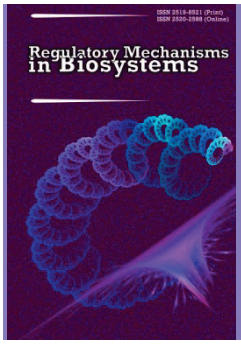

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Efficiency of *Melissa officinalis* leaf extract in amelioration of oxidative status and histological changes in male albino rats with induced hypothyroidism

Z. R. Majeed, A. A. Sharhan

Al-Qasim Green University, Babylon, Iraq

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Medical Biotechnology Department, College of Biotechnology, Al-Qasim Green University, Babylon, 51013, Iraq.
E-mail: dheyaaali452@gmail.com

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The study was conducted to demonstrate the role of ethanolic leavf extract from *Melissa officinalis* in treatment of hypothyroidism disease which was induced by the drug carbimazole. The aim of this study was to investigate the effects of oral administration of *M. officinalis* on oxidative status and histological changes in rats with induced hypothyroidism. Fifty male rats were divided into five groups, ten for each. Group I was selected as negative control and administered orally with normal saline alone, group II served as positive control and tadministered carbimazole (5 mg/kg) anti-thyroid drug for six weeks to induce hypothyroidism. Group III was administered carbimazole (5 mg/kg) for six weeks to induce hypothyroidism, then treated with plant extract (75 mg/day). Group IV was administered carbimazole (5 mg/kg) for six weeks to induce hypothyroidism, then treated with plant extract (150 mg/day) and group V was administered carbimazole (5 mg/kg) for six weeks to induce hypothyroidism then treated with thyroxin (50 µg). The results showed that there was no significant difference in MDA levels in the third group when compared with groups I, IV and V while the results showed a significant decrease when compared with group II. The results showed no significant differences in the levels of SOD in group III when compared with the groups I, IV and V, while there was a significant increase when compared with group II. The results of the histological study of the thyroid gland in group II showed an irregular shape of the colloids with thickening in the epithelial cells and uneven distribution of the thyroglobulin (some appeared full and others were empty) with slight infiltration of inflammatory cells and thyroid cells apoptosis showed a normal structure of the thyroid gland, while the result demonstrated repair to normal structure in groups III, IV and V, which looked the same as the control group. In the liver section in the II group, hepatocytes were arranged irregularly around the central vein, in addition to the presence of inflammatory material in the central vein, and presence of inflammatory cells, as well as apoptosis in the hepatocytes, while the result showed return to normal structure in the III, IV and V group, which looked the same as the control group. Also the V group showed a slight infiltration on inflammatory cells. On the other hand, the results for group II showed irregular shape of the renal nephrons with severe infiltration of lymphocytes, severe hemorrhage and irregular shape of the renal tubules, while the results for the III, IV and V groups revealed a return to normal structure the same as in the control. In conclusion, *M. officinalis* leaves extract regulate thyroid levels in rats. It alleviated the inflammatory response by suppressing the MDA and increasing SOD in treatment groups. These results might strengthen the protective effect of *M. officinalis* extract in a rat model of hypothyroidism.

Keywords: *Melissa officinalis*; extract; hypothyroidism; antioxidant enzyme; oxidative stress; liver; kidney; rat.

Introduction

The thyroid gland plays a crucial role in regulating the body's metabolism by producing thyroid hormones, primarily thyroxine (T_4) and triiodothyronine (T_3). These hormones influence nearly every cell in the body, affecting growth, development, and energy expenditure (Salman et al., 2024). Thyroid hormones enhance the oxidation of fatty acids in the liver and muscle, promoting energy production and reducing fat storage (Wang et al., 2024). There are number of disorders associated with the thyroid gland functions such as hypothyroidism, hyperthyroidism and thyroid nodules (Falgoos & Abdulredha, 2020). The antithyroid medication carbimazole was employed to induce hypothyroidism. When administered for 45 days, it exhibited an increase in TSH level (Hussein et al., 2022). Levothyroxine is a synthetic form of thyroxine hormone. It is also known as LT4 and is regarded as the standard medication used to treat hypothyroid people (Vargas-Uricoechea & Wartofsky, 2024).

The thyroid gland is both a target and a source of oxidative stress due to its metabolic activity. The synthesis of thyroid hormones involves oxidative processes, including the oxidation of iodide to iodine, which can produce reactive oxygen species (ROS). Balancing oxidative stress is crucial for thyroid health, and interventions like antioxidants in the diet or supplements may help (Al-Suhaimi & Khan, 2022). Malondialdehyde (MDA) and superoxide dismutase (SOD) are closely linked in the context of thyroid health, particularly regarding oxidative stress. High MDA levels can damage thyroid cells and disrupt hormone synthesis, while sufficient SOD activity is essential for maintaining a healthy thyroid environment and hormone production. Enhancing SOD activity through diet or supplements may help reduce MDA levels and protect thyroid function, highlighting the importance of maintaining a balance between these two markers (da Silva et al., 2023).

