının lavanta'da (L.) verim ve kaliteye etkisi üzerinde araştırma. EÜ Zir Fak Der. 1988; 25(2): 135-145.
5. Ceylan A. Tıbbi Bitkiler II (Uçucu Yağ Bitkileri). Bornova (Türkiye). Ege Üniv Zir Fak. Yayınları. 1996.
6. Baytop T. Türkiye'de Bitkiler ile Tedavi (Geçmişte ve Bugün). İlaveli İkinci baskı, İstanbul (Türkiye). Nobel Tıp Kitabevleri. 1999.
7. An M, Haig T, Hatfield P. On site field sampling and analysis of fragrance from living lavender (*Lavandula angustifolia* L.) flowers by- solid-phase microextracion coupled to gas chromatography and ion-trap mass spectrometry. J Chromatogr A. 2001; 917: 245-250.
8. Cavanagh HM, Wilkinson JM. Lavender essential oil: a review. Austral Infect Control. 2005; 10(1): 35-37.
9. Uritu CM, Mihai CT, Stanciu GD, Dodi G, Alexa-Stratulat T, Luca A, et al. Medicinal plants of the family Lamiaceae in pain therapy: A review. Pain Res Manag. 2018; 2018: 7801543.
10. Cavanagh HTT, Wilkinson JT. Biological activities of lavender essential oil. Phytother Res. 2002; 16(4): 301-308.
11. Prashar A, Locke IC, Evans CS. Cytotoxicity of lavender oil and its major components to human skin cells. Cell Prolifer. 2004; 37(3): 221-229.
12. Hart S, Lis-Balchin M. Pharmacology of Lavandula essential oils and extracts in vitro and in vivo. In: Lavender. CRC Press. 2002; 154-168.

13. Holmes C, Hopkins V, Hensford C, MacLaughlin V, Wilkinson D, Rosenvinge H. Lavender oil as a treatment for agitated behaviour in severe dementia: a placebo controlled study. *Int J Geriatric Psych.* 2002; 17(4): 305-308.
14. Caprari C, Fantasma F, Monaco P, Divino F, Iorizzi M, Ranalli G, et al. Chemical Profiles, in vitro antioxidant and antifungal activity of four different *Lavandula angustifolia* L. EOs. *Molecules.* 2023; 28(1): 392.
15. Valiollah HG, Ghannadi A, Badie S. Anti-inflammatory and analgesic properties of the leaf extracts and essential oil of *Lavandula angustifolia* Mill. *J Ethnopharmacol.* 2003; 89: 67-71.
16. Di Sotto A, Mazzanti G, Carbone F, Hrelia P, Maffei F. Genotoxicity of lavender oil, linalyl acetate, and linalool on human lymphocytes in vitro. *Environ Mol Mutagen.* 2011; 52(1): 69-71.
17. Puškárová A, Bučková M, Kraková L, Pangallo D, Kozics K. The antibacterial and antifungal activity of six essential oils and their cyto/genotoxicity to human HEL 12469 cells. *Scient Rep.* 2017; 7(1): 1-11.
18. Al-Sheddi ES. Cytotoxic potential of petroleum ether, ethyl acetate, chloroform, and ethanol extracts of *Lavandula coronopifolia* against human breast carcinoma cell line (MDA-MB-321). *Asian Pac J Cancer Prev.* 2019; 20(10): 2943-2949.
19. Genç H. Lavanta yağının benign prostat hiperplazili hastaların ameliyat öncesi yaşam bulguları ve kaygı düzeyine etkisi, İnönü Üniversitesi, Sağlık Bilimleri Enstitüsü, Yüksek Lisans Tezi. 2017.
20. López V, Nielsen B, Solas M, Ramírez MJ, Jäger AK. Exploring pharmacological mechanisms of lavender (*Lavandula angustifolia*) essential oil on central nervous system targets. *Front Pharmacol.* 2017; 8: 280.
21. Şentürk. A. Hemodiyaliz Hastalarına İnhalasyon Yolu ile Lavanta Yağı Uygulamasının Anksiyete Düzeyi ve Uyku Kalitesine Etkisi, Erciyes Üniversitesi, Sağlık Bilimleri Enstitüsü, Yüksek Lisans Tezi. 2015.
22. Velasco-Rodríguez R, Pérez-Hernández MG, Maturano-Melgoza JA, Hilerio-López AG, Monroy-Rojas A, Arana-Gómez B, et al. The effect of aromatherapy with lavender (*Lavandula angustifolia*) on serum melatonin levels. *Complem Ther Med.* 2019; 47: 102208.
23. Köse E, Sarsılmaz M, Meydan S, Sönmez M, Kuş İ, Kavaklı A. The effect of lavender oil on serum testosterone levels and epididymal sperm characteristics of formaldehyde treated male rats. *Eur Rev Med Pharmacol Sci.* 2011; 15: 538-542.
