



Treatment of Hypothyroidism with Flavonoid Rich Extract of *Fucus vesiculosus* L Algae in Adult Rats

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Abstract

Background: Thyroid-related diseases, such as hypothyroidism, affect large populations worldwide and have severe health effects. *Fucus vesiculosus* L seaweed, which is full of iodine and other biologically active ingredients, has always been recognized as a remedy for hypothyroidism. The objective of this study was to explore the effects of a flavonoid extract of the algae, *Fucus vesiculosus* L, on the thyroid hormones in rat. **Method:** Thirty-two mature rats were separated into four categories and given different amounts of the seaweed extract over the span of a month. Blood samples were then taken and assessed for thyroid hormones, antioxidants, and liver enzymes. The effect of the flavonoid extract of the *Fucus vesica* algae on thyroid hormones in the serum of adult rats was studied, by estimation thyroid hormones, glutathione peroxidase, and peroxynitrite, in addition to liver enzymes in the blood serum of (32) adult rats. **Results:** The results showed that the TSH level a significant decrease in all groups compared to the control group after a month of dosing. T3 also showed a significant increase in all groups compared to the control, in addition to T4, which showed a significant increase in all groups. As for

the level of glutathione peroxidase, it showed a significant decrease in all groups compared to the control group, while peroxynitrite showed a significant decrease in all groups compared to the control group. As for liver enzymes, they showed a significant decrease in all groups compared with the control group. **Conclusion:** In summary, the *Fucus vesiculosus* L. seaweed flavonoid extracts showed a marked deviations in the concentrations of thyroid hormones and exposed potential hepato-protective and antioxidative activity in adult rats.

Keywords: *Fucus vesicularis* L algae , Thyroid hormones, Glutathione peroxidase, Peroxynitrite, Liver enzymes

Introduction

The thyroid gland plays a crucial role in the endocrine system, regulating various physiological processes such as oxygen utilization, growth, development, and cellular metabolism (Singh et al., 2021). Thyroid hormones (TH) are pivotal in controlling the organism's metabolism, impacting energy expenditure, body weight, and essential metabolic processes necessary for proper growth and development (Gnocchi et al., 2016).

The prevalence of thyroid conditions varies significantly among populations due to factors like diet, nutrition, and geographic location. For instance, in India, hypothyroidism affects 11% of the population, compared to 2% in the UK and 4.6% in the USA. Hashimoto's thyroiditis, an autoimmune disorder, is the leading cause of hypothyroidism in regions with sufficient dietary iodine. Other less common causes include previous radioactive iodine therapy, damage to the anterior pituitary gland or hypothalamus, certain medications, or prior thyroid surgery (Abid et al., 2016).

Significance | Flavonoid extract from *Fucus vesiculosus* algae showed a thyroid activity modulator for the treatment of thyroid disorders.

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In industrialized nations, iodine deficiency remains a significant threat to thyroid function, despite a global decrease in prevalence from 13.1% to 3.2% over the past 25 years, as indicated by overall goiter rates. In the USA alone, an estimated 4.8 million infants are at risk of iodine deficiency, leading to potential lifetime productivity losses (Gorstein et al., 2020).

Traditional medicine has long relied on plants and herbs, particularly algae, which constitute the foundation of medical systems for a large portion of the world's population, notably in developing countries. Medicinal plants have been utilized for millennia to address health issues, enhance flavor, preserve food, and combat disease spread. Their secondary metabolites offer diverse and crucial biological effects, aiding in microbial defense, disease treatment and prevention, blood salt and fat regulation, immune system activation, and other health benefits (Shrook et al., 2023).