Higher plants as sources for medicine, as they are found to possess a reservoir of bioactive compounds (Kadhim et al., 2016), continue to play a dominant role in the maintenance of human health. Reports available on green plants show they represent a reservoir of effective chemotherapeutants, these are non-phytotoxic, more systemic and easily biodegradable. Hence a thorough validation of the herbal drugs has emerged as a new branch of science emphasizing and prioritizing the standardization of the natural drugs and products because several of the phytochemicals have complementary and overlapping mechanisms of action (Al-Rubaye et al., 2017; Zazharskyi et al., 2019).

Most of the plants have medicinal as well as nutritional activities, and many of the plants have been applied for the same objectives. Natural

drugs (herbs) are being used to amend the harmful effects caused by foreign organisms or via any imperfection of the body (Alalwany et al., 2021).

Melissa officinalis L., commonly known as lemon balm, honey balm, balm mint, garden balm, or common balm is a perennial herbaceous plant that belongs to the family Lamiaceae (mint family). It is found predominantly in the Mediterranean region and elsewhere such as Central Asia, Iran, Europe, Serbia, America, and Africa. *Melissa officinalis* has such strong ability to grow fast and establish itself in its natural habitat that some gardeners call it a weed. Scientific research has confirmed that the medicinal benefits of *M. officinalis* are due to the presence of wide range of secondary metabolites such as flavonoids, phenolic acid, and terpenes. Other secondary metabolites of *M. officinalis* are mostly from its essential oil (EO). In addition, containing a large amount of rosmarinic acid (Kittler et al., 2018), it is consumed as herbal tea to ameliorate digestion and gastrointestinal disorders due to its antispasmodic properties (Lieshchova & Brygadyrenko, 2021; Bilan et al., 2023). Consequently, a previous study reported the protective effect of this plant against oxidative stress-derived degenerative diseases (Abo-Zaid et al., 2023). Lemon balm leaves extract is registered in the FDA list of substances added to food as a flavoring agent or adjuvant (food and drug). *Melissa officinalis* essential oil has been reported to be medicinal (Gavarić et al., 2024).

Materials and methods

Preparation of extract. The dried leaves of the plant *M. officinalis* were obtained from the local market in Hilla City, Iraq. The dried plant material was coarsely powdered and subjected to extraction with ethanol (70%) by soxhlet (Soxhlet, 1879) for 24 hrs, and then the extract was placed in container and put in the oven at a temperature of 40 degrees for 48 hours, the extract was stored at 4 degrees until use (Shakeri et al., 2016).

Fifty (50) male rats were divided into five groups, ten for each. Group I served as negative control and was administered orally with normal saline alone. The second group used as positive control was administered carbimazole (5 mg/kg) anti-thyroid drug for six weeks for induction of hypothyroidism (Abdel-Fattah et al., 2015).The third group was administered carbimazole (5 mg/kg) for induction of hypothyroidism for six weeks then treated with plant extract (75 mg/day). The fourth group was administered carbimazole (5 mg/kg) for induction of hypothyroidism for six weeks then treated with plant extract (150 mg/day) for four weeks (Abdel-Aziz, 2018), the fifth group was administered carbimazole (5 mg/kg) for induction of hypothyroidism then treated with thyroxin drug (50 µg) for four weeks (Alva-Sánchez et al., 2009).

Malondialdehyde was estimated by thiobarbituric acid (TBA) assay method of Buege & Aust (1978) while, serum superoxide dismutase was measured following the method of Marklund & Marklund (1974).

Histopathological examination. Thyroid, liver and kidney tissue samples were collected and fixed in a 10% neutral buffered formalin solution for histopathology. Tissue specimens were processed as follows: dehydrated in an ascending concentration of ethanol, cleared in xylene, embedded in paraffin wax, and sectioned at a 5-µm thickness. The prepared slide sections were stained with hematoxylin and eosin (Bancroft & Layton, 2013) and examined by a light digital microscope (Olympus XC30, Tokyo, Japan).

Statistical analysis. The statistical analysis of the obtained data was performed by using one-way ANOVA, which includes estimation of mean ± standard error (x ± SE) and comparison between means under probability ($P < 0.05$) according to Statistical Package foe Social Science (SPSS) system (version 20) (Al-Rawi & Khalaf-Allah, 2000).

Results and discussion

Oxidative status. In Table 1 the results showed insignificant differences in the concentrations of MDA in the third group (carbimazole and plant extract 75 mg/day) when compared with the first (normal saline), fourth group (carbimazole and plant extract 150 mg/day) and fifth groups (carbimazole and thyroxin drug), while there was a significant decrease compared with the second (carbimazole) group. The results revealed that there was no significant difference in SOD in the third group (carbimazole & plant extract 75 mg/day) when compared with the first group, fourth (carbimazole and plant extract 150 mg/day), and fifth groups (carbimazole and thyroxin) while the results showed a significant increase ($P < 0.05$) when compared with second.

