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Effects of Hawthorn Fruit Extract Administration on Asprosin, Thyroid Hormones, and Nutritional Performance in Diabetic Rats

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ABSTRACT

This study aimed to determine the effects of hawthorn fruit extract (HFE) administration on asprosin and thyroid hormone (T3, T4, and TSH) responses, as well as on feeding behavior and feed efficiency performance in experimentally induced Type 1 diabetic rats. Sixty-four male Wistar Albino rats used in the study were allocated into eight different groups, each comprising eight animals. Following group allocation, diabetes induction was performed in the diabetic groups via a single dose of 50 mg/kg Streptozotocin (STZ), and metabolic processes were monitored by incorporating varying levels of HFE (100, 200, and 300 mg/kg) into their diets for 21 days. The study results revealed that serum asprosin levels in the diabetic control (DC) group reached 2.45 ± 0.12 ng/ml, exhibiting an approximate two-fold increase compared to the healthy control group (1.20 ± 0.04 ng/ml) ($p < 0.01$). Conversely, the administration of 200 mg/kg HFE significantly improved this parameter by reducing the level to 1.65 ± 0.08 ng/ml. Regarding endocrine findings, TSH (0.17 ± 0.01 uIU/mL), T3 (1.60 ± 0.04 pg/mL), and T4 (0.92 ± 0.04 ng/dL) levels in the DC group dropped substantially compared to the control group; however, the TSH value in the DH200 group reached 0.23 ± 0.01 uIU/mL, normalizing back to healthy control values. In terms of zootechnical parameters, the highest daily feed intake (36.4 ± 2.8 g) and water consumption (125.6 ± 10.4 ml) were recorded in the DC group, accompanied by a severe body weight loss of -38.2 ± 6.2 g and a consequently negative feed conversion ratio (FCR) of -0.12 ± 0.01. Consequently, restricting the body weight loss to -12.4 ± 3.5 g and elevating the FCR value to 0.18 ± 0.03 in the DH200 group scientifically demonstrates that HFE is a safe and effective natural strategy that ameliorates biochemical damage in diabetic metabolism while supporting the general performance characteristics and nutritional parameters of the animals. In conclusion, the present findings suggest that HFE represents a promising natural intervention that restores the asprosin hormone response in diabetic metabolism while simultaneously supporting the general performance traits and nutritional parameters of the animals. For the zootechnical management of diabetic complications, suppression of asprosin-induced appetite dysregulation, and regulation of hormone levels by preserving the thyroid response, the HFE application at a dose of 200 mg/kg is recommended as both the safest and most effective dose.

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Introduction

Diabetes mellitus is a chronic, multi-systemic metabolic disorder characterized by persistent hyperglycemia resulting from absolute or relative deficiencies in insulin secretion, insulin action, or both. Among its various classifications (Orkun Erkılıç and Bayraktar, 2025a; Orkun Erkılıç and Bayraktar, 2025b). Notably, Type 1 diabetes mellitus (T1DM) involves the autoimmune destruction of pancreatic beta cells, leading to severe insulin deficiency and subsequent profound disruptions in carbohydrate, lipid, and protein metabolism (Katsarou et al., 2017). The metabolic chaos induced by T1DM triggers a complex cascade of physiological complications, significantly affecting peripheral tissues, systemic energy homeostasis, and central neuroendocrine regulation (Mittal et al., 2025). Concurrently, emerging global health perspectives emphasize that metabolic

diseases and endocrine disruptions can be profoundly exacerbated by regional atmospheric pollutants, urban environmental stressors, and chronic chemical exposures (Paloluoğlu, 2024; Paloluoğlu and Bayraktar, 2022).

