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Effects of Dietary Nettle (*Urtica dioica*) Leaf Powder on Performance, Welfare, Hematological Profile, and Oxidative Status in Broiler Turkeys

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ABSTRACT

Medicinal plants, such as nettle (*Urtica dioica*), are increasingly popular as sustainable alternatives to synthetic growth promoters and antioxidants in poultry production. The present study aimed to evaluate the effects of dietary nettle leaves on growth performance, welfare indicators, hematological and biochemical parameters, and oxidative status of broiler turkeys (*Meleagris gallopavo*) reared under intensive conditions. Seventy-two turkeys were randomly assigned to one of three dietary treatments from 3 to 15 weeks of age, including a control diet (CN), a diet with 3% nettle leaf powder (N3), and a diet with 6% nettle leaf powder (N6). Growth performance was monitored until week 13, while blood, carcass, and organ parameters were measured at the end of the trial. Mortality occurred only in the control group (3.33%), while there was no mortality in groups N3 or N6. Growth performance was significantly influenced by diet and sex. Male turkeys fed the N3 diet achieved higher final body weight compared to those receiving the CN or N6 diets. Conversely, no growth-promoting effect was observed in female turkeys. Female turkeys receiving the N3 diet exhibited lower final body weight and a higher feed conversion ratio than those in the CN group, indicating reduced feed efficiency. Nettle supplementation had no significant effect on carcass yield, organ development, or welfare indicators, including feather cleanliness and tarsal and plantar lesions. Hematological parameters, notably mean corpuscular volume, mean corpuscular hemoglobin, and platelet count, were significantly affected by nettle supplementation diets, whereas biochemical parameters remained within physiological ranges, indicating preserved systemic homeostasis. Dietary nettle supplementation enhanced antioxidant status, with both supplemented groups exhibiting significantly increased total antioxidant capacity, as measured by 2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonic acid; ABTS) radical scavenging activity, and a decrease in lipid peroxidation, assessed by thiobarbituric acid-reactive substances (TBARS), compared to the control group. Nettle leaf supplementation enhanced antioxidant defenses without compromising turkeys' welfare. A sex-dependent pattern was observed in growth performance parameters, with male turkeys exhibiting a greater response than females at the 3% nettle leaf inclusion level. However, both sexes exhibited consistent increases in antioxidant levels, highlighting the potential of nettle as a natural supplement in turkey production.

Keywords: Broiler turkey, Growth performance, Nettle leaf, Oxidative status, Phytogenic feed additive

INTRODUCTION

Oxidative stress is a major concern in basic biology and animal production sciences, as it plays a crucial role in initiating metabolic disturbances, reducing productive performance, and affecting animal welfare (Ponnampalam et al., 2022). An imbalance between pro-oxidant processes

and antioxidant defense mechanisms is characterized by the excessive generation of reactive oxygen species (ROS). When endogenous antioxidant systems fail to adequately neutralize ROS, oxidative damage accumulates at the molecular and cellular levels, disrupts redox homeostasis, and consequently results in altered physiological functions, accelerated cellular aging, and ultimately cell death (Vágási et al., 2019; Yang et al., 2024). This condition is recognized as a critical factor in poultry health and productivity (Surai et al., 2019; Grela et al., 2023).

In modern poultry production systems, particularly in fast-growing species such as broiler turkeys (*Meleagris gallopavo*), oxidative stress is increased by elevated metabolic rates, intensive rearing conditions, environmental challenges, and nutritional imbalances (Aryal et al., 2025). In poultry, oxidative stress damages the intestinal mucosa and impairs digestion and subsequent nutrient absorption (Mishra and Jha, 2019; Li et al., 2024). Moreover, oxidative stress interferes with normal metabolic processes and elevates plasma corticosterone levels, leading to decreased feed intake, reduced body weight gain, and impaired growth performance (Desbruslais and Wealleans, 2022; Oke et al., 2024). Oxidative stress can negatively affect meat quality by increasing the risk and extent of lipid oxidation, thereby reducing shelf life and sensory quality (Choi et al., 2023). Additionally, oxidative stress could potentially compromise immune competence and welfare indicators, thereby reducing overall productivity and economic sustainability (Ghanima et al., 2020). Consequently, nutritional strategies to strengthen antioxidant defenses have become a priority in contemporary poultry nutrition (Surai et al., 2019; Oke et al., 2024).

Turkey production has gained global attention due to the high nutritional value of turkey meat, characterized by high-quality protein and a favorable lipid profile. Compared with broiler chickens, turkeys exhibit longer growth cycles and greater sensitivity to dietary composition and environmental stressors, requiring optimized feeding strategies to ensure adequate growth performance, welfare, and product quality throughout the production period (Surai and Fisinin, 2016; Ncho et al., 2025). In Algeria, turkey production is currently constrained by different structural challenges, including high feed costs, heavy reliance on imported feed products, and extended rearing periods, which collectively limit production efficiency and profitability (Feliachi, 2003; Sadoudi et al., 2024). According to estimates from the Food and Agriculture Organization (FAO), approximately 70,000 turkeys were recorded in 2009, primarily raised in backyard systems in Eastern regions of Algeria, such as Oum El Bouaghi, Batna, and Constantine (FAO, 2019). Over the last two decades, turkey production in Algeria has undergone significant development, driven by the adoption of intensive production systems and improved genetic strains. Recent Food and Agriculture Organization of the United Nations (FAOSTAT) data indicated that turkey meat production reached approximately 34,971 tons in 2024, highlighting the growing importance of turkey farming within the Algerian poultry sector (FAO, 2024). Despite this development, the Algerian turkey industry continues to face significant challenges, including elevated feed costs, reliance on imported raw products, competition with heavy broiler chicken farming, and prolonged rearing periods that limit production turnover and profitability (Sadoudi et al., 2024).