Table 1
The effect of ethanolic extract of *Melissa officinalis* leaves on the serum levels of oxidant MDA and antioxidant SOD in male rats (mean ± SE)

Groups	SOD, units/mL	MDA, µmol/L
Group I (normal saline)	33.77 ± 0.18^{a}	5.75 ± 0.08^{a}
Group II (carbimazole)	21.43 ± 0.23^{b}	8.04 ± 0.06^{b}
Group III (carbimazole and plant extract 75 mg/day)	33.41 ± 0.17^{a}	6.05 ± 0.05^{a}
Group V (carbimazole and plant extract 15 mg/day)	35.14 ± 0.25^{a}	6.43 ± 0.09^{a}
Group VI (carbimazole and thyroxin)	33.26 ± 0.23^{a}	5.45 ± 0.05^{a}

Note: different letters indicated a significant difference at $P < 0.05$.

In Table 2, the results in histological study of the thyroid gland showed a normal structure of the thyroid gland. In the third group (carbimazole and plant extract 75 mg/day), the fourth group (carbimazole and plant extract 150 mg/day) and fifth group (carbimazole and thyroxin drug) the results were the same as the control negative group. On the other hand, the control positive group (carbimazol) showed an irregular shape of the colloids with thickening in the epithelial cells and uneven distribution of the thyroglobulin (some appeared full and others were empty) with slight infiltration of inflammatory cells and thyroid cells apoptosis.

This result may be due to the fact that regulation of thyroid hormones can influence oxidative stress levels. In hypothyroidism, metabolic slowdown associated with hypothyroidism can impact the synthesis and activity of antioxidant enzymes, which increase oxidative stress in the body MDA, which may lead to the depletion of antioxidant defenses, including SOD (Sankha et al., 2021). Thyroid hormones, particularly T_3, are essential for the regulation of SOD. Inhibiting the production of thyroid hormones by carbimazole disrupts the regulatory mechanisms that promote the synthesis of SOD, contributing to its reduction and leading to higher MDA levels (Yang et al., 2020).

Melissa officinalis is rich in antioxidants, such as flavonoids and rosmarinic acid. These compounds can enhance the body's overall antioxidant capacity, which can scavenge free radicals and reduce oxidative damage. Thereby, increase in serum SOD concentration in the third and fourth groups and decrease in MDA may be due to the fact that plant extracts could inhibit the generation of early chemical reactive species that subsequently initiate lipid peroxidation or, alternatively, they could block a common final pathway in the process of polyunsaturated fatty acids peroxidation (Scimone et al., 2024). *Melissa officinalis* has compounds that can inhibit lipid peroxidation and its extract was found able to stabilize cell membrane and prevent the oxidation of membrane lipids; thus, it reduced both renal and hepatic level of MDA, potentially stimulating the expression or activity of SOD. *Melissa officinalis* inhibits lipid peroxidation and is able to stabilize cell membrane and prevents the oxidation of membrane lipids; it reduced both renal and hepatic level of MDA and increased SOD (Villegas et al., 2024).

Thyroid gland histology. Carbimazole reduces thyroid hormone production by inhibiting thyroid peroxidase. This reduces the formation of thyroxine (T_4) and triiodothyronine (T_3) within the colloid, leading to less uniformity in colloid appearance (Ciaccio et al., 2024). The irregular shape reflects altered synthesis and storage of thyroglobulin, the precursor to thyroid hormones, and changes in colloid turnover. The epithelial cells lining the thyroid follicles may undergo hypertrophy or hyperplasia as they try to compensate for reduced hormone production, this thickening is a result of the increased activity of the thyroid follicular cells in response to feedback from the hypothalamic-pituitary axis, which senses lower circulating thyroid hormone levels and stimulates thyroid-stimulating hormone (TSH) secretion (Basolo et al., 2022). The thyroid follicles are responsible for storing and releasing thyroglobulin, which gets converted into T_3 and T_4. When carbimazole blocks thyroid hormone production, the process becomes uneven, leading to variable colloid contents in different follicles. Thyroid follicular cells may undergo apoptosis (programmed cell death) due to stress or the inhibitory effects of carbimazole on hormone production (Olfat et al., 2019).

