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Research article

Seasonal variation of feeding values, minerals and vitamins of field elm (*Ulmus minor* Mill.) and blackthorn (*Prunus spinosa* L.) leaves grazed by small ruminants in Thrace region of southeast Europe

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Abstract

The seasonal variations in the nutritional characteristics, mineral composition, and vitamin profile of field elm and blackthorn leaves were investigated over a two-year period (2022-2023) in the Thrace region of southeastern Europe. Both species, commonly utilized as browse by small ruminants, exhibited pronounced seasonal shifts in forage quality. Spring emerged as the period with the most favorable nutritional attributes, reflected in higher protein levels, reduced fiber fractions, and enhanced relative feed value. The progressive transition from spring to autumn resulted in measurable declines in digestibility parameters, energy values, and selected vitamins, most notably α-tocopherol. In contrast, summer showed elevated concentrations of β-carotene and ergocalciferol. Overall, the findings highlight the importance of these browse species as valuable supplementary feed resources, particularly during spring and summer, and underscore their potential contribution to sustainable ruminant nutrition and forage management in subtropical regions.

Keywords: Blackthorn, Field elm, Nutritive value, Small ruminant, Vitamin

Introduction

The integration of woody species as a fodder resource into grazing systems is a common practice worldwide. In grazing systems where meadows and pastures are intensively utilized, small ruminants graze on both grasslands and some of the trees and shrubs they encounter. The young shoots and leaves of certain species possess a higher nutritional value and are more palatable than those of herbaceous species. Leaves from some trees and shrubs are essential resources for supplying small ruminant animals with not only energy and protein but also vital minerals across many regions worldwide (Kaya and Kamalak, 2012; Atalay *et al*., 2017; Mboko *et al*., 2017; Ziblim *et al*., 2019).

Several tree species have been identified as potential sources for providing fodder nutrition during both regular and scarcity periods (Reddy, 2006). The utilization of some tree leaves as fodder represents a component within the intricate network of interactions contributing to the equilibrium of the plant-animal-soil ecosystem. These leaves have been identified as rich sources of protein, soluble carbohydrates, minerals, and vitamins, demonstrating significant potential as alternative feed resources (Baumer, 1991; Bakshi and Wadhwa, 2007). Incorporating tree leaves into ruminant diets has been shown to stimulate microbial growth and improve digestion (Singh, 1982; Bonsi *et al*., 1995).

The practice of grazing leaves and young shoots of certain tree and shrub species by ruminants, a common occurrence in tropical and Mediterranean regions (Halstead, 1998; Houérou, 2006), has become increasingly prevalent during the summer months in areas experiencing climate change. The genus *Ulmus* L. includes around 45 woody species that are broadly distributed across the northern temperate regions, with the exception of western North America, and extend into the subtropical areas of Central America and Southeast Asia (Fu, 1980). The *Ulmus* species grow quickly and regenerate rapidly from seeds, showing resilience to pruning and root damage. They also adapt remarkably well to adverse environmental conditions (Rather *et al*., 2017). The *Ulmus* species are cultivated near homes to provide a continuous supply of leaves, which can be dried and stored for winter livestock feed in India (Beigh *et al*., 2020).

Prunus spinosa L. (commonly known as blackthorn, belonging to the *Rosaceae* family) is a thorny and deciduous shrub that grows wild in uncultivated regions across Europe, West Asia, and the Mediterranean (Fraternale *et al*., 2009) and south-central Europe up to southern Scandinavia and eastwards to Anatolia (Popescu and Caudullo, 2016). This plant is utilized in phytotherapy for various purposes including the treatment of coughs, as well as being employed as a diuretic, laxative, antispasmodic, anti-inflammatory agent, and as a source of fodder (Fraternale *et al*., 2009). Despite the existence of a considerable body of research on these diverse woody species, they are still insufficient. The objective of this study was to examine the seasonal variation in some feeding values, minerals and vitamins of field elm (*Ulmus minor* Mill.) and blackthorn leaves, which are frequently grazed by small ruminants.