Among phytogenic feed additives, nettle (*Urtica dioica*) has attracted increasing attention due to its broad availability, economical cost, and long history of use as both a nutritional source and medicinal plant in Europe and other temperate regions (Devkota et al., 2022). Nettle leaves are characterized by their nutritional and phytochemical compounds, with reported contents of crude protein, minerals, vitamins, and bioactive compounds such as phenolic compounds and flavonoids. The nutritional properties and antioxidant-related constituents support the potential application of nettle as a natural dietary additive in livestock production (Adhikari et al., 2015; Moula et al., 2019). Different studies have demonstrated the strong antioxidant potential of nettle, largely attributed to its high content of polyphenols and flavonoids, which enhance free-radical scavenging capacity and support endogenous antioxidant defense systems (Gülçin et al., 2004; Jaiswal and Lee, 2022; Wójciak et al., 2024). In animal nutrition, dietary inclusion of nettle powder or extracts has been associated with improvements in growth performance, immune response, and oxidative stability in broiler chickens and other livestock species under experimental and farm conditions (Loetscher et al., 2013; Kregiel et al., 2018). Despite the recognized antioxidant and biological properties of nettle, scientific data regarding its use in turkey nutrition remain limited. Previous studies in broiler chickens have demonstrated that dietary nettle supplementation can modulate antioxidant gene expression, improve physiological responses, and enhance productive performance (Ahmadipour and Khajali, 2019; Pedraza et al., 2025). However, in broiler turkeys, the combined effects of nettle leaf inclusion on growth performance,

welfare indicators, hematological parameters, and oxidative status have not yet been clearly established. The present study aimed to evaluate the effects of dietary nettle leaf (*Urtica dioica*) inclusion on growth performance, welfare indicators, blood parameters, and oxidative status of broiler turkeys reared under intensive conditions, to assess its potential as a functional feed ingredient in sustainable turkey production systems.

MATERIALS AND METHODS

Ethical approval

All study procedures and experimental protocols involving animals were conducted in accordance with institutional ethical standards and were approved by the Animal Welfare, Experimentation, and Zootechnical Group of the University of Blida, Algeria (78 CBEEA-Blida: No. 28/SD/20190331). The present study adhered to national and international guidelines for the care and use of animals in research.

Study location and duration

The current study was conducted in 2021 over 15 weeks at a privately operated apiary owned by Aberkane Saïd, located in Aïn Turk, Bouïra Province, northern Algeria. The location had a Mediterranean climate.

Plant powder preparation

Aerial parts of *Urtica dioica*, including stems and leaves, were gathered from the Azazga district (Tizi Ouzou province), approximately 130 km east of Algiers, during the period from November 2019 to January 2020. The harvested stems and leaves were air-dried in the shade within a well-ventilated area at ambient temperature for approximately two weeks until a constant weight was achieved, as determined by the absence of further mass loss between two consecutive measurements taken 24 hours apart (difference < 1%). During the drying period, the recorded temperature ranged from 22 to 40˚C. Drying was carried out according to the traditional method commonly practiced by local producers in the study area, with a mean of 24˚C and a median of 25˚C. Variation reflected natural environmental fluctuations during shade drying under field and semi-controlled room conditions rather than a fixed experimental temperature. Shade drying was selected instead of oven drying to minimize potential thermal degradation of heat-sensitive bioactive compounds. The drying process was conducted without direct sunlight exposure or artificial heating to preserve the plant material's phytochemical properties. The primary criterion for confirming drying completion was the stabilization of weight, indicating that the moisture level had reached equilibrium despite temperature fluctuations. The dried plant material was then mechanically ground using a laboratory mill and sieved to obtain a homogeneous fine powder. The resulting powder was stored in paper bags at room temperature until incorporation into the experimental diets. No solvent extraction was applied. The analytical composition of the nettle powder used in the present study is presented in Table 1.

Table 1. Chemical composition of nettle powder used for turkeys' experimental diet

Items	Mean	Standard deviation	Median	Minimum	Maximum	Coefficient of variation (%)
Dry matter (%)	89.02	1.78	88.10	87.28	91.36	2.14
Organic matter (%)	84.93	3.40	84.34	80.62	90.22	4.37
Crude protein (%)	25.08	1.25	24.87	23.36	27.92	5.28
Crude fat (%)	2.69	0.19	2.67	2.08	2.99	6.91
Crude fiber (%)	12.07	0.85	11.65	10.41	13.61	7.24
Gross energy (kcal/kg)	3450	1.73	3337	3268	3612	5.12
Crude ash (%)	13.99	1.68	13.66	8.39	17.50	12.35

Values were obtained from five independent nettle powder samples (n = 5). Data are presented as mean, median, standard deviation (SD), coefficient of variation (CV), minimum, and maximum values.