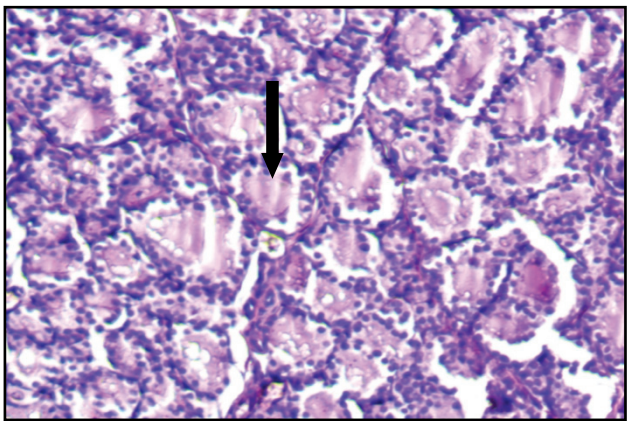

Fig. 1. Thyroid gland section from rat in first group (NS) showing normal structure appearance of thyroid follicles contain colloid materials (black arrow)

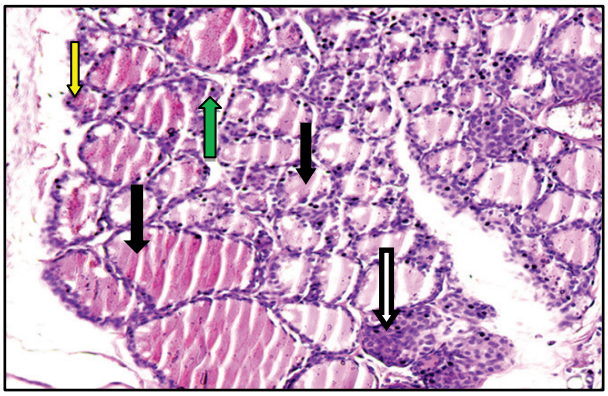

Fig. 2. Thyroid gland section from rat in second group (carbmizol) show irregular distribution of thyroglobulin (black arrow), inflammatory cells (white arrow) thickening in the epithelial cells (green arrow) and apoptotic cells (yellow arrow)

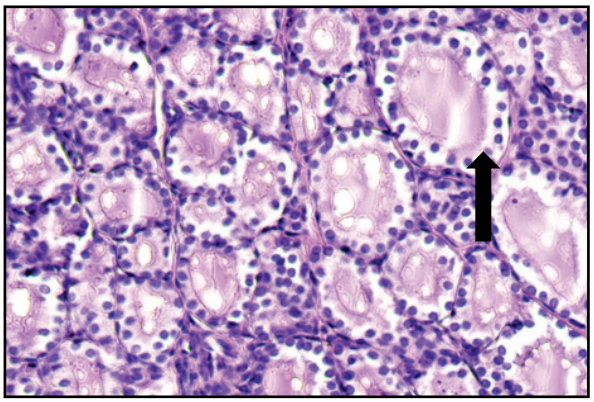

Fig. 3. Thyroid gland section from rat in third group (carbimazole and plant extract 75 mg/day) showing all the follicles filled with colloid materials (black arrow)

Melissa officinalis contains compounds like rosmarinic acid, which have antioxidant properties. These antioxidants can help reduce oxidative stress on thyroid cells, promoting cellular stability and healthier colloid production. While *M. officinalis* doesn't directly impact the thyroid peroxidase enzyme like carbimazole, its regulatory effect on thyroid hormone levels may help balance colloid formation and storage, potentially improving follicular architecture. *Melissa officinalis* can regulate thyroid function through its mild antithyrotropic properties. It may help restore a more even distribution of thyroglobulin by improving the balance between hormone synthesis and release. This can lead to a more uniform colloid content across the thyroid follicles, reducing the disparity between "full" and "empty" follicles (Singh et al., 2021).

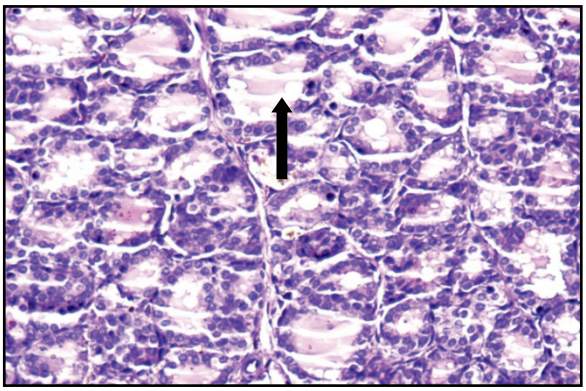

Fig. 4. Thyroid gland section from rat in fourth group (carbimazole and plant extract 150 mg/day) showing the follicles refilled with colloid materials (black arrow)

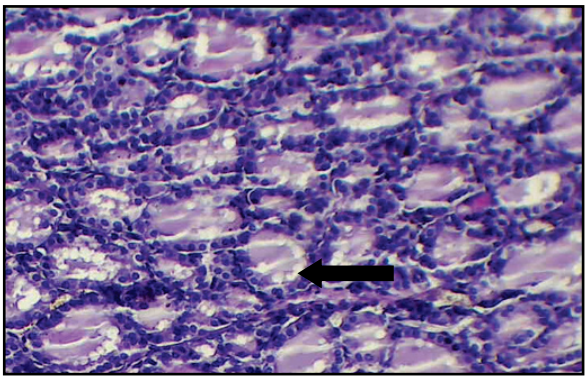

Fig. 5. Thyroid gland section from rat in fifth group (carbimazole and thyroxin drug) showing the follicles return to normal shape and filled with colloid materials (black arrow)