Utilizing natural biological products in thyroid gland treatment is viewed as safer than chemicals and synthetic drugs, with algae products emerging as a pure, healthy, and sustainable pharmaceutical option. Algae, as photosynthetic microorganisms adaptable to various environments, possess numerous properties making them excellent candidates for therapeutic use. Found in both freshwater and marine environments, algae produce a wide array of bioactive compounds within their cells (Ghadir et al., 2021). This study illustrates the potential of plants like *Fucus vesiculosus* in treating hypothyroidism through diverse mechanisms. *Fucus vesiculosus*, belonging to the seaweed family Laminariales, stands out for its high polyphenol content (Bogolitsyn et al., 2020), making it a staple in both culinary and medicinal practices for generations. Recognized as a natural antioxidant, it combats free radicals (Song et al., 2000), while research by Mayer et al. (2011) suggests its efficacy in inhibiting malignancy growth, stimulating lipase enzyme activity, regulating blood sugar and cholesterol levels, enhancing cardiac metabolism, and activating the thyroid gland.

This algae has a long history in traditional folk medicine for treating thyroid disorders, particularly hypothyroidism, due to its iodine richness, which stimulates thyroid function, enhancing energy metabolism and reducing fat deposits. Moreover, it may aid in weight loss, potentially reduce the risk of estrogen-related cancers, and alleviate menstrual symptoms when integrated into a low-calorie diet (Aufaira et al., 2021). Thyroid hormones govern numerous metabolic processes in the body, and any hormonal imbalance can profoundly impact various organs (Aufaira et al., 2021).

Glutathione peroxidase, a member of the active peroxidase family, plays a crucial role in protecting organisms from oxidative damage within the main biological cycle. With a molecular weight of 44,000 daltons, it contains selenium in the form of selenocysteine, making it a selenoprotein (Sarıkaya & Doğan, 2020). Widely distributed in

various cell types, it localizes in mitochondria and cytoplasm, functioning as an enzymatic antioxidant by effectively scavenging free radicals and peroxides generated during oxidation processes (Vertongen et al., 2021). Peroxynitrite radical (ONOO), a reactive nitrogen species, is formed rapidly when nitric oxide (NO) reacts with the superoxide radical (O₂^{•-}), constituting a significant fat-soluble radical (Ferdinandy et al., 2021).

Liver enzyme testing, particularly the assessment of AST and ALT levels, is pivotal in diagnosing liver diseases. These enzymes serve as crucial indicators and are used to monitor the progression of various liver disorders. Elevated levels of AST and ALT in the bloodstream indicate liver or tissue damage, aiding in diagnosis and prognosis (Ammar et al., 2021; Cao et al., 2004). Hence, the present study aims to investigate the impact of flavonoid extract from *Fucus vesiculosus* L algae on thyroid hormone levels in the serum of adult rats.

Materials and methods

Animals used in the study

Thirty-two adult rats, weighing approximately 0.5 kg each and aged between 2 to 4 months, were utilized in this study conducted from March to April 2023 at the university. The rats were housed in iron cages with metal covers and sawdust-covered floors, maintained under hygienic conditions. To ensure cleanliness, the sawdust was replaced two to three times per week, and the cages were sterilized regularly. The rats had constant access to water and were provided with meals in designated food containers to minimize food scattering. Both water and food were checked daily for quality and availability.

Preparation of algae

The algae were obtained in dry form, sterilized to remove contaminants, and then finely powdered using a blender. The resulting powder was stored in dark containers in the refrigerator until required.

Determination of proximate composition of the dried algae:

The proximate composition of the dried *Fucus vesiculosus* was determined at the central laboratory of the Food Technology Research Institute, Agric. The moisture, crude fiber, ash, protein, and fat contents were measured following the methods outlined by the Association of Official Analytical Chemists (AOAC, 2010).

Total Carbohydrate (%) content was calculated using the formula:

$$\text{Total Carbohydrate} = 100 - (\% \text{ moisture} + \% \text{ fat} + \% \text{ ash} + \% \text{ crude fibers} + \% \text{ protein})$$

Iodine content

The formula of Kirkbright et al. (1974) was utilized to determine the iodine content using Atomic Absorption Spectroscopy.

Selenium content

The selenium content was determined using the formula method described by Walkinson (1966) with a minifluorometer (model TD-360, Turner Design, Sunnyvale, CA, USA).