Animals and management

The experimental trial included two levels of nettle powder (3% and 6%) incorporated into grower and finisher diets manufactured by Sadoudi Frères (Fréha, Algeria). The trial started at three weeks of age, following a standard adaptation period, during which turkeys were maintained under identical management conditions. Turkeys were housed in floor pens under controlled

environmental conditions, with ventilation and temperature adjusted by age, and a uniform stocking density applied across all treatments. Feed and water were provided *ad libitum* throughout the experimental period. All turkeys were clinically healthy at the start of the trial and received routine preventive veterinary care according to standard farm management practices.

A total of 72 turkeys (36 males and 36 females) were allocated to nine pens (8 turkeys per pen), corresponding to three dietary treatments, each with three replicates. Each pen contained equal numbers of males and females (4 each). Sex was included as a fixed factor in the statistical analysis of performance data. At the beginning of the trial (week 3), turkeys exhibited homogeneous live body weights across dietary treatments, averaging 565.5 g in the control group, 584.8 g in Group N3, and 564.4 g in Group N6, indicating comparable baseline conditions prior to dietary allocation. From 3 weeks of age, all turkeys were randomly assigned to nine floor pens of 15 m² each, with eight turkeys per pen (4 males and 4 females), corresponding to a stocking density of approximately 1.9 m² per turkey. In the present experiment, the litter consisted of chopped straw applied at a rate of 7 kg/m² in all experimental pens. A 16-hour light/8-hour dark lighting program was implemented from the second week of age onwards. Light intensity was maintained at approximately 40 lux, measured at turkey level using a lux meter, to ensure uniform illumination across all pens. The management conditions were applied consistently across all treatments and followed the recommendations of the breeder's management guide (Aviagen Turkeys, 2024).

Experimental diet

The experimental groups consisted of a control group receiving a basal commercial diet and two supplemented groups receiving the same basal diet enriched with nettle leaf powder at 3% (N3) and 6% (N6). Nettle powder was thoroughly mixed with the commercial feed at each feed preparation to ensure homogeneous distribution. The diets were prepared by incorporating 300 g of nettle powder per 9.7 kg of commercial feed for Group N3, and 600 g per 9.4 kg of commercial feed for Group N6. Feed was prepared in batches and offered daily.

The diet composition and nutritional characteristics of the experimental feeds used during the two rearing phases (grower and finisher) are presented in Tables 2 and 3. The diets were formulated to meet the nutritional requirements of growing turkeys in accordance with the National Research Council (NRC, 1994) recommendations for poultry.

Table 2. Composition of feed with different levels of nettle leaf powder for turkeys during the grower phase (4-6 weeks)

Diet ingredients	CN	N3%	N6%
Corn	41.4	39.3	38.3
Wheat	3.20	1.74	0.01
Soybean meal	47.6	48.2	48.0
Vegetable oil	2.86	3.14	3.10
Dicalcium phosphate	2.91	2.81	2.79
Salt	0.27	0.27	0.27
Methionine	0.21	0.21	0.21
Lysine	0.25	0.24	0.26
Mineral-vitamin premix[1]	0.45	0.45	0.45
Stinging nettle powder (SNP)	0.45	3.00	6.00
Carbonate de calcium	0.81	0.69	0.63
Nutrient composition			
Crude protein (%)	25.5	25.5	25.2
Calcium (%)	1.01	1.01	1.04
Lysine (%)	1.50	1.51	1.51
Phosphorus (%)	0.54	0.52	0.51
Methionine (%)	0.46	0.46	0.46
Metabolizable energy (kcal/kg)	2840	2840	2831

CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Table 3. Composition of feed with different levels of nettle leaf powder for turkeys during the grower phase (7-15 weeks)

Diet ingredients	CN	N3%	N6%
Corn	48.0	49.3	49.3
Wheat	3.00	0.10	0.01
Soybean meal	40.9	39.4	36.6
Vegetable oil	3.68	3.91	3.93
Dicalciumphosphate	2.51	2.56	2.52
Salt	0.45	0.45	0.45
Methionine	0.20	0.19	0.20
Lysine	0.21	0.21	0.22
Mineral-vitamin premix[1]	0.27	0.27	0.27
Nettle leaves	0	3.00	6.00
Carbonate de calcium	0.80	0.63	0.54
Calculated nutrient composition			
Crude protein (%)	21.7	21.7	21.4
Calcium (%)	0.89	0.89	0.91
Lysine (%)	1.32	1.33	1.33
Phosphorus (%)	0.45	0.43	0.44
Methionine (%)	0.43	0.41	0.42
Metabolizable energy (kcal/kg)	2940	2939	2924

CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Growth performance

The individual body weights of all turkeys were documented biweekly (weeks 3, 5, 7, 9, 11, and 13), starting in week 3, using a calibrated digital scale. Feed consumption was monitored per pen during these intervals by quantifying the feed supplied and subtracting the remaining feed gathered before each weighing session. Body weight gain was calculated for each 14-day interval (weeks 3-5, 5-7, 7-9, 9-11, and 11-13) as well as cumulatively over the entire experimental period (week 3

to week 13). The feed conversion ratio (FCR) was determined for each period and for the overall study duration as the ratio of total feed intake to body weight gain per pen. Mortality was recorded daily throughout the experimental period, from week 3 to week 15 of age, and cumulative mortality rates were calculated for each treatment group.