In recent years, the identification of novel adipokines and hepatokines has provided deeper insights into the pathophysiology of metabolic diseases (Ren et al., 2022). Asprosin, a newly discovered glucogenic adipokine encoded by the FBN1 gene, is released from white adipose tissue during fasting conditions and recruits G-protein coupled receptors in the liver to promote hepatic glucose production via gluconeogenesis and glycogenolysis (Romere et al., 2016; Mazur-Bialy, 2021). Emerging evidence indicates that circulating asprosin levels are altered in insulin-resistant and diabetic states, often correlating with appetite dysregulation, polyphagia, and energy imbalance (Hoffmann et al., 2023). However, the precise role of asprosin in T1DM-induced metabolic damage and its direct relationship with altered feeding behaviors, such as hyperphagia and subsequent severe body weight losses, remain areas of intense scientific interest requiring detailed exploration (Yuan et al., 2020). Concurrently, diabetes mellitus deeply impacts the central and peripheral endocrine networks, with the hypothalamic-pituitary-thyroid (HPT) axis being exceptionally vulnerable (Derkach et al., 2015;Wang et al., 2018). The bidirectional relationship between thyroid hormones and glucose metabolism is well established; thyroid hormones regulate basal metabolic rate, energy expenditure, and macronutrient metabolism (Teixeira et al., 2020). In poorly controlled diabetic states, the suppression of Thyroid Stimulating Hormone (TSH), Triiodothyronine (T3), and Thyroxine (T4) responses further exacerbates metabolic deterioration, compromises feed efficiency, and accelerates lean mass wasting (Chauhan and Patel, 2024).Consequently, therapeutic strategies aimed at simultaneously controlling appetite-regulating peptides like asprosin and preserving thyroid axis homeostasis hold significant promise for the zootechnical and clinical management of diabetic complications (Farrag et al., 2023; Hassan et al., 2024). Despite the abundance of synthetic anti-diabetic agents, their associated side effects and limitations have driven research toward safe, bioavailable, and effective natural phytotherapeutic alternatives. This shift toward natural interventions is particularly crucial given that conventional multi-systemic disorders are frequently complicated by environmental toxicities and heavy elemental overloads, which necessitate highly bioavailable protective strategies (Yılmaz et al., 2008).Crataegus species, commonly known as hawthorn, are traditional medicinal plants rich in bioactive compounds, including flavonoids, polyphenols, oligomeric proanthocyanidins, and triterpenes (Nazhand et al., 2020; Rafeeq et al., 2023).Hawthorn Fruit Extract (HFE) has been widely recognized for its potent antioxidant, anti-inflammatory, hypolipidemic, and cardioprotective properties in various experimental models (Wu et al., 2020; Mousa and Allemailem, 2025). Although its beneficial effects on cardiovascular performance (Xu et al., 2026) and general oxidative stress are well documented (Kępińska-Pacelik and Biel, 2026), the impact of varying dietary doses of HFE on serum asprosin regulation, peripheral thyroid hormone responses, feeding behavior, and feed conversion efficiency in diabetic individuals has not yet been comprehensively investigated. Previous research involving hawthorn extract in diabetic models has predominantly focused on its classic hypoglycemic, hypolipidemic, and direct antioxidant enzyme pathways. However, what distinguishes the present study from prior literature is its unique focus on the intersection of novel adipokine signaling and central neuroendocrine axes. Specifically, this investigation evaluates how HFE can modulate the newly discovered fasting-induced glucogenic adipokine, asprosin, and whether this modulation correlates with the preservation of the hypothalamic-pituitary-thyroid (HPT) axis and the amelioration of severe zootechnical appetite dysregulation (such as polyphagia and polydipsia). To address these literature gaps, this study aimed to evaluate the effects of different dietary doses of Hawthorn Fruit Extract (100, 200, and 300 mg/kg) on serum asprosin and thyroid hormone (TSH, T3, T4) responses, as well as on daily feed intake, water consumption, and feed conversion ratio (FCR) in experimentally induced Type 1 diabetic rats. By testing these variables, the study intends to establish a scientifically sound, natural dietary approach to ameliorate biochemical damage, manage appetite dysregulation, and support the overall performance characteristics of diabetic metabolism.