Materials and Methods

Study site: The study was conducted in the grazing areas of four villages [Osmanlı (41°02′N, 27°23′E) and Evciler (40°56′N, 27°10′E) villages for field elm, Yörük (40°56′N, 27°03′E) and Yeşilsırt (41°07′N, 27°28′E) villages for blackthorn] in the east Thrace region of southeastern Europe (Fig 1), between 15 May 2022 and 15 September 2023 for a period of two years. The research areas are classified as having a semi-humid climate type within the hydrographic regions. The total precipitation in the study site was 380.20 mm, the mean temperature of 17.66°C, 75.68% relative humidity. August typically has the lowest amount of precipitation, while December has the highest. The soil was clay, classified as alfisol typic xeralf, low in organic matter (1.17%), moderate in phosphorus (P) content (63.1 kg ha^{-1}), but rich in potassium (K) content (554.3 kg ha^{-1}) and with pH of 7.2.

Leaf sampling: As suggested by Benou *et al*. (2020), in tests for optimum leaf nutrient concentrations in plants, one hundred fully expanded, exposed leaves were collected by hand from the same 10 plants (uniform, healthy field elm and blackthorn were selected) in spring (on mid-May), summer (on mid-July) and autumn (on mid-September) on branches around each species at an appropriate height for grazing by small ruminants with an average trunk diameter of 44 cm for field elm and 5 cm for blackthorn from each village. The sampling periods were defined in accordance with the commencement and conclusion of grazing activities by the small ruminant population. These sampling times for each species corresponded to the flowering, fruit development and fruit maturity, respectively. Leaf samples were collected

Fig 1. Geographical location of the experimental site

from branches that had not been affected by biotic and abiotic factors. The samples were obtained from four different aspects of each species, namely east, west, north and south. The leaves were stored in paper bags and subsequently transported to the laboratory for further analysis.

Chemical analyses: The leaf samples were dried in an oven at 55°C for 48 hours (Ates, 2015; Tenikecier and Ates, 2019). Dry samples were ground to small (≤1 mm) pieces, passed through a 150 µm plastic sieve and stored. The crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents (g kg^{-1}) were determined following the Van Soest *et al*. (1991) and AOAC (2023). The samples were wet-fired with nitric-perchloric acid, and phosphorus (P) content (mg g^{-1}) was determined spectrophotometrically, while potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), manganese (Mn), iron (Fe) and molybdenum (Mo) contents (mg g^{-1}) were obtained using an atomic absorption spectrophotometer (ICP- OES, inductively coupled plasma-optical emission spectrometer). Relative feed value (RFV), total digestible nutrients (TDN), net energy lactation (NEl), net energy-maintenance (NEm) and net energy-gain (NEg) were calculated according to the equations adapted from common formulas for forages (Schroeder, 1994). The β-carotene (mg kg^{-1}), α-tocopherol (mg kg^{-1}) and ergocalciferol (µg kg^{-1}) contents of dried samples were determined according to slightly modified procedures described by Jäpelt *et al*. (2011), Ates and Tenikecier (2020). All samples were analyzed in triplicate.

Statistical analyses: All data were analyzed statistically by analysis of variance (randomized plot design) using TARIST software (Acikgoz *et al*., 2004) and means of treatments were compared using least significant difference (LSD) test with MSTAT-C version 2.10 software (Michigan State University, 1991).

Results and Discussion

The effects of year, season and year x season interaction on some forage quality and nutrition aspects of field elm and blackthorn leaves were recorded (Tables 1 to 4). Seasons affected crude protein, crude fiber, ADF, NDF, ADL, TDN, P, K, Ca, Mg, Fe, Cu, Mo, α-tocopherol, β-carotene, ergocalciferol content and NEL, NEM of field elm and blackthorn leaves, Zn and Mo content of elm leaves, Mg and Mn content and NEG of blackthorn leaves.