Slaughter procedures and carcass traits

At the end of the experimental period, 27 female turkeys (nine turkeys per treatment group) were randomly selected, removed from their pens, and transferred to individual cages. Turkeys were fasted for 12 hours prior to slaughter, with free access to water. Carcass traits were evaluated exclusively in females in order to minimize variability related to sexual dimorphism, which can significantly affect carcass composition and fat deposition in turkeys. Carcass evaluation was performed only on female turkeys to ensure more homogeneous and reliable comparisons between dietary treatment groups. Furthermore, the current study was designed as an exploratory trial, and resource limitations restricted the inclusion of both sexes in the slaughter analysis. Immediately before slaughter, live body weight was documented. After slaughter and plucking, the carcass weight was measured following evisceration. The individual weights of internal organs, namely the liver, heart, proventriculus, gizzard, and spleen, as well as abdominal fat, were measured separately for each turkey. Carcass yield was then computed according to the following equation (Sadoudi et al., 2024).

$$\text{Carcass yield (\%)} = \frac{\text{Eviscerated carcass weight} \times 100}{\text{Live body weight}}$$

Welfare assessment indicators

At the end of the trial, animal welfare was assessed for each turkey using external physical indicators, including feather cleanliness, tarsal joint lesions, and plantar footpad dermatitis (Figure 1). Each parameter was independently evaluated by three trained observers using the Welfare quality® (2009) protocol. Scores ranged from 0 to 4, where score 0 indicated the absence of visible alterations, score 1 indicated mild alterations, score 2 indicated moderate lesions without functional impairment, score 3 indicated marked lesions associated with impaired condition, and score 4 indicated severe lesions or extensive tissue damage. Final scores were determined by agreements among observers to minimize subjectivity and inter-observer variability.

Determination of antioxidant activity

Total antioxidant capacity

At the end of the experiment, blood serum samples were collected from 18 turkeys (six per group), and serum was separated. Total antioxidant capacity was carried out using the 2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonic acid; ABTS) assay, following the method described by Re et al. (1999). In brief, ABTS radical cation ($ABTS^+$) was generated by mixing 7 mM of ABTS with 2.45 mM of potassium persulfate, which was then incubated at room temperature in the dark for 12-16 hours. Before conducting the assay, the $ABTS^+$ solution was diluted in phosphate buffer (pH 7.4) to obtain an absorbance of 0.70 ± 0.02 at 734 nm. For the assay, 1 mL of the diluted $ABTS^+$ solution was mixed with 10 µL of serum sample, and the decrease in absorbance was recorded at 734 nm exactly six minutes after mixing. Antioxidant activity was expressed as the percentage inhibition of the ABTS radical. All measurements were conducted in triplicate.

Lipid peroxidation

Lipid peroxidation was evaluated by measuring thiobarbituric acid-reactive substances (TBARS) in serum samples obtained at the end of the experiment, following the method described by Devasagayam et al. (2003). Serum samples (1 mL) were deproteinized with 0.5 mL of 30% trichloroacetic acid (TCA) and incubated at 0°**C** for 120 minutes, then centrifuged at 3000 rpm for 10 minutes at 4°C. One milliliter of the resulting supernatant was mixed with 0.25 mL of 1% thiobarbituric acid (TBA) prepared in 0.05 M NaOH and 0.075 mL of EDTA (0.1 mol/L). The mixture was heated at 95˚C for 15 minutes, cooled, and the absorbance was measured at 535 nm. Each sample was analyzed in triplicate. The TBARS levels were used as an index of lipid peroxidation.

Hematological and biochemical analyses

The procedures employed for hematological and biochemical analyses were adapted from the study of Sadoudi et al. (2024).

Blood sampling

Approximately 5 mL of blood was collected from the wing vein of 27 female turkeys (nine per group) at 6, 10, and 14 weeks of age. For hematological assessments, blood was drawn into ethylenediaminetetraacetic acid tubes (EDTA), whereas samples intended for biochemical analysis were collected in lithium heparin tubes. All samples were kept at a cool temperature, then centrifuged at 3000 rpm for 10 minutes, and plasma was analyzed on the same day.

Hematological parameters

Hematological measurements were performed using an automated analyzer (Mindray BC-30s), as described by Post et al. (2003). The evaluated parameters included white blood cell count (WBC), red blood cell count (RBC), hemoglobin concentration (Hb), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and platelet count (PLT).

Biochemical parameters

Biochemical analyses were performed using a BioSystems BA200 analyzer (BioSystems S.A., Spain). The variables measured included glucose (Gly), triglycerides (TG), total cholesterol (Chol), total protein (Prot T), and albumin (Alb).

Statistical analysis

Data on growth performance, hematological parameters, and biochemical parameters were analyzed using a two-way analysis of variance (ANOVA) according to the following equation.

$$Yijkl = \mu + Ai + Bj + (AB)ij + eijkl$$

where Y_{ijkl} represented the observed variables, μ was the overall mean, A_i was the effect of dietary treatment, B_j was the effect of age, $(AB)_{ij}$ was the interaction between diet and age, and e_{ijkl} was the residual error. Mortality rates among groups were compared using Fisher's exact test. Carcass traits and organ weights were analyzed using the PROC ANOVA procedure in SAS software (2012), with statistical significance set at p-value less than 5% ($p < 0.05$).