Diet preparation

The diet was composed of the following ingredients per 100g: Casein ($\geq 80\%$ protein) 14%, Corn oil 4%, Bran 4%, mineral mixture 4% (according to Hegsted et al., 1941), vitamin mixture 1% (according to Campbell, 1963), DL-methionine 0.3%, and corn starch up to 100g (Reeves et al., 1993).

Study design

The animals were randomly divided into 4 groups, with 8 rats in each group. They were orally dosed with 1 cc daily, receiving the flavonoid extract of *Fucus vesiculosus* L algae according to the following groups:

Group 1 (Positive control group C1): orally dosed with plain water.

Group 2 (Negative control group G1): orally dosed with 1 cm³ daily of 50 mg/cm³ of the flavonoid extract of *Fucus vesiculosus* L algae for every 0.5 of body weight.

Main Group 1 (G2): orally dosed with 1 cm³ daily of 100 mg/cm³ of the flavonoid extract of *Fucus vesiculosus* L algae for every 0.5 of body weight.

Main Group 2 (G3): orally dosed with 1 cm³ daily of 150 mg/cm³ of the flavonoid extract of *Fucus vesiculosus* L algae for every 0.5 of body weight.

Biochemical analysis of serum:

At the end of the experiment, rats were fasted overnight before being euthanized and having their hepatic portal vein blood samples collected while under ether sedation. Each sample was placed in a dry, clean centrifuge tube and centrifuged for 10 minutes at 3000 rpm to separate the serum. The serum was carefully pipetted into clean, dry Wasserman tubes and then frozen at -20°C until further analysis.

Sample collection:

Blood samples were collected from the animals after a month of dosing following a 12-hour fasting period. Four cubic centimeters of blood were drawn and transferred into clean, dry plastic tubes devoid of anticoagulants. The blood was then centrifuged at 2500 cycles per minute for 10 minutes to separate the serum. The serum was divided into three parts and stored at -20°C in small Eppendorf tubes until biochemical tests for thyroid hormones, glutathione peroxidase (GPX), and peroxynitrite were conducted, along with liver enzymes analysis.

Thyroid Hormone Estimation:

Thyroid hormone concentrations were estimated using ELISA techniques following the instructions provided by Monobind, a US-based company. T3 levels were determined according to the method described by Braverman et al. (1996), while T4 levels were estimated

following the method outlined by Mazzafferi et al. (1998). TSH hormone levels were assessed based on the method detailed by Shamsian et al. (2016).

Glutathione Peroxidase and Peroxynitrite Estimation in Blood Serum:

The activity of GPX enzyme was determined using a colorimetric method, where the absorbance intensity correlated with the color density of the formed complex, as per Green et al. (1984). Peroxynitrite concentration was assessed using a modified method described by Al-Zamely (1998).

Estimation of Liver Enzymes in Blood Serum:

The activity of liver enzymes including AST (Aspartate Aminotransferase), ALT (Alanine Aminotransferase), and ALP (Alkaline Phosphatase) was determined following the method outlined by Winn et al. (1998).

Statistical Analysis:

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software, version SAS 2012. Duncan's Multiple Range Test was employed to compare means, with significance levels set at $P \leq 0.01$ and 0.05 . T-tests were utilized to compare the groups receiving the flavonoid extract with the control group after one month of dosing, as described by Al-Rawi (2000).

Results

The thyroid hormones for controls and treated groups were shown in Table 1. The result showed (-ve) control group recorded (5.991 + 0.973) over than (+ve) control group. A significant decrease was observed in the levels of thyroid hormones, including thyroxine (T4), in the group treated with the flavonoid extract compared to the control group. While T3 recorded value of (-ve) control group of 1.531+ 0.473 over the (+ve) control group (0.725 + 0.649) which show that there is a significant decrease in level of T3 in group treated with the flavonoid extract compared to the control group. Table also clear that the TSH of (-ve) control group recorded (0.513 +0.0921) less than (+ve) control group with a significant differences between them.