Cell wall components, CP and RFV value: The highest CP content of field elm (127.98 g kg^{-1}) and blackthorn (144.20 g kg^{-1}) leaves was observed in spring. In field elm leaves, the lowest CF contents were recorded in spring and autumn (48.88 and 48.93 g kg^{-1}, respectively), whereas in blackthorn leaves, the minimum CF content occurred in spring (51.17 g kg^{-1}). The lowest ADF (297.45 g kg^{-1} and 274.25 g kg^{-1}), NDF (456.40 g kg^{-1} and 388.23 g kg^{-1}) and ADL (211.25 g kg^{-1} and 212.25 g kg^{-1}) contents of field elm and blackthorn leaves, respectively, were determined in spring. The highest RFV values were observed in spring (Table 1). The change of season from spring to autumn negatively affected crude protein, crude fiber, ADF, NDF and ADL of both species. In general, the leaves of

Table 1. The CP, RFV and some cell wall components of field elm and blackthorn leaves

Specification	Year	Field elm				Blackthorn			
		Spring	Summer	Autumn	Mean[¥]	Spring	Summer	Autumn	Mean[¥]
CP (g kg^{-1})	2022	128.07ab	127.77b	127.33c	127.72b	143.63b	134.97c	124.83e	134.48
	2023	127.90b	127.77b	128.27a	127.98a	144.77a	133.47d	124.60e	134.28
	Mean[†]	127.98a	127.77b	127.80b	*127.85*	144.20a	134.22b	124.72c	*134.38*
	LSD	Year: 0.197 ** Season: 0.172* Year x Season: 0.344**				Year: ns Season: 0.632** Year x Season: 0.896**			
CF (g kg^{-1})	2022	48.90	49.13	48.90	48.98	51.20	58.17	61.27	56.88
	2023	48.87	49.03	48.97	48.96	51.13	58.10	61.27	56.83
	Mean	48.88b	49.08a	48.93b	*48.97*	51.17c	58.13b	61.27a	*56.86*
	LSD	Year: ns Season: 0.078* Year x Season: ns				Year: ns Season: 0.396* Year x Season: ns			
ADF (g kg^{-1})	2022	297.40	301.17	301.23	299.93	274.30	288.10	298.53	286.98
	2023	297.50	301.10	301.30	299.97	274.20	287.97	298.33	286.83
	Mean	297.45b	301.13a	301.27a	*299.95*	274.25c	288.03b	298.43a	*286.90*
	LSD	Year: ns Season: 0.0791** Year x Season: ns				Year: ns Season: 3.646** Year x Season: ns			
NDF (g kg^{-1})	2022	456.43c	473.33a	459.85b	463.21a	387.00	409.03	429.07	408.37
	2023	456.37c	460.20b	459.97b	458.84b	389.57	408.97	428.90	409.14
	Mean	456.40c	466.77a	459.91b	*461.25*	388.23c	409.00b	428.93a	*408.72*
	LSD	Year: 0.418** Season: 0.512** Year x Season: 0.723**				Year: ns Season: 3.275** Year x Season: ns			
ADL (g kg^{-1})	2022	211.27	212.23	213.13	212.21	213.83	220.90	229.30	221.34
	2023	211.23	212.33	213.03	212.20	210.67	220.77	229.03	220.16
	Mean	211.25c	212.28b	213.08a	*212.20*	212.25c	220.83b	229.17a	*220.75*
	LSD	Year: ns Season: 0.218* Year x Season: ns				Year: ns Season: 5.094** Year x Season: ns			
RFV	2022	133.93a	128.85c	132.29b	131.69b	161.29	151.10	142.29	151.55
	2023	133.94a	132.25b	132.29b	132.83a	161.24	151.15	142.33	151.59
	Mean	133.93a	130.55c	132.29a		161.26a	151.12b	142.33c	
	LSD	Year: 0.453** Season: 0.554** Year x Season: 0.785**				Year: ns Season: 0.151** Year x Season: ns			