RESULTS

Growth performance and welfare indicators

Overall mortality recorded throughout the experimental period was 0% in the supplemented groups (N3 and N6), whereas a mortality rate of 3.33% was observed in the control group, indicating enhanced overall flock viability, particularly in the groups receiving nettle supplementation.

At the end of the trial, final body weight differed significantly among the experimental groups (Table 4). Female turkeys in the control group had a significantly higher body weight compared to those in the groups N3 and N6 ($p < 0.05$). Male turkeys fed the N3 diet demonstrated a higher final body weight compared to the control group and Group N6 ($p < 0.05$), while Group N6 did not differ significantly from the control group. In male turkeys, Group N3 exhibited the highest final body weight, significantly exceeding the values recorded in the control group and Group N6 ($p < 0.05$). Additionally, the control group had significantly higher body weight than Group N6 ($p < 0.05$).

The present results indicated that live body weight was influenced by sex and age ($p < 0.05$), whereas the effect of dietary treatment was not statistically significant ($p < 0.05$). The current results demonstrated that growth performance parameters were primarily associated with physiological differences related to sex and age, with a tendency for dietary influences.

The FCR was significantly influenced by dietary treatment (Table 5). Group N3 exhibited a higher FCR compared to the control group and Group N6 ($p < 0.05$), indicating reduced feed efficiency at this inclusion level.

Slaughter traits and organ weights of female turkeys are presented in Table 6. A numerical increase was observed in Group N3 for live weight at slaughter, post-bleeding weight, and empty carcass weight compared to the control group and Group N6. No significant differences were observed among treatments in carcass yield or in internal organ weights, including liver, gizzard, proventriculus, and heart ($p > 0.05$), indicating that dietary nettle supplementation did not adversely affect organ development.

The welfare indicator findings are presented in Figure 2. The present results indicated that neither observer effect nor dietary treatment had a significant impact on lesion scores for any of the evaluated welfare parameters ($p > 0.05$), confirming the reliability and consistency of the scoring procedure.

Regarding feather cleanliness, a score of 0 for clean plumage was observed in the majority of turkeys across all three groups, specifically, 83.4% in Group N3, 80.6% in Group N6, and 86.1% in the control group. Similarly, no significant differences were observed among dietary treatments for tarsal lesions ($p > 0.05$). Most turkeys demonstrated no evidence of tarsal lesions, corresponding to a score of 0 in 91.7% of turkeys in Group N3, 97.2% in Group N6, and 88.8% in the control group. A comparable trend was observed for plantar lesions, with the majority of turkeys across all experimental groups receiving a score of 0, indicating optimal foot health and overall welfare.

Hematological and biochemical parameters

The effects of dietary nettle leaf inclusion on hematological and biochemical parameters are presented in Table 7. Significant differences were observed for

selected hematological indices among the experimental groups. Turkeys in Group N3 exhibited a significantly lower MCV (153.7 fL) compared to those in the control group (161.6 fL) and Group N6 (159.9 fL; $p < 0.05$). In addition, PLT count was significantly higher in Group N3 (8.78×10^3 μL^{-1}) than in Group N6 (4.44×10^3 μL^{-1}) and the control group (4.89×10^3 μL^{-1}; $p < 0.05$).

The MCH was significantly lower in Group N3 (68.8 pg) compared to the control group (71.4 pg; $p < 0.05$), whereas no significant difference was observed between Group N6 and the other treatment groups ($p > 0.05$). No significant differences were found among dietary treatments in the remaining hematological indices or measured biochemical parameters ($p > 0.05$).

Oxidative status

Findings related to the oxidative status of the turkeys are summarized in Table 8. Total antioxidant status (TAS), assessed using the ABTS radical-scavenging assay, demonstrated a significantly higher percentage of inhibition in the nettle-supplemented groups compared to the control group. The ABTS inhibition was 86.3% in Group N3 and 88.0% in Group N6, significantly higher than the 80.2% observed in the control group ($p < 0.05$). Lipid peroxidation, assessed by TBARS determination, was significantly reduced in the nettle-supplemented groups ($p < 0.05$). The lowest TBARS levels were recorded in groups N3 and N6 at 0.204 and 0.195, respectively, compared with 0.271 in the control group ($p < 0.05$).

Table 4. Live weight of turkeys fed diets containing different levels of nettle leaf at 3, 7, and 13 weeks of age

Age (week)	Sex	CN	N3%	N6%	SE	Sex group age	R^2
3	Female	565.5	584.8	564.4	90.0	$p < 0.001$	0.95
	Male	654.5	718.8	644.4	102.9		
7	Female	1186	1158	1151	90.0		
	Male	1385	1466	1408	102.9		
13	Female	6386[a]	6098[b]	5938[b]	90.0		
	Male	7807[b]	7908[a]	7482[b]	102.9		
$p < 0.001$	$p < 0.001$	Diet $P < 0.001$					

[a,b] Means values with different superscript letters on the same row indicate significant differences ($p < 0.05$), SE: Standard error, R^2: Coefficient of determination, CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Table 5. Feed conversion ratio of turkeys fed diets containing different levels of nettle leaf between 3 and 13 weeks of age