Hassan et al. (2020) suggested that the anti-inflammatory effects of *M. officinalis* can help mitigate thyroid inflammation and reduce the infiltration of inflammatory cells. Compounds like rosmarinic acid and eugenol exhibit anti-inflammatory action by inhibiting pro-inflammatory cytokines, which can help to lower inflammation caused by carbimazole's effects or mild thyroiditis (Abo-Zaid et al., 2023).

Also the antioxidant and cytoprotective properties of *M. officinalis* could potentially reduce the stress-induced apoptosis in thyroid cells. By reducing oxidative stress and inflammatory signaling, *M. officinalis* can protect thyroid cells from apoptosis, supporting thyroid cell viability and function (Mannaa et al., 2021; Nizamudeen et al., 2023).

Liver histology. The results showed a normal structure in the third group, fourth group and fifth group, the same as in the first group. Also the fifth group showed a slight infiltration of inflammatory cells while the control positive group showed hepatocytes arranged irregularly around the central vein, in addition to the presence of inflammatory material in the central vein, and presence of inflammatory cells, as well as apoptosis in the hepatocytes.

The carbimazole, like many drugs, can have adverse effects on the liver due to its metabolism and the formation of reactive metabolites, which may lead to hepatotoxicity (Hussein Naser et al., 2022). It is metabolized in the liver to active compounds, including methimazole. During metabolism, reactive metabolites can form, which may cause oxidative stress and damage to hepatocytes. This leads to structural disorganization in the hepatic lobules (Hashem et al., 2016), where hepatocytes lose their normal radial arrangement around the central vein (Bischoff et al., 2018). It may trigger an immune-mediated liver injury, where the body's immune system attacks hepatocytes. This can cause central vein inflammation (central veinitis), where inflammatory material, such as fibrin, dead cells, or immune complexes, accumulates in the central veins (Schranz et al.,

2019). Carbimazole can lead to the recruitment of inflammatory cells, such as lymphocytes, neutrophils, and macrophages, as part of the body's response to liver damage. These inflammatory cells infiltrate the liver parenchyma and central vein areas to clear damaged or dying cells and manage oxidative stress (Hegazy et al., 2023).

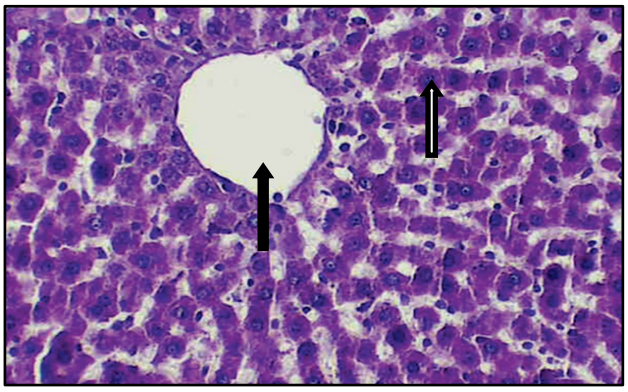

Fig. 6. Liver section from rat in the control group (NS) showing the central vein (black arrow), and normal hepatocyte architecture hepatocytes (white arrow)

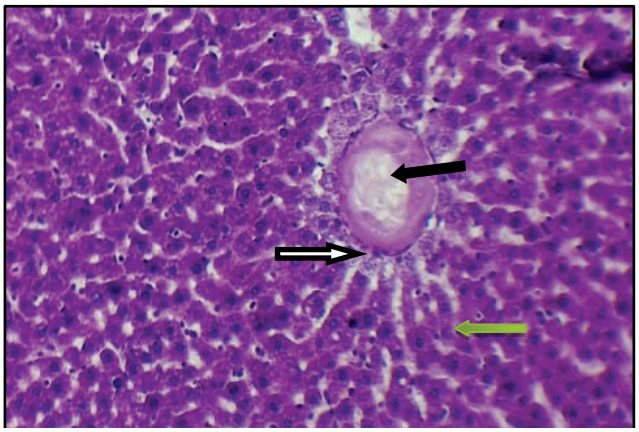

Fig. 7. Liver section from rat in second group (carbimazole) showing clear inflammation substance in the central vein (black arrow), leukocytes infiltrations (white arrow) and hepatocyte apoptosis (yellow arrow)