Table 1 showed that the mean value of the AST (U/L) of the (-ve) control group showed 30.116 less than the (+ve) control group, with a significant difference between them. The value of ALT (U/L) of the (-ve) control group recorded value of (21.145 \pm 2.248) less than of -ve control group value (27.312 \pm 7.58). The table also represent the ALP U/L value recorded (8.123 \pm 1.128) less than of (+ve) control group value (13.341 \pm 4.12). The study overall revealed a significant decrease in the levels of liver enzymes, including alanine aminotransferase (ALT) and aspartate aminotransferase (AST), in the group administered with the flavonoid extract of *Fucus vesicularis* L algae. ALT and AST are markers of liver function, and their decreased levels imply a potential protective effect of the algae extract on liver health.

Table 1. shows the mean \pm standard deviation of thyroid hormones, antioxidants, and liver enzymes for the samples under study.

Mean \pm SD				Groups
G3 n =32	G2 n =32	G1 n =32	C1 n =32	Parameter
0.249 \pm 0.035c	0.377 \pm 0.038b	0.513 \pm 0.021a	0.683 \pm 0.236 a	TSH (ng /dl)
1.012 \pm 0.283b	1.221 \pm 0.427b	1.531 \pm 0.437a	0.725 \pm 0.649c	T3 (μ g/dl)
7.791 \pm 0.612c	6.104 \pm 1.032b	5.991 \pm 0.793b	9.702 \pm 0.222a	T4 (ng/dl)
3.787 \pm 0.924c	4.712 \pm 0.567b	4.922 \pm 0.622b	5.502 \pm 0.722a	GPX (U/L)
140.54 \pm 28.93b	128.15 \pm 17.87c	130.98 \pm 37.19c	160.002 \pm 37.28a	Peroxynitrit (mg/dl)
23.765 \pm 10.98c	25.451 \pm 3.268c	30.116 \pm 12.67b	38.012 \pm 8.21a	AST U/L
16.082 \pm 1.981c	19.432 \pm 2.287c	21.145 \pm 2.248b	27.312 \pm 7.58a	ALT U/L
4.902 \pm 1.186c	6.127 \pm 1.45c	8.123 \pm 1.128b	13.341 \pm 4.12a	ALP U/L

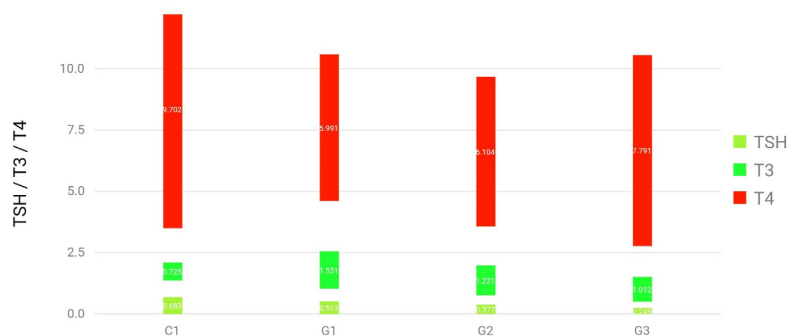


Figure 1. The average level of TSH, T3, T4 (micro IU/ml) in the blood sera of the experimental rat treated with the flavonoid extract of the *Fucus vesicularis L* algae after a month of dosing.

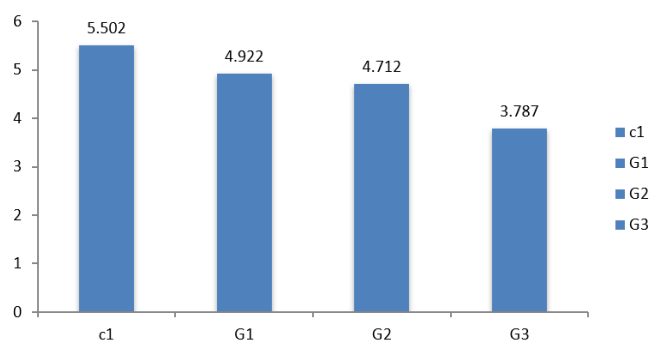


Figure 2. The average level of the GPX enzyme (IU/L) in the blood sera of the experimental rat treated with the flavonoid extract of *Fucus vesicularis L* algae after a month of dosing.