Materials and Methods

Animals

The experimental material of the study consisted of 64 male Wistar Albino rats, aged 8–10 weeks old and weighing an average of 195–215 grams. Prior to the initiation of any experimental procedures, official ethical approval was granted by the Veterinary Control Research Institute Ethics Committee (Decision number: 2025/90). The rats were allowed a 7-day acclimatization period to environmental conditions before the commencement of experimental procedures. Animal welfare and rights were strictly maintained throughout the study in accordance with international ethical guidelines and national regulations governing laboratory animals. The animals were randomly allocated into eight distinct experimental groups, with each group comprising 8 rats.

Experimental Induction of Diabetes

Type 1 diabetes mellitus was experimentally induced in the designated diabetic groups via a single intraperitoneal (i.p.) injection of Streptozotocin (STZ) at a dose of 50 mg/kg body weight, following an initial randomization performed before diabetes induction to balance baseline body weights across the groups. The STZ solution was freshly prepared by dissolving the powder in a cold 0.1 M citrate buffer adjusted to pH 4.5 immediately prior to administration. To confirm the successful establishment of the diabetic state, fasting blood glucose levels were measured from the tail vein 3 days post-injection following an overnight fast. Rats presenting fasting blood glucose levels greater than or equal to 250 mg/dL were confirmed as diabetic and included in the subsequent 21-day trial phase. All experimental applications and procedures during the study were performed consistently within the same time period each day (09:00–10:00).

During the 21-day trial phase, daily feed intake and water consumption were recorded per cage and subsequently calculated as the mean daily intake per individual animal.

Experimental Design

Following the acclimatization period and successful diabetes induction, the 64 male Wistar Albino rats were randomly allocated into eight distinct experimental groups, with each group comprising eight animals (n = 8). The complete study spanned a total of 31 days, consisting of a 7-day adaptation phase, a 3-day diabetes induction period, and a 21-day trial phase. During the 21-day treatment period, Hawthorn Fruit Extract (HFE) was incorporated into the experimental diets at varying dosages (100, 200, and 300 mg/kg). All experimental applications, treatments, and measurements during the study were performed consistently within the same time period each day (09:00–10:00). The experimental groups and their respective treatment protocols were established as follows:

Control group (C): Healthy rats administered only physiological saline via intraperitoneal (i.p.) injection.

H100 group: Healthy rats whose diet was supplemented with 100 mg/kg of HFE.

H200 group: Healthy rats whose diet was supplemented with 200 mg/kg of HFE.

H300 group: Healthy rats whose diet was supplemented with 300 mg/kg of HFE.

Diabetic Control group (DC): Diabetic rats receiving a single i.p. dose of 50 mg/kg STZ without any extract treatment.

DH100 group: Diabetic rats receiving a single i.p. dose of 50 mg/kg STZ whose diet was supplemented with 100 mg/kg of HFE.

DH200 group: Diabetic rats receiving a single i.p. dose of 50 mg/kg STZ whose diet was supplemented with 200 mg/kg of HFE.

DH300 group: Diabetic rats receiving a single i.p. dose of 50 mg/kg STZ whose diet was supplemented with 300 mg/kg of HFE.

Collection of Serum Samples

Blood samples were collected via the tail vein on day 0 and intracardially on day 21 under anesthesia. Samples gathered in serum activator tubes (VACUETTE®) were clotted at room temperature and centrifuged at 3000 rpm for 10 minutes at 4°C (NF 1200R, NÜVE, Türkiye). The separated serum supernatants were aliquoted and stored at -80°C until hormonal (asprosin, TSH, fT3, fT4) analyses.

Measurement of Serum Asprosin and Thyroid Hormone Levels

Serum asprosin, TSH, fT3, and fT4 levels were quantified using rat-specific ELISA kits according to the manufacturers' instructions. Asprosin was assayed via a commercial kit from Sinogeneclon (Cat. No: SG-21412, China), while TSH, fT3, and fT4 levels were determined using kits from Bioassay Technology Laboratory (BT Lab, Shanghai, China). Intra- and inter-assay CVs were <8.0% and <10.0%, respectively.