	Groups				P-value			R^2
Age (week)	CN	N3%	N6%	SE	Groupe	Age	Groupe*Age	
4 - 6	1.89[b]	1.99[a]	1.83[b]	0.03	$P < 0.001$	$P < 0.001$	$P < 0.001$	0.63
7 - 13	2.61[b]	2.78[a]	2.58[b]	0.04				

[a,b,c] Means with different superscript letters on the same row indicate significant differences ($p < 0.05$). SE: Standard error, R^2: Coefficient of determination, CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Table 6. Live weight, carcass yield, and weight of different organs of turkeys fed diets containing different levels of nettle leaf at 15 weeks of age (slaughter period)

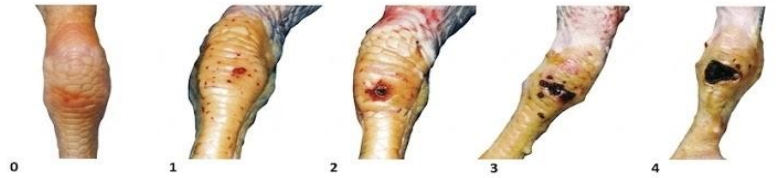
Parameters	CN	N3%	N6%	SE	P-value	R^2
Live weight (g)	6005	6554	5994	191.9	0.08	0.19
Weight after bleeding (g)	5580	6097	5566	183.7	0.08	0.19
Empty weight (g)	4824	5227	4770	172.3	0.06	0.21
Liver (g)	84.3	104.4	100.2	7.53	0.18	0.13
Rate (g)	7.38	6.75	6.98	0.43	0.61	0.04
Heart (g)	18.9	20.4	19.1	1.04	0.51	0.06
Proventricule (g)	11.4	12.0	11.7	0.43	0.57	0.04
Gizzard (g)	108.5	107.0	103.8	6.21	0.86	0.02
Abdominal fat (g)	21.7	21.6	24.5			
Carcass yield (%)	80.3	79.8	79.6	0.98	0.78	0.04

SE: Standard error, R^2: Coefficient of determination, CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Plumage;

Score 0	Score 1	Score 2	Score 3
Clean plumage	Minimal damage	Dirty plumage	Very dirty plumage

Tarsi:



Score 0	Score 1	Score 2 - 4
No lesion	Minimal lesions	Lesions confirmed according to their severity

Pododermatitis:

Score 0	Score 1	Score 2 - 4
No lesion	Minimal lesions	Lesions confirmed according to their severity

Figure 1. Welfare quality indicators of turkeys in the present experiment

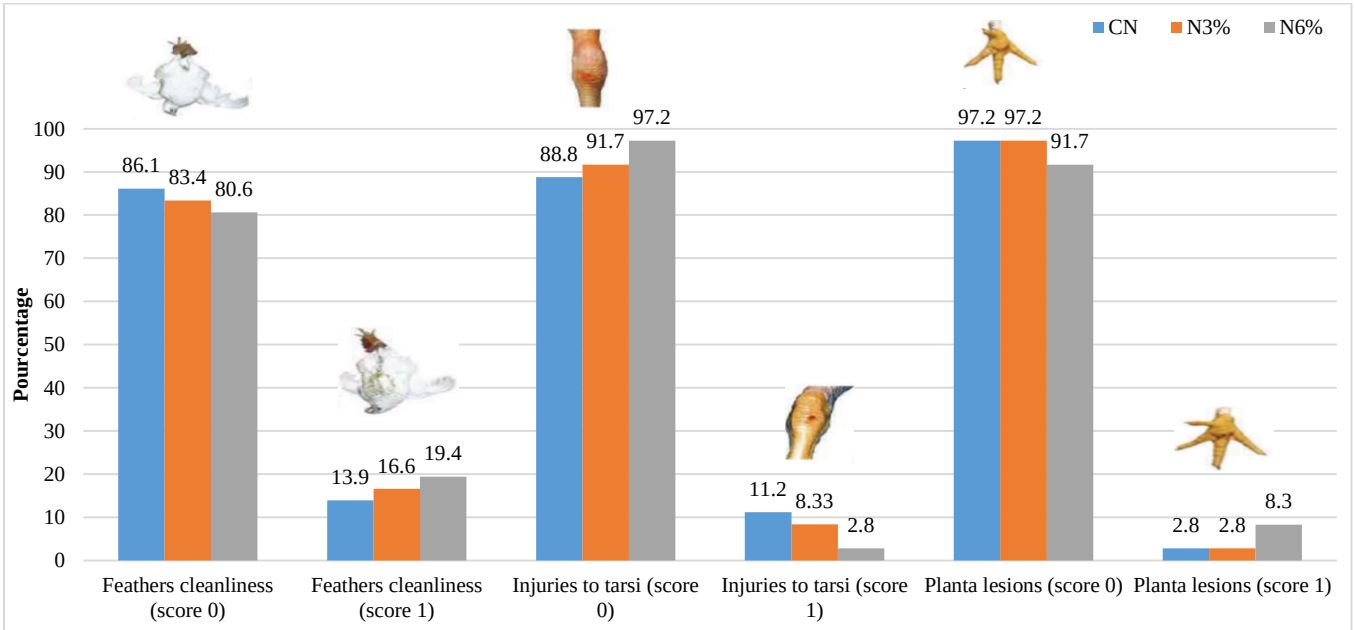


Figure 2. Feather cleanliness scores, shank lesions, and foot lesions of turkeys fed different levels of nettle. CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Table 7. Blood and biochemical parameters of turkeys that received different levels of nettle at 14 weeks of age