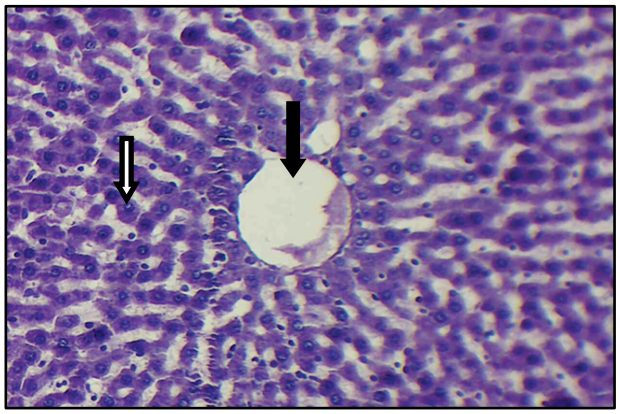

Fig. 8. Liver section of rat in the third group (carbimazole and plant extract 75 mg/day) showed normal hepatic cell architectures (white arrow) with normal central vein (black arrow)

Carbimazole's metabolism can generate reactive oxygen species (ROS) and other toxic intermediates, leading to oxidative stress within hepatocytes. Several studies have proved that stress can trigger apoptosis (programmed cell death) as a protective mechanism to remove damaged or dysfunctional cells. Research had proved that the inflammatory response triggered by carbimazole may also contribute to apoptosis through the release of pro-apoptotic cytokines like TNF-α and Fas ligand, which are signals for hepatocytes to undergo apoptosis (Aldubayan, 2019).

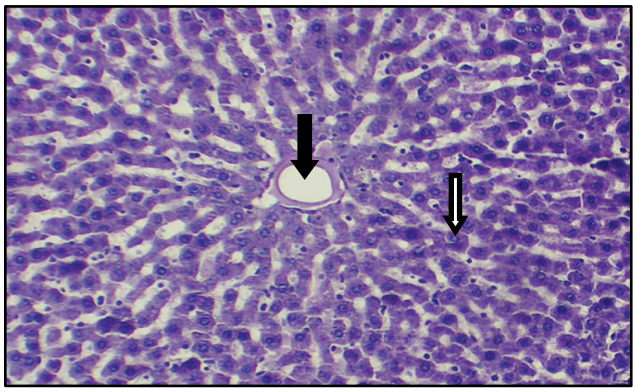

Fig. 9. Liver section of rats in the fourth group (carbimazole and plant extract 150 mg/day) revealed normal hepatic cells architectures (white arrow) with normal central vein (black arrow)

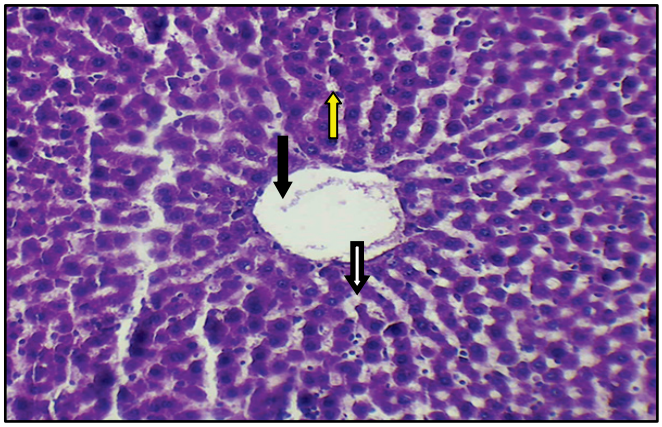

Fig. 10. Liver section of rats in the fifth group (carbimazole and thyroxin) showing a degree of improvement with low leukocyte infiltration (yellow arrow) around the central vein (black arrow) and normal hepatic cell architectures (white arrow)

Melissa officinalis contains active compounds such as rosmarinic acid, caffeic acid, and flavonoids that exhibit hepatoprotective properties. These compounds help stabilize liver cell membranes, preventing further damage to hepatocytes and promoting their structural integrity (Guan et al., 2022). By reducing cellular injury, *M. officinalis* may help restore the normal architecture of hepatocytes around the central vein, aiding in the repair of disorganized liver tissue and promoting a healthier, more regular arrangement of hepatocytes (Zead et al., 2024). *Melissa officinalis* has significant anti-inflammatory properties due to compounds like rosmarinic acid and eugenol. These compounds can help reduce the accumulation of inflammatory material in the central vein by inhibiting the production of pro-inflammatory cytokines such as TNF-α and IL-6, by lowering inflammation, it helps reduce central vein inflammation and the build-up of inflammatory exudates (Gajjar et al., 2024). This can reduce the recruitment and infiltration of inflammatory cells like lymphocytes, neutrophils, and macrophages into the liver. By calming the immune response, it may decrease the presence of these cells in the liver parenchyma and central vein, minimizing further damage (Bernini & Velotti, 2021). The antioxidant and anti-apoptotic properties of *M. officinalis* help protect hepatocytes by reducing mitochondrial dysfunction, a key factor in apoptosis. *Melissa officinalis* preserves mitochondrial function, which in turn reduces the likelihood of apoptosis caused by oxidative damage (Abo-Zaid et al., 2023).