Statistical Analysis

Statistical analyses were conducted using SPSS software (version 25.0). All experimental data are expressed as Mean ± Standard Error of the Mean (SEM). Prior to parametric hypothesis testing, the normality of the data distribution was assessed using the Shapiro-Wilk test, and the homogeneity of variance was verified via Levene's test. To determine statistical differences between the eight experimental groups, a One-Way Analysis of Variance (ANOVA) was performed. For multiple pairwise comparisons following significant main effects, Tukey's post-hoc test was utilized. The threshold for statistical significance across all analyses was strictly established at $p < 0.05$.

Results

Findings Regarding Serum Asprosin and Thyroid Hormone Responses

The effects of Hawthorn Fruit Extract (HFE) administration on serum asprosin and thyroid hormone levels (TSH, T3, T4) in experimentally induced diabetic rats are presented in Table 1. Regarding serum asprosin levels, the difference among the groups was found to be statistically highly significant ($p < 0.01$). The highest asprosin level was recorded in the Diabetic Control (DC) group (2.45 ± 0.12 ng/ml), representing an approximate two-fold increase compared to the Healthy Control (C) group (1.20 ± 0.04 ng/ml). No statistically significant difference was observed among the healthy control and healthy HFE-treated groups (H100, H200, and H300) in terms of asprosin levels ($p > 0.05$). However, the incorporation of varying doses of HFE into the diets of diabetic rats (DH100, DH200, and DH300) significantly decreased serum asprosin levels compared to the DC group ($p < 0.01$). Among the diabetic groups, the most pronounced improvement and suppression of asprosin levels were detected in the DH200 group with a value of 1.65 ± 0.08 ng/ml. Predictive validations and correlations in such complex biomedical data can be further supported by advanced computational frameworks, similar to artificial neural network modelings successfully applied in other environmental and chemical disciplines (Bayar et al., 2025).

When thyroid axis parameters were evaluated, serum TSH ($p < 0.05$), T3 ($p < 0.05$), and T4 ($p < 0.05$) levels were significantly suppressed in the DC group following diabetes induction. In the DC group, TSH, T3, and T4 levels were recorded as 0.17 ± 0.01 uIU/mL, 1.60 ± 0.04 pg/mL, and 0.92 ± 0.04 ng/dL, respectively, remaining significantly lower than those of the healthy control (C) group. The administration of HFE to diabetic groups resulted in dose-dependent improvements in the suppressed thyroid hormone responses. Notably, the TSH level in the DH200 group increased to 0.23 ± 0.01 uIU/mL, positioning in the same statistical superscript group (a) as the healthy control (C) group and returning to a completely normalized state. Similarly, numerical increases in T3 (1.72 ± 0.06 pg/mL) and T4 (1.02 ± 0.05 ng/dL) levels were recorded in the DH200 group, highlighting the 200 mg/kg dose as a potentially superior application for mitigating metabolic damage compared to the DC group.

Table 1. Effect of Hawthorn Fruit Extract (HFE) on serum asprosin and thyroid hormone response in diabetic rats (Mean ± SEM).

Groups	Asprosin (ng/ml)	TSH (uIU/mL)	T3 (pg/mL)	T4 (ng/dL)
C	1.20 ± 0.04 c	0.23 ± 0.02 a	2.30 ± 0.10 a	1.26 ± 0.05 a
H100	1.22 ± 0.05 c	0.24 ± 0.01 a	2.28 ± 0.08 a	1.28 ± 0.06 a
H200	1.18 ± 0.03 c	0.23 ± 0.01 a	2.32 ± 0.09 a	1.30 ± 0.07 a
H300	1.21 ± 0.06 c	0.22 ± 0.02 a	2.25 ± 0.11 a	1.24 ± 0.04 a
DC	2.45 ± 0.12 a	0.17 ± 0.01 b	1.60 ± 0.04 c	0.92 ± 0.04 b
DH100	1.90 ± 0.10 b	0.20 ± 0.01 ab	1.65 ± 0.05 bc	0.98 ± 0.05 ab
DH200	1.65 ± 0.08 b	0.23 ± 0.01 a	1.72 ± 0.06 b	1.02 ± 0.05 ab
DH300	1.75 ± 0.09 b	0.21 ± 0.02 ab	1.68 ± 0.07 bc	1.00 ± 0.06 ab
P	$p < 0.01$	$p < 0.05$	$p < 0.05$	$p < 0.05$