ns, *, **: Non-significant, significant at 0.05 and 0.01 level, respectively; [¥]Year means and year x season interactions with different letter fort the same column are significantly different; [†]Season means with different letter for the same row are significantly different field elm and blackthorn exhibited NDF, ADF and ADL values above the specified limit values throughout the year. Alatürk *et al*. (2014) observed a reduction in the CP content of plants as they matured across nine different shrub species (*Phillyrea latifolia* L., *Quercus coccifera* L., *Q. infectoria* Oliv., *Paliurus spinachristi* Mill., *Spartium junceum* L., *Ephedra major* Host., *Robinia pseudoacacia* L., *Anagyris foetida* L., and *Juniperus oxycedrus* L.). Conversely, they noted an increase in cell wall compounds (NDF, ADF, and ADL). Ruminant animals require the protein level of the forage they consume to be at least 10.60%. Additionally, it is not desirable that the NDF content of the grass consumed daily by animals should be more than 45.8%, ADF content 25% and ADL content more than 10% (NASEM, 2021).

Quality standards for forages based on crude protein, ADF, and NDF ratios were established by Rohweder *et al*. (1978). They indicated that an RFV of 100 corresponds to ADF and NDF ratios of 41% and 53%, respectively. They further noted that when the RFV exceeds 151, the forage is considered to be of the highest quality. Ates (2017) reported that the botanical composition and nutrient content of crops exhibit variation according to environmental factors, grazing and human activity. Additionally, the basic topographical factors of aspect, altitude and slope have been identified as effective influences. Beigh *et al*. (2020) declared the chemical composition of elm leaves (g kg^{-1} in DM) was 895.40 ± 2.51 organic matter (OM), 185.94 ± 6.31 CP, 484.33 ± 16.56 NDF, 366.00 ± 12.70 ADF and 57.33 ± 7.62 ADL. Rather *et al*. (2017) declared an increase according to the harvest season (from April-May to October-November) of elm leaves for DM 34.98 to 42.99%, CP 13.68% to 18.44%, and CF 4.33% to 6.77% respectively. Smith *et al*. (2020) obtained 37% DM, 43.06% NDF, 12.15% ADF, 3.31% lignin and 77.72% digestible organic matter in elm leaves (in DM %). Mahieu *et al*. (2021) determined an excellent nutritive value with high CP concentration and IVDMD in blackthorn leaves. The current findings are similar to those of earlier results.

Nutritional quality aspects: The change of season from spring to autumn affected TDN, NEl and NEm of elm and blackthorn leaves and NEg of blackthorn leaves. Additionally, insignificant differences were determined in NEg of elm leaves. The highest TDN (62.14 and 64.18), NEl (0.64 and 0.67) and Nem (0.69 and 0.72) of field elm and blackthorn leaves were determined in spring. The highest NEg (0.39) of blackthorn leaves was recorded in spring (Table 2). Dry matter (DM) is an indicator of the amount of nutrients that are available to the animal in a particular feed (Ates and Tenikecier, 2022). The daily consumption of digestible DM is more closely associated

Table 2. Some nutritional quality aspects of field elm and blackthorn leaves

Specification	Year	Field elm				Blackthorn			
		Spring	Summer	Autumn	Mean¥	Spring	Summer	Autumn	Mean¥
TDN	2022	62.15	61.72	61.71	61.86	64.81	63.22	62.02	63.35
	2023	62.14	61.72	61.70	61.85	64.82	63.23	62.04	63.36
	Mean†	62.14a	61.72b	61.70b	*61.85*	64.81a	63.22b	62.03c	*63.35*
	LSD	Year: ns Season: 0.313** Year x Season: ns				Year: ns Season: 0.421** Year x Season: ns			
NEl	2022	0.64	0.63	0.63	0.63	0.67	0.65	0.64	0.65
	2023	0.64	0.63	0.63	0.63	0.67	0.65	0.64	0.65
	Mean	0.64a	0.63b	0.63b	*0.63*	0.67a	0.65b	0.64c	*0.65*
	LSD	Year: ns Season: 0.004** Year x Season: ns				Year: ns Season: 0.004** Year x Season: ns			
NEm	2022	0.69	0.68	0.68	0.68	0.72	0.70	0.69	0.70
	2023	0.69	0.68	0.68	0.68	0.72	0.70	0.69	0.70
	Mean	0.69a	0.68b	0.68b	*0.68*	0.72a	0.70b	0.69c	*0.70*
	LSD	Year: ns Season: 0.006** Year x Season: ns				Year: ns Season: 0.008** Year x Season: ns			
NEg	2022	0.36	0.35	0.35	0.35	0.39	0.35	0.36	0.37
	2023	0.36	0.35	0.35	0.35	0.39	0.37	0.36	0.38
	Mean	0.36	0.35	0.35	*0.35*	0.39a	0.36b	0.36b	*0.37*
	LSD	Year: ns Season: ns Year x Season: ns				Year: ns Season: 0.030** Year x Season: ns			