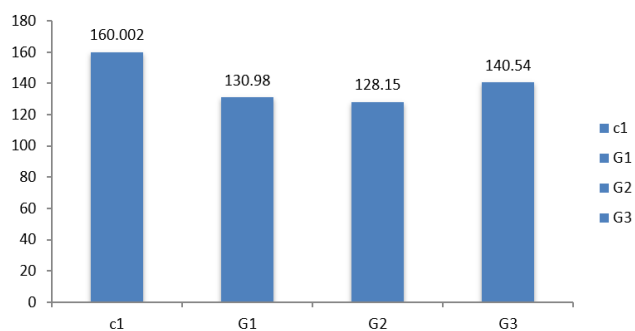


Figure 3. The average level of peroxynitrite (mg/dL) in the blood serum of the experimental rat treated with the flavonoid extract of the *Fucus vesicularis L* algae after a month of dosing

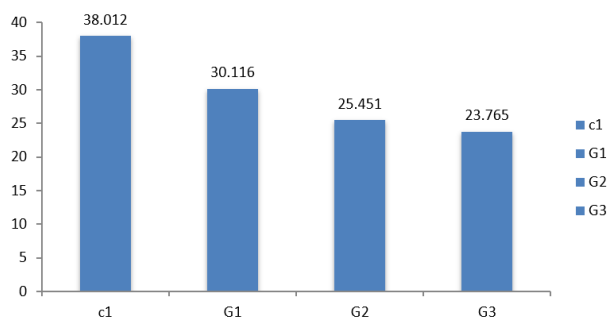


Figure 4. The average level of AST (units/international) in the blood sera of the experimental rat treated with the flavonoid extract of *Fucus vesicularis L algae* after a month of dosing.

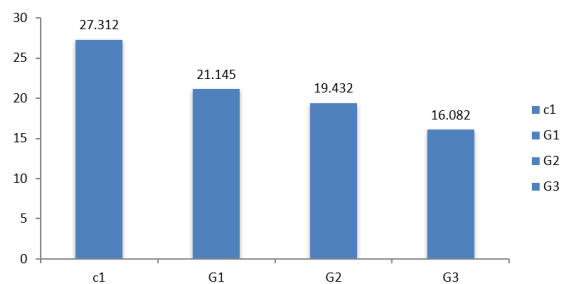


Figure 5. Average ALT level (IU/L) in the blood sera of the experimental rat treated with the flavonoid extract of *Fucus vesicularis L algae* after a month of dosing.

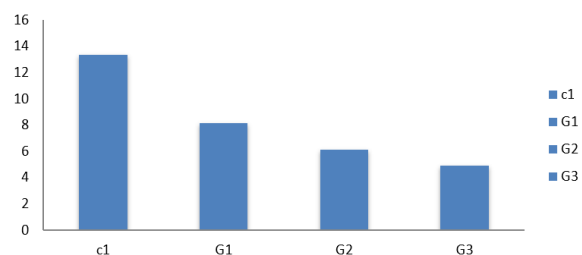


Figure 6. Average ALP level (IU/L) in the blood sera of the experimental rat treated with the flavonoid extract of *Fucus vesicularis L algae* after a month of dosing.

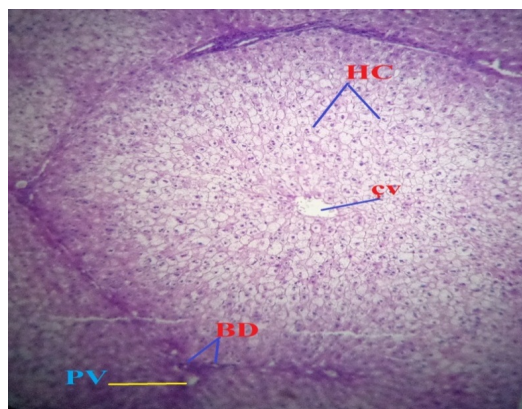


Figure 9. A cross section of the liver showing the central vein, hepatocytes of the bile duct and the portal vein of the control group X(C1) 200(HE)