24. Hamidi M, Ziaee M, Delashoub M, Marjani M, Karimitabar F, Khorami A, et al. The effects of essential oil of *Lavandula angustifolia* on sperm parameters quality and reproductive hormones in rats exposed to cadmium. *J Rep Pharmaceut Sci.* 2015; 4(2): 135-142.
25. Kashani MS, Tavirani MR, Talaei SA, Salami M. Aqueous extract of lavender (*Lavandula angustifolia*) improves the spatial performance of a rat model of Alzheimer's disease. *Neurosci Bull.* 2011; 27(2): 99.
26. Bitwell C, Indra S, Luke C, Kakoma MK. A review of modern and conventional extraction techniques and their applications for extracting phytochemicals from plants. *Scient Afr.* 2023; 19: e01585.
27. Batubara I, Suparto IH, Sa'diah S, Matsuoka S, Mitsunaga T. Effects of inhaled citronella oil and related compounds on rat body weight and brown adipose tissue sympathetic nerve. *Nutrients.* 2015; 7: 1859-1870.
28. Hong SJ, Cho J, Boo CG, Youn MY, Pan JH, Kim JK, Shin EC. Inhalation of patchouli (*Pogostemon Cablin Benth.*) essential oil improved metabolic parameters in obesity-induced sprague dawley rats. *Nutrients.* 2020; 12: 2077.
29. Haque MR, Ansari HS. Anti-obesity effect of arq zeera and its main components thymol and cuminaldehyde in high fat diet induced obese rats. *Drug Res.* 2018; 68: 637-647.
30. Asnaashari S, Delazar A, Habibi B, Vasfi R, Nahar L, Hamedeyazdan S, Sarker SD. Essential oil from citrus aurantifolia prevents ketotifen-induced weight-gain in mice. *Phytother Res.* 2010; 24: 1893-1897.
31. Ogawa K, Ito M. Appetite-enhancing effects of trans-cinnamaldehyde, benzylacetone and 1-phenyl-2-butanone by inhalation. *Planta Med.* 2016; 82: 84-88.

32. Ogawa K, Tashima A, Sadakata M, Morinaga O. Appetite-enhancing effects of vanilla flavours such as vanillin. *J Nat Med.* 2018; 72: 798-802.
33. Yamamoto T, Inui T, Tsuji T. The odor of *Osmanthus fragrans* attenuates food intake. *Sci Rep.* 2013; 3-8.
34. Mekonnen A, Tesfaye S, Christos SG, Dires K, Zenebe T, Zegeye N, et al. Evaluation of skin irritation and acute and subacute oral toxicity of *Lavandula angustifolia* essential oils in rabbit and mice. *J Toxicol.* 2019; 1: 5979546.
35. Torki M, Mohebbifar A, Mohammadi H. Effects of supplementing hen diet with *Lavandula angustifolia* and/or *Mentha spicata* essential oils on production performance, egg quality and blood variables of laying hens. *Vet Med Sci.* 2021; 7: 184-193.
36. Homayun B, Lin X, Choi HJ. Challenges and recent progress in oral drug delivery systems for biopharmaceuticals. *Pharmaceutics.* 2019; 11: 129.
37. Windisch W, Schedle K, Plitzner C, Kroismayr A. Use of phytogetic products as feed additives for swine andpoultry. *J Anim Sci.* 2008; 86: 140-148.
38. Yokoyama I, Nakai Y, Suzuki Y, Ohata M, Komiya Y, Nagasao J, et al. DMHF (2,5-dimethyl-4-hydroxy-3(2H)-furanone), a volatile food component generated by the Maillard reaction, promotes appetite and changes gene expression in the rat brain through inhalation. *J Food Sci.* 2020; 85.
39. Suzuki K, Simpson KA, Minnion JS, Shillito JC, Bloom SR. The role of gut hormones and the hypothalamus in appetite regulation. *Endocr J.* 2010; 57: 359-372.
40. Timper K, Brüning JC. Hypothalamic circuits regulating appetite and energy homeostasis: Pathways to obesity. *Dis Model Mech.* 2017; 10: 679-689.
41. Guzmán A, Hernández-Coronado CG, Rosales-Torres AM, Hernández-Medrano JH. Leptin regulates neuropeptides associated with food intake and GnRH secretion. *Ann Endocrinol.* 2019; 80(1): 38-46.
42. Izquierdo AG, Crujeiras AB, Casanueva FF, Carreira MC. Leptin, obesity, and leptin resistance: Where Are We 25 Years Later? *Nutrients.* 2019; 11: 2704
43. Gündüz B. Daily rhythm in serum melatonin and leptin levels in the syrian hamster (*Mesocricetus auratus*). *Comparat Biochem Physiol.* 2002; 132: 393-401.
44. Sharma K, Lanzilotto A, Yakubu J, Therkelsen S, Vögel CD, Du Toit T, et al. Effect of Essential Oil Components on the Activity of Steroidogenic Cytochrome P450. *Biomolecules.* 2024; 14(2): 203.
45. Koulivand PH, Khaleghi Ghadiri M, Gorji A. Lavender and the nervous system. *Evid-Based Complem Altern Med.* 2013; 1: 681304.