Parameters	Treatmment groups			SE	P-value	R^2
	CN	N3%	N6%			
WB (103 /ml)	106.8	118.0	123.0	7.66	0.31	0.10
RB (106 /ml)	2.09	2.08	2.18	0.06	0.48	0.06
HB (g/dl)	14.9	14.3	15.2	0.44	0.34	0.09
Hct (%)	33.7	32.0	34.8	1.06	0.18	0.13
VGM (fl)	161.6^{a}	153.7^{b}	159.9^{a}	2.03	0.02	0.26
TCMH (pg)	71.4^{a}	68.8^{b}	69.9^{ab}	0.55	0.009	0.32
CCMH (g/dl)	44.2	44.8	43.7	0.36	0.14	0.15
Plt (103 /ml)	4.89^{b}	8.78^{a}	4.44^{b}	1.36	0.046	0.21
Gly (g/l)	3.07	2.91	3.09	0.64	0.11	0.16
TG (g/l)	1.03	0.62	0.92	0.29	0.59	0.04
Chol (g/l)	1.07	1.15	1.14	0.07	0.66	0.04
Prot T (g/l)	39.2	41.8	43.0	4.32	0.82	0.02
Alb (g/l)	14.9	16.0	15.7	0.55	0.36	0.08
RDW (g/l)	11.3	12.1	11.7	0.39	0.14	0.25

^{a,b,c} Means values with different superscript letters on the same row indicated significant differences ($p < 0.05$), SE: Standard error, R^2: Coefficient of determination, CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

Table 8. The oxidative status of turkeys that received different levels of nettle at 14 weeks of age

Parameters	Feed Groups			P-value	R^2
	CN	N3%	N6%		
TAS (%)	80.2 ± 0.84^{a}	86.3 ± 0.78^{b}	88.0 ± 0.99^{b}	P < 0.001	0.72

^{a,b,c} Means values with different superscript letters on the same row indicate significant differences ($p < 0.05$), SE: Standard error, R^2: Coefficient of determination, CN: Control group, N3%: Diets supplemented with nettle leaf powder at 3%, N6%: Diets supplemented with nettle leaf powder at 6%.

DISCUSSION

Mortality

Mortality remained low across all experimental groups, exhibiting no signs of treatment-related adverse effects. The observed mortality rates were consistent with previous studies reporting that dietary nettle supplementation at inclusion levels between 1% and 6% did not adversely affect survival in poultry species, including broiler chickens and Japanese quail (Loetscher et al., 2013; Safamehr et al., 2013; Moula et al., 2019).

Growth performance

Male turkeys receiving 3% nettle supplementation achieved a higher final body weight (7908 g) than control males (7807 g), whereas female turkeys exhibited lower final body weight and higher FCR values in the present study. The FCR recorded in turkeys receiving 3% nettle supplementation (N3 group; 2.78) was higher than that of the control group (2.61), indicating reduced overall feed efficiency despite the improvement in body weight observed in male turkeys. Male turkeys exhibited a more favorable response to 3% nettle supplementation than females, as reflected by their higher final body weight. Sex-related differences in growth performance may be associated with differences in growth potential, endocrine regulation, nutrient utilization, and metabolic requirements between male and female turkeys (Lilburn and Nestor, 1991; Havenstein et al., 2003). Male turkeys typically grow faster and accumulate more lean tissue than females, resulting from pronounced sexual dimorphism and variations in nutrient distribution (NRC, 1994; Havenstein et al., 2003). The physiological differences in growth rate, nutrient metabolism, and feed efficiency may enable male turkeys to obtain more nutrients and bioactive compounds from nettle. Similar sex-dependent responses to dietary interventions have been reported by Zuidhof et al. (2014) in poultry, in which males and females exhibited different feed utilization efficiency, growth patterns, and metabolic adaptation to nutritional strategies. The reduced growth efficiency observed in female turkeys receiving 3% nettle supplementation was likely attributable to variations in

their metabolic adaptation to the supplement, rather than a direct adverse effect of the nettle. Consistent with the present study, Bölükbaşi et al. (2008) reported that dietary supplementation with *Nigella sativa* oil improved growth performance and feed efficiency in broiler chickens. More recently, Sadoudi et al. (2024) demonstrated that phytogenic supplementation improved growth performance and antioxidant status in poultry under intensive rearing conditions. In the present study, the response to nettle supplementation was sex-dependent. Such differences among studies might be related to the type of phytogenic additive used, inclusion level, animal species, sex, age, and experimental conditions.

Organ weights

No notable differences were observed among dietary treatments for carcass yield or internal organ weights (liver, spleen, heart, gizzard, and abdominal fat). Consistent with the present results, Safamehr et al. (2013) reported no notable effect of low to moderate dietary nettle inclusion on the development of internal organs in poultry. The absence of remarkable effects on liver and spleen weights observed in the present study was consistent with the findings of Loetscher et al. (2013), who supplemented broiler diets with 25 g/kg (2.5%) dried nettle and reported no major adverse effects on organ development. Although the inclusion levels used in the present study (3% and 6%) were higher than those evaluated by Loetscher et al. (2013), no substantial changes in internal organ weights were detected, suggesting that nettle supplementation at these levels did not adversely affect organ development in turkeys.