Histology of the kidneys. The result of examining kidney sections showed normal structure in the third group, fourth group and fifth group, the same as in the first group. On the other hand, the second group showed irregular shape of the renal nephrons with severe infiltration of lymphocytes, severe hemorrhage and irregular shape of the renal tubules.

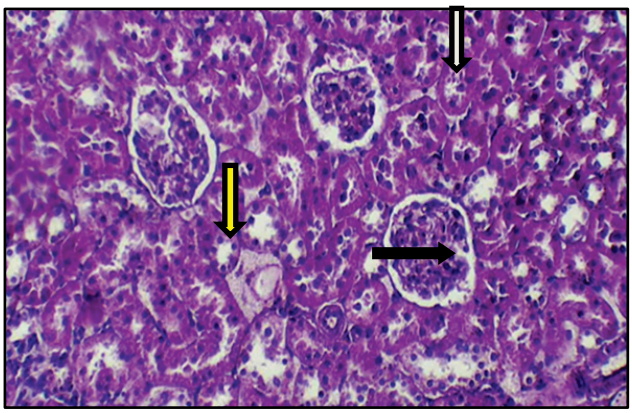

Fig. 11. Kidney section of control group (NS) showed normal shapes of glomeruli (black arrow), distal convoluted (yellow arrow) and proximal convoluted (white arrow)

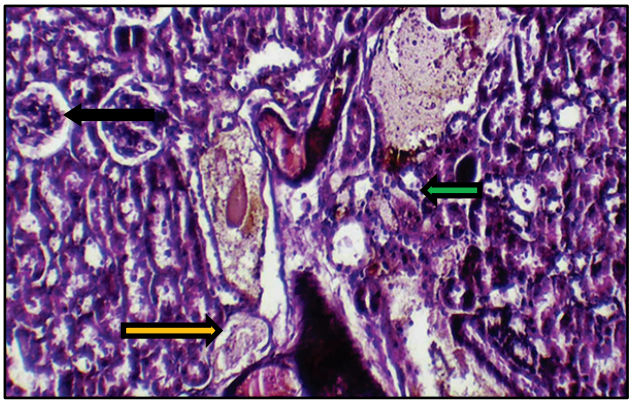

Fig. 12. Kidney section of second group showed irregular shape of the renal nephrons (black arrow), with severe infiltration of lymphocyte (green arrow), severe hemorrhage and irregular shape of the renal tubules (orange arrow)

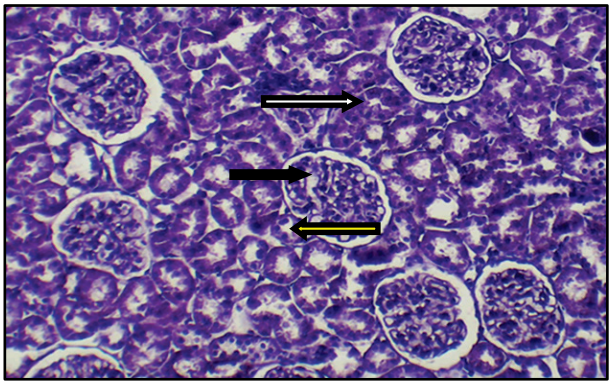

Fig. 13. Kidney section of third group showed normal architecture of kidney glomeruli (black arrow), distal (yellow arrow and proximal convoluted white arrow)

These metabolites can damage renal tissues, including the nephrons (the functional units of the kidney). The toxicity may disrupt the normal structure of the nephrons, leading to an irregular shape. The nephron's glomeruli and tubules may suffer from oxidative stress and cellular injury, causing swelling, atrophy, or degeneration of kidney cells. This cellular damage disrupts the normal architecture of nephrons, leading to their irregular appearance (Rao et al., 2022). Carbimazole can trigger an immune-mediated reaction that affects the kidneys. This can lead to interstitial nephritis, an inflammatory condition in which lymphocytes and other immune cells infiltrate the renal interstitium (the space between the tubules). Infiltration occurs as part of the immune system's response to the drug and lymphocytes gather to attack and clear damaged renal cells or perceived foreign antigens (Kroemer et al., 1992; Nagy & Malcomson, 2022). In some cases, carbimazole may cause an autoimmune-like reaction, where the immune system mistakenly attacks kidney tissues. This immune response leads to severe lymphocyte infiltration, causing inflammation and disruption of normal renal function.