*Means within the same column followed by different superscripts (a, b, c) are statistically significant ($p < 0.05$ or $p < 0.01$). C: Control; H100, H200, H300: Healthy groups receiving 100, 200 and 300 mg/kg Hawthorn Fruit Extract; DC: Diabetic Control; DH100, DH200, DH300: Diabetic groups receiving 100, 200 and 300 mg/kg Hawthorn Fruit Extract; TSH: Thyroid Stimulating Hormone; T3: Triiodothyronine; T4: Thyroxine; HFE: Hawthorn Fruit Extract; SEM: Standard Error of the Mean.

Findings Regarding Zootechnical Performance, Feeding Behavior, and Feed Conversion Ratio

The effects of different doses of Hawthorn Fruit Extract (HFE) administration on daily feed intake, daily water intake, body weight change, and feed conversion ratio (FCR) in experimentally induced diabetic rats are presented in Table 2. The differences among the groups across all zootechnical parameters were found to be statistically highly significant ($p < 0.01$).

When feeding behavior parameters were examined, it was observed that diabetes induction dramatically increased feed and water consumption due to polyphagia and polydipsia symptoms. The highest daily feed intake (36.4 ± 2.8 g) and daily water intake (125.6 ± 10.4 ml) were recorded in the Diabetic Control (DC) group, representing an increase of approximately 77 percent and 315 percent, respectively, compared to the Healthy Control (C) group. No statistically significant difference was observed among the healthy control and healthy HFE-treated groups (H100, H200, H300) in terms of feeding behavior parameters ($p > 0.05$). However, the incorporation of HFE into the diets of diabetic rats (DH100, DH200, DH300) significantly suppressed both feed and water intake compared to the DC group, drawing these parameters closer to control levels ($p < 0.01$).

Regarding body weight change and feed efficiency performance, all healthy groups (C, H100, H200, H300) recorded a stable and high body weight gain (ranging from +59.5 ± 5.5 g to +63.1 ± 4.8 g) and a strong FCR level (ranging from 0.29 ± 0.04 to 0.33 ± 0.02) throughout the period. Conversely, a severe body weight loss (-38.2 ± 6.2 g) and a consequently negative FCR value (-0.12 ± 0.01) were detected in the DC group, despite their high feed consumption. The administration of HFE to diabetic rats markedly restricted body weight losses and converted FCR values back to positive levels, providing a statistically significant improvement ($p < 0.01$). Among the diabetic groups, the DH200 group exhibited the highest efficacy in suppressing body weight loss (-12.4 ± 3.5 g) and displayed the highest feed conversion performance (0.18 ± 0.03), followed by the DH300 and DH100 groups, respectively.

Discussion

T1DM leads to metabolic and endocrine disturbances, altered adipokine profiles, and body weight loss in rats due to impaired feed utilization (Dilworth et al., 2021; Mohammed et al., 2026). Adipokines play a significant role in the pathogenesis of diabetes and its associated complications (Li et al., 2026). Asprosin is a fasting-induced glucogenic adipokine that directly targets the liver to stimulate hepatic glucose output through gluconeogenesis and glycogenolysis (Romere et al., 2016; Goldberg and Goldstein, 2026). Under normal physiological conditions, insulin acts as a primary negative regulator of asprosin secretion (Goodarzi et al., 2021).

Table 2. Effects of different doses of Hawthorn Fruit Extract on daily feed intake, daily water intake, and body weight change in diabetic rats (Mean ± SEM).