Blood biochemical parameters

There were no notable differences in serum biochemical parameters among treatment groups, suggesting that dietary nettle inclusion did not alter the turkeys' metabolic status under the experimental conditions. The absence of notable changes in blood parameters in the present study was consistent with previous studies reporting no alterations in lipid or protein profiles following nettle supplementation (Khosravi et al., 2008; Keshavarz et al., 2014). Although Mansoub (2011) and Safamehr et al. (2012) documented reductions in cholesterol and triglycerides following nettle supplementation, these reductions were not observed in the current study, possibly due to differences in inclusion levels, dietary formulations, or animal species.

Welfare indicators

Welfare parameters, including feather cleanliness and lesion scores, were not notably affected by nettle supplementation. The predominance of score 0 across all groups indicated an overall favorable welfare status. The observed responses to nettle supplementation could be linked to its strong antioxidant and liver-protective properties, though the precise underlying pathways remain unclear. The findings on welfare parameters were consistent with the results of Mirsaiidi Farahani and Hosseinian (2022), who suggested that antioxidant-rich plant constituents, including vitamin C derived from nettle, might help modulate stress in poultry. Maintaining proper litter conditions is known to decrease footpad lesions (Eichner et al., 2007; Kaukonen et al., 2016).

Oxidative status

Dietary nettle supplementation improved oxidative status in broiler turkeys, as evidenced by increased antioxidant activity and reduced lipid peroxidation. The Oxidative status findings are consistent with those of Golshan et al. (2015), who reported that nettle supplementation enhanced antioxidant capacity in broiler chickens and improved oxidative stress markers in other animal models, including mice with polycystic ovary syndrome (Bandariyan et al., 2021). Different studies have demonstrated the strong antioxidant potential of methanolic and ethanolic nettle leaf extracts (Gülçin et al., 2004; Kataki et al., 2012; Khare et al., 2012). Gülçin et al. (2004) notably reported that aqueous nettle extract at doses of 50, 100, and 250 µg inhibited linoleic acid peroxidation by 39%, 66%, and 98%, respectively. Similarly, Ghaima et al. (2013) observed a 76% inhibition of lipid peroxidation attributable to nettle extract, surpassing the 65% inhibition observed with α-tocopherol. However, Keshavarz et al. (2014) and Loetscher et al. (2011) found no remarkable improvement in TBARS levels in broiler chickens fed diets supplemented with 10 or 25 g nettle powder/kg feed. In addition, Kukrić et al. (2012) reported lower antioxidant activity in ethanolic nettle extracts than in reference antioxidants such as vitamin C and butylated hydroxyanisole.

CONCLUSION

The present study demonstrated that dietary inclusion of nettle leaves (*Urtica dioica*) at 3% was safe and beneficial for broiler turkeys reared under intensive conditions. Nettle supplementation at 3% improved growth performance and carcass traits without negatively

affecting welfare indicators, internal organ development, or hematological and biochemical profiles. In addition, nettle supplementation enhanced systemic antioxidant capacity and reduced lipid peroxidation, suggesting an improved oxidative status in supplemented turkeys. The relationship between nettle supplementation and welfare was a complex issue that could not be directly determined in the present study, as no physiological stress indicators, such as corticosterone levels, were measured. Nevertheless, the current study possessed some limitations. The composition of the gut microbiota, the activity of digestive enzymes, and stress-related hormonal markers were not assessed, thereby limiting a comprehensive understanding of the underlying mechanisms. Future studies should encompass these parameters, as well as dose-response relationships and long-term effects in commercial production settings.

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Authors' contributions

Ahmed Sadoudi contributed to the investigation, experimental trial, conceptualization, methodology, data curation, and preparation of the original draft. Dahia Saidj contributed to the review and editing of the manuscript. Yuva Bellik contributed to supervision, conceptualization, methodology, validation, quality control, and manuscript review and editing. Leghel Touazi participated in the investigation, experimental trial, conceptualization, methodology, laboratory analyses, and manuscript review and editing. Krimou Yahi contributed to data curation, data management, and the experimental trial. Boubekeur Aberkane provided resources and technical support and contributed to the experimental work and conceptualization. Mokrane Iguer-Ouada contributed to supervision, conceptualization, methodology, validation, quality control, and manuscript review and editing. Nassim Moula contributed to the original draft preparation, conceptualization, methodology, data interpretation, manuscript review and editing, and overall coordination of the study. All authors have read and approved the last edition of the manuscript.

Availability of data and materials

The datasets generated and/or analyzed during the current study are included in this published article and are available upon reasonable request from the corresponding author.

Competing interests

The authors declared no conflict of interest.

Ethical considerations

The authors declared that this study is original and has not been submitted for publication elsewhere. They also affirmed that the information contained within this manuscript is free from plagiarism and misconduct and has not been manipulated. Additionally, the authors confirmed that no artificial intelligence tools were utilized in the design, conduct, analysis, or authorship of the present study. The authors accept full responsibility for the originality of this manuscript.

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