Figure 10. Cross-section showing little lymphocytic infiltration near the portal vein and bile ducts, noting normal hepatocytes of group G1

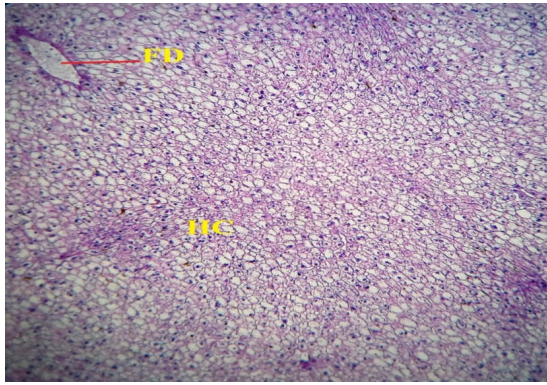


Figure 11. A cross-section of the liver showing the beginning of fibrin deposition in the central vein, with normal liver cells observed for group IV XG2 200(HE)

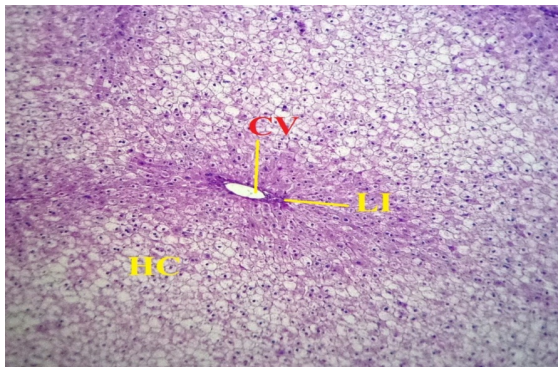


Figure 12. A cross-section of the liver showing very little lymphocytic infiltration near the central vein, with normal hepatocytes observed for group G3

Moreover, the flavonoid extract exhibited a significant reduction in the levels of antioxidants in the serum. Antioxidants are crucial in neutralizing harmful free radicals and maintaining cellular homeostasis. The decrease in antioxidant levels could indicate a potential alteration in the antioxidant defense system by the algae extract. The results showed a significant decrease at $p \leq 0.05$ in the level of each (thyroid hormones, antioxidants and oxidative stress, liver enzymes) in the serum of the group dosed with the flavonoid extract of *Fucus vesicularis* L algae compared to the control group, as in Figures (1, 2, 3, 4, 5, 6, 7, 8) respectively.

Discussion

The literature lacks studies on the impact of *Fucus vesiculosus* flavonoid extract on thyroid hormones in adult rat serum. *Fucus vesiculosus* is rich in iodine, affecting thyroid hormone levels and overall mineral balance, potentially leading to nerve damage and kidney diseases. Pre-use testing for mineral levels is recommended (Zaragoza et al., 2008). Additionally, its mucopolysaccharide content may hinder medication absorption, posing risks of bleeding and diarrhea, particularly when combined with anticoagulants or antiplatelet drugs (Skibola et al., 2004). Thyroid diseases can result from gland or pituitary/hypothalamus dysfunction, impacting TSH and TRH secretion (Mishra et al., 2012).

Thyroid diseases are prevalent, impacting approximately 13 adults, with higher incidence rates among the elderly. In women, insufficient secretion of TRH and TSH can lead to thyroid defects or iodine deficiency, impairing nerve axon branching and dendritic appendage formation, resulting in severe mental disability and short stature, termed cretinism. Hypothyroidism manifests in adults (Mishra et al., 2012). Continuous stimulation of the thyroid gland by TSH prompts the production of colloidal fluid, enlarging the gland to a weight of 300-500 grams or more in humans (Agustin et al., 2013).

Marine algae, with its rich iodine content and high levels of fiber, minerals, and polyunsaturated fatty acids, is a valuable source of nutrients (Hall et al., 2012). Seaweed's iodine content makes it a popular dietary aid, as confirmed by Chater et al. (2012). Additionally, Kang et al. (2016) demonstrated that marine algae can contribute to weight reduction, supporting its use as an anti-obesity agent.