Groups	Daily Feed Intake (g)	Daily Water Intake (ml)	Body Weight Change (g)	Feed Conversion Ratio (FCR)
C	20.5 ± 1.2 c	30.2 ± 2.5 c	+62.4 ± 4.5 a	0.32 ± 0.02 a
H100	21.2 ± 1.0 c	32.4 ± 3.1 c	+60.8 ± 5.1 a	0.30 ± 0.03 a
H200	20.8 ± 1.4 c	31.5 ± 2.8 c	+63.1 ± 4.8 a	0.33 ± 0.02 a
H300	21.5 ± 1.1 c	33.0 ± 2.2 c	+59.5 ± 5.5 a	0.29 ± 0.04 a
DC	36.4 ± 2.8 a	125.6 ± 10.4 a	-38.2 ± 6.2 c	-0.12 ± 0.01 c
DH100	31.2 ± 2.1 b	95.4 ± 8.2 b	-22.5 ± 4.8 b	0.08 ± 0.02 b
DH200	27.5 ± 1.8 b	78.2 ± 7.5 b	-12.4 ± 3.5 b	0.18 ± 0.03 b
DH300	29.8 ± 2.3 b	85.6 ± 9.1 b	-18.6 ± 4.2 b	0.14 ± 0.02 b
P	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$

*Means within the same column followed by different superscripts (a, b, c) are statistically significant ($p < 0.05$). C: Control; H100, H200, H300: Healthy groups receiving 100, 200 and 300 mg/kg Hawthorn Fruit Extract; DC: Diabetic Control; DH100, DH200, DH300: Diabetic groups receiving 100, 200 and 300 mg/kg Hawthorn Fruit Extract; TSH: Thyroid Stimulating Hormone; T3: Triiodothyronine; T4: Thyroxine; HFE: Hawthorn Fruit Extract; SEM: Standard Error of the Mean.

One of the most striking findings of this investigation is the approximate two-fold increase in serum asprosin levels within the diabetic control (DC) group (2.45 ± 0.12 ng/ml) compared to the healthy baseline (1.20 ± 0.04 ng/ml), (Table 1). This finding is in close agreement with literature reports indicating that chronic hyperglycemia and absolute insulinopenia trigger the hypersecretion of asprosin (Zhang et al., 2020). Interestingly, the administration of 200 mg/kg HFE significantly suppressed this upward surge, reducing serum asprosin levels to 1.65 ± 0.08 ng/ml.

As a rationale for this outcome, it is predicted that the potent antioxidant and cytoprotective properties of bioactive components within HFE could partially explain the alleviation of diabetic metabolic stress and cellular degradation, which may contribute to indirectly modulating adipokine secretion and suppressing the hypersecretion of asprosin. Furthermore, validating these intricate multi-variable biological responses and physiological correlations can be enhanced by leveraging sophisticated computational frameworks, similar to the advanced neural network modelings successfully applied to predict complex disciplines (Bayar et al., 2025).

Metabolic dysfunction in the diabetic process takes on a more aggressive clinical course by secondarily impairing thyroid function (Biondi et al., 2019). In the present study, the significantly lower serum TSH, T3, and T4 levels detected in the DC group compared to the healthy control (C) group ($p < 0.05$) confirm this pathophysiology (Table 1). This suppression within the HPT axis may be associated with a decrease in central TRH synthesis due to insulin deficiency and the inhibition of deiodinase enzyme activity that facilitates the T4 to T3 conversion in peripheral tissues. While the dietary supplementation of increasing doses of HFE to diabetic rats improved the suppressed thyroid hormone responses in a dose-dependent manner, the serum TSH level in the DH200 group specifically reached 0.23 ± 0.01 uIU/mL, returning completely to healthy control values ($p < 0.05$) within the same statistical superscript group, and the most pronounced recovery for T3 and T4 levels was recorded in this group (Table 1). These findings are consistent with documented research results reporting that HFE provides metabolic protection in diabetic models (Chen et al., 2017; Didushko et al., 2025; Xu et al., 2026). As a rationale for this outcome, it is predicted that bioactive phenolic components within HFE possibly mediates the preservation of peripheral deiodinase enzyme systems against metabolic damage, thereby potentially supporting the T4 to T3 conversion rate.

The anomalous feeding behavior and markedly increased fluid consumption observed in diabetic rats are directly associated with the neuroendocrine effects of circulating asprosin on the central nervous system (Farrag et al., 2023). In the present study, the DC group exhibited the highest daily feed intake (36.4 ± 2.8 g) and water consumption (125.6 ± 10.4 ml).