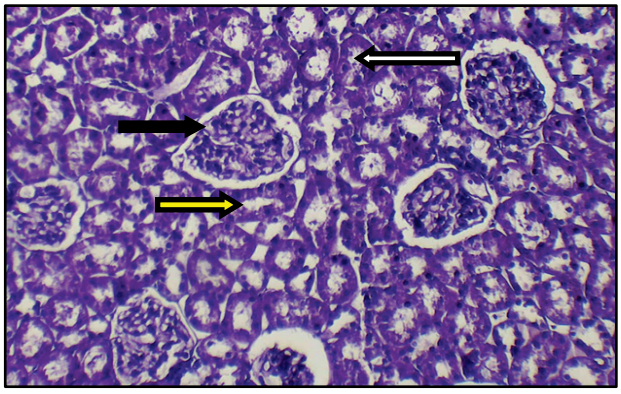

Fig. 14. Kidney section of fourth group showed normal architecture of kidney glomeruli (black arrow), distal (yellow arrow) and proximal convoluted (white arrow)

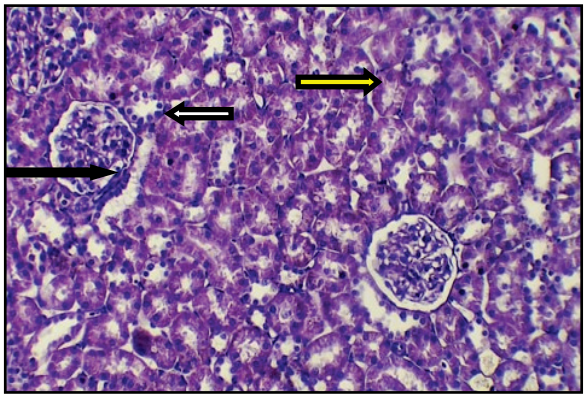

Fig. 15. Kidney section of fourth group showed normal architecture of kidney glomeruli (black arrow), distal (yellow arrow) and proximal convoluted (white arrow)

The carbimazole-induced toxicity can cause damage to the renal vasculature, leading to weakening of the blood vessels in the kidneys. Different studies suggested the damage which can result in hemorrhage, where blood leaks from the damaged vessels into surrounding tissues (Sharhan et al., 2020; Akhigbe et al., 2021). The immune-mediated inflammatory response can also damage the small blood vessels (capillaries) in the kidneys' glomeruli and tubules, increasing the risk of hemorrhage. The inflammation may make the vessels more prone to rupture, leading to bleeding in the affected areas (Martin, 2019). Carbimazole-induced nephrotoxicity can lead to acute tubular necrosis (ATN) (Shell & Sullivan, 2020), where the epithelial cells lining the renal tubules are damaged or die, this injury can cause the tubules to lose their regular shape, as the cellular architecture is compromised. Damaged or necrotic tubules may become dilated, collapsed, or distorted, resulting in their irregular appearance.

The generation of reactive oxygen species (ROS) during carbimazole metabolism can cause oxidative damage to renal cells, leading to cellular dysfunction, inflammation, and tissue injury. This contributes to the irregular shape of nephrons and tubules (Hegazy et al., 2023).

Melissa officinalis contains rosmarinic acid, caffeic acid, and other bioactive compounds that protect kidney cells from damage. By reducing oxidative stress and cellular injury, *M. officinalis* can help preserve the structural integrity of nephrons, preventing further disorganization and maintaining a more regular shape (Boo, 2024). The antioxidants in *M. officinalis* can support the repair and regeneration of damaged renal cells, promoting the recovery of nephron architecture and reducing structural irregularities caused by carbimazole toxicity (Guan et al., 2022). The anti-inflammatory properties of *M. officinalis* help reduce the infiltra-

tion of lymphocytes and other immune cells in the kidneys. The key compounds, such as rosmarinic acid and eugenol, suppress the release of pro-inflammatory cytokines like TNF-α, IL-6, and IL-1β, which are responsible for attracting immune cells. This action can help mitigate the inflammatory response triggered by carbimazole and reduce lymphocyte infiltration into the renal tissue (Ahmeda et al., 2020; El-Ahmady et al., 2021). The antioxidant properties of *M. officinalis* help protect the blood vessels within the kidneys from oxidative damage caused by carbimazole metabolites. By neutralizing reactive oxygen species (ROS), this can reduce damage to the vascular endothelium (the inner lining of blood vessels), thereby preventing or minimizing hemorrhage (Phillips, 2023). By lowering inflammation, *M. officinalis* helps to stabilize blood vessels and reduce the likelihood of rupture or bleeding. The anti-inflammatory action helps to control the inflammatory processes that can weaken blood vessels and lead to hemorrhage in the kidneys (Phillips, 2023).

Conclusion

Melissa officinalis leaf extract regulates thyroid levels in rats. It alleviated the inflammatory response by suppressing the MDA and increasing SOD in the treatment groups. These results demonstrate the protective effect of *M. officinalis* extract in a rat model of hypothyroidism.

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