Treatment with *Fucus vesicularis* and antithyroid algae disrupts thyroid function, affecting metabolic processes, body weight, and growth by modulating thyroid hormones (Silva et al., 2004). *Fucus vesicularis* algae play a role in maintaining thyroid gland function, regulating hormone secretion, and reducing thyroid weight (Rupérez et al., 2002). Rich in iodine, *Fucus vesicularis* algae influences metabolic processes through thyroid hormones (Rupérez et al., 2002). Additionally, flavonoid extracts may regulate

thyroid hormone levels, as evidenced in studies involving mice (Sabah et al., 2020).

The significant increase in the level of the GPX enzyme can be attributed to several factors: the active compounds found in the alga *Fucus vesiculosus* have the ability to remove free radicals or possess an antioxidant mechanism. Additionally, these substances may activate enzymatic antioxidants that scavenge free radicals (Shirwaiar et al., 2004). The GPX enzyme contains selenium, playing a crucial role in maintaining thyroid function. Prolonged selenium deficiency and low blood levels are associated with thyroid cancer (Alf et al., 2013). Moreover, the efficacy of the GPX enzyme is notably affected by thyroid diseases. Mohaned et al. (2012) reported a significant decrease in GPX enzyme effectiveness in individuals with hyperthyroidism.

Peroxynitrite levels also exhibited a significant decrease. This reduction may be attributed to the presence of numerous phenols and flavonoids in *Fucus vesiculosus*. These compounds are known for their ability to directly eliminate peroxynitrite radicals (Joe et al., 2004).

The high concentrations of vitamins C and E found in fucus moss are believed to contribute to the reduction in peroxynitrite radicals due to their antioxidant properties (Han et al., 2007). Another possible reason for the decrease in peroxynitrite levels could be the generation of free radicals, which oxidize fats in cell membranes. Unsaturated fatty acids, being the most exposed part to free radical reactions due to their double bonds, are particularly susceptible to oxidative stress (Al-Hassani et al., 2004). However, the decrease observed in groups treated with flavonoid extract suggests that flavonoids act as antioxidants. Flavonoid compounds exhibit antioxidative properties through their oxidative-reductive characteristics, which are pivotal in neutralizing free radicals, scavenging oxygen, or destroying peroxides (Habla et al., 2010).

Thyroid hormone levels play a crucial role in maintaining normal liver function. Increased levels of transaminase enzymes are often observed in individuals with hypothyroidism, sometimes leading to symptoms resembling those of liver disease (Pseudo Liver Disease), such as muscle pain and fatigue. This increase is accompanied by elevated AST activity (Inkinen et al., 2004).

The results of our current study indicate that the liver tissue remains unaffected by the extracts under trial, a finding corroborated by the histological study. This suggests that the flavonoid extract exhibits minimal toxicity towards tissues, indicating the safety of utilizing *Fucus vesiculosus* algae, as it does not disrupt cell membranes or lead to hepatitis, preventing the leakage of liver enzymes into the bloodstream (Dong et al., 2003). The observed decrease in liver enzyme levels may primarily stem from an extended dosing period, coupled with the protective effects of *Fucus vesiculosus* and its active compounds, particularly flavonoids, on liver cells. These compounds play a crucial role in scavenging free radicals and

alleviating oxidative stress, thereby stabilizing liver cells and preventing enzyme leakage.

Furthermore, a significant decrease in ALT enzyme levels was noted, aligning with Al-Douri's findings of low ALT levels, suggesting that liver cell damage is minimal, thus preventing enzyme release into the bloodstream (Al-Douri, as cited in the current study). Similarly, the significant decrease in ALP enzyme levels is consistent with Al-Douri's findings regarding the effect of lemongrass extract on ALP enzyme activity (Samarrai et al., 2013). This decrease may also be attributed to the absence of liver cell breakdown, as evidenced by the presence of numerous active compounds in *Fucus vesiculosus* algae.