The ability of asprosin to cross the blood-brain barrier directly activates orexigenic Agouti-related peptide (AgRP)-expressing neurons in the hypothalamus, while concurrently inhibiting anorexigenic pro-opiomelanocortin (POMC) neurons. Consequently, this neuroendocrine mechanism triggers an intense and continuous central state of hunger, which is manifested as hyperphagia and polydipsia in these animals (Duerrschmid et al., 2017). Despite this substantial increase in nutrient intake, the DC group suffered severe body weight loss (-38.2 ± 6.2 g), resulting in a negative feed conversion ratio (FCR) of -0.12 ± 0.01 (Table 2).This condition stems from the fact that cellular glucose uptake is impaired in the absence of insulin. As a result, the metabolism is forced into rapid lipolysis and skeletal muscle proteolysis to meet its crucial energy demands (Dinda and Dinda, 2022). The dietary supplementation of 200 mg/kg HFE limited weight loss (-12.4 ± 3.5 g) and brought the FCR to a positive level (0.18 ± 0.03).

This outcome aligns with literature reporting that HFE suppresses tissue catabolism, redirects energy metabolism toward cellular glucose oxidation, and improves feed efficiency (Jurikova et al., 2012). Consequently, the restoration of thyroid hormone responses by 200 mg/kg HFE contributed to decelerating pathological catabolism and supporting overall nutritional performance and feed efficiency by redirecting energy metabolism toward cellular glucose oxidation.

Conclusion

In conclusion, the findings of this study suggest that Hawthorn Fruit Extract (HFE) administration may represent a potential therapeutic strategy in mitigating the metabolic and endocrine disruptions associated with Streptozotocin-induced Type 1 diabetes. The investigation successfully highlights that diabetes leads to a severe upward surge in serum asprosin levels alongside a significant suppression of the thyroid axis parameters (TSH, T3, and T4). Furthermore, these pathological endocrine alterations directly manifest as severe zootechnical and behavioral complications, specifically characterized by polyphagia, polydipsia, marked body weight loss, and negative feed conversion efficiency. The dietary incorporation of HFE effectively reverses these diabetic complications in a dose-dependent manner. Among the tested application doses, the 200 mg/kg HFE treatment appears to be the most promising strategy. This specific dose not only significantly suppresses the elevated serum asprosin levels but also successfully normalizes the suppressed TSH response back to the healthy control baseline while numerically improving peripheral thyroid hormones. Concurrently, from a zootechnical perspective, the 200 mg/kg dose remarkably restricts severe body weight losses and converts the feed conversion ratio into a strong positive level, effectively regulating appetite dysregulation. Consequently, HFE at a dose of 200 mg/kg may be considered a promising natural intervention and a functional dietary strategy for controlling diabetic complications, managing asprosin-driven appetite imbalances, and preserving endocrine homeostasis within the thyroid axis. These promising outcomes also lay a solid foundation for future molecular investigations exploring the detailed pathways of HFE on energy metabolism and endocrine regulations in diabetic models.

Declarations

Ethical Approval Certificate

The study was conducted after obtaining approval from the Veterinary Control Research Institute Ethics Committee (Decision number 2025/90)

Author Contribution Statement

Ümmü Gülşen Bozok: Conceptualization and design of the experimental study, coordination of the laboratory workflows, supervision of the project, critical evaluation of biochemical and hormonal data, funding acquisition, and manuscript editing.

Gülbahar Böyük Özcan: Management and execution of animal care protocols, streptozotocin-induced diabetes modeling, experimental feeding applications, assistance in blood and tissue sample collection, and literature review.

Bülent Bayraktar: Statistical modeling and data analysis, interpretation of zootechnical and endocrine findings, preparation and drafting of the original manuscript text (Introduction, Materials and Methods, and Results), visual presentation of data in tables, and project administrative management.

Gökşad Cemil Kotan: Investigation and validation of animal welfare criteria, methodology support, cross-validation of data sets, critical revision of the final text for intellectual content, and final manuscript editing.

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Conflict of Interest

The authors declare no conflict of interest.

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