The results of the current study revealed minimal necrosis and lymphocyte infiltration in all groups, with liver cells exhibiting normalcy compared to the control group. In the groups treated with flavonoid extract, G1 displayed minimal lymphocyte infiltration near the portal vein and bile ducts, with normal liver cells. However, fibrin deposition was observed in the central vein of G2, despite normal liver cells, compared to the control group.

Literature review did not yield studies on the effect of flavonoid extract from *Fucus vesiculosus* algae on serum liver enzymes in adult rats. However, Al-Samarrai et al. (2013) demonstrated that treatment with *Fucus vesiculosus* and its extracts resulted in the formation of normal liver cells and coverage cells. The observed changes, such as lymphocyte infiltration and necrosis in the control and flavonoid extract-treated groups, could stem from alterations in metabolic processes. Increased peroxidation might induce changes in cellular metabolism within and outside the liver tissues. Abbia et al. (2020) conducted a study that supports these findings. They observed significant reductions in plasma biochemical markers, including triglycerides, total and conjugated bilirubin, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP), following the administration of *Fucus vesiculosus* and *Ascophyllum nodosum*. Moreover, individuals fed a high-fat meal supplemented with the basal diet for four weeks to induce obesity, and treated with alcoholic extract and fucus powder, exhibited lower blood levels of glutamic oxaloacetic transaminase (GOT), ALP, and glutamic-pyruvic transaminase (GPT) (El-Shaer et al., 2021).

Increased accumulation of fat peroxidation products within cells can lead to hydrogen removal, causing cell deformation or death (Thomas et al., 2003). Furthermore, the liver's metabolic activity escalates during detoxification processes in response to exposure to toxic substances, aiming to counterbalance the stress induced by toxins. This heightened activity, aimed at liberating energy sources like glucose, may result in cell death and decomposition, with necrosis occurring subsequently either after severe degeneration or abruptly. Phagocytic cells eliminate small portions immediately,

while the remaining material liquefies and enters the lymph and veins (Winrow et al., 1993).

Despite observed distortions, liver cells appeared normal in both the control group and the groups treated with extracts. This preservation of normalcy could be attributed to the antioxidative properties of the active compounds found in *Fucus vesiculosus*. Studies have indicated that treatment with these extracts containing effective compounds accelerates cellular repair processes. The active compounds stimulate cells to release chemical attractants for inflammatory cells, which aid in the removal of damaged tissue and stimulate cellular repair mechanisms.

The active compounds present in *Fucus vesiculosus* encourage healthy tissue regeneration to compensate for damaged cells. Additionally, these compounds may prevent fat accumulation in liver tissue by promoting the transfer of fat from the liver to the blood serum, inhibiting lipogenesis, or stimulating fat oxidation in bodily tissues. They may also hinder the effectiveness of enzymes involved in fat synthesis processes (Winrow et al., 1993).

However, despite the significant results obtained, there are several limitations to consider. Firstly, the study exclusively involved adult rats, and extrapolating these findings directly to humans may not be appropriate due to potential differences in thyroid physiology and metabolism between species. Secondly, the study focused solely on the impact of the algal extract on thyroid hormones and did not assess any potential negative effects or other physiological outcomes. To ensure the safety and effectiveness of the extract as a therapeutic intervention for thyroid diseases, future research should investigate its broader impacts on overall health as well as any possible adverse effects.

Conclusion

In conclusion, the flavonoid extract derived from *Fucus vesiculosus* L. algae exerted notable alterations in thyroid hormones in the serum of adult rats. The study findings revealed significant changes in thyroid hormone levels when the flavonoid extract from *Fucus vesiculosus* L. algae was administered. These results suggest a noticeable impact of the algal extract on thyroid function, potentially serving as a thyroid activity modulator. Particularly, the observed alterations in thyroid hormone levels imply that the extract regulates thyroid function in the rat model. Overall, the study results suggest that *Fucus vesiculosus* L. algae extract may hold promise for the treatment of human thyroid diseases in the future.

Author contribution

S.M.E. conceptualized, conducted the experiment, analyzed data, prepared the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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