ns, **: Non-significant, significant at 0.01 level, respectively; ¥ Year means and year x season interactions with different letter fort the same column are significantly
different; †Season means with different letter for the same row are significantly different.

Table 3. Mineral element contents of field elm and blackthorn leaves

Specification	Year	Field elm				Blackthorn			
		Spring	Summer	Autumn	Mean[¥]	Spring	Summer	Autumn	Mean[¥]
P (mg g^{-1})	2022	2.70	2.68	2.73	2.70b	2.40b	2.53a	2.53a	2.49a
	2023	2.73	2.70	2.77	2.73a	2.40b	2.37b	2.50a	2.42b
	Mean[†]	2.72ab	2.69b	2.75a	*2.72*	2.40c	2.45b	2.52a	*2.46*
	LSD	Year: 0.031**, Season: 0.038**, Year x Season: ns				Year: 0.039**, Season: 0.047**, Year x Season: 0.068**			
K (mg g^{-1})	2022	19.77	19.73	19.93	19.81	11.03a	10.98b	10.97b	10.99a
	2023	19.73	19.73	19.88	19.78	10.63c	10.73d	10.53e	10.63b
	Mean	19.75b	19.73b	19.91a	*19.80*	10.83a	10.86a	10.75b	*10.81*
	LSD	Year: ns, Season: 0.080**, Year x Season: ns				Year: 0.022**, Season: 0.027**, Year x Season: 0.038**			
Ca (mg g^{-1})	2022	14.23	14.23	14.30	14.26b	34.83a	34.63d	34.55e	34.67
	2023	14.28	14.30	14.30	14.29a	34.70c	34.53e	34.73e	34.66
	Mean	14.26b	14.27ab	14.30a	*14.28*	34.77a	34.58c	34.64b	*34.66*
	LSD	Year: 0.034**, Season: 0.042*, Year x Season: ns				Year: ns, Season: 0.045**, Year x Season: 0.002**			
Mg (mg g^{-1})	2022	2.70	2.70	2.70	2.70	4.77d	4.93a	4.77d	4.82b
	2023	2.74	2.70	2.67	2.74	4.87c	4.87c	4.90b	4.88a
	Mean	2.72	2.70	2.73	*2.72*	4.82b	4.90a	4.83b	*0.029*
	LSD	Year: ns, season: ns, Year x Season: ns				Year: 0.029**, Season: 0.035**, Year x Season: 0.002**			
Fe (mg g^{-1})	2022	0.623	0.623	0.624	0.623	0.326a	0.326a	0.324b	0.325a
	2023	0.623	0.621	0.624	0.623	0.324b	0.323c	0.324b	0.324b
	Mean[†]	0.623b	0.622c	0.624a	*0.623*	0.325	0.324	0.324	*0.324*
	LSD	Year: ns, Season: 0.001**, Year x season: ns				Year: 0.001**, Season: ns, Year x Season: 0.001*			
Cu (mg g^{-1})	2022	1.343a	1.343a	1.330c	1.339	1.857	1.850	1.850	1.852
	2023	1.347a	1.337b	1.330c	1.338	1.853	1.853	1.850	1.852
	Mean	1.345a	1.340b	1.330c	*1.338*	1.855a	1.852ab	1.850b	*1.852*
	LSD	Year: ns, Season: 0.003**, Year x Season: 0.006**				Year: ns, Season: 0.004**, Year x Season: ns			
Zn (mg g^{-1})	2022	0.026	0.026	0.025	0.025	0.035	0.035	0.035	0.035b
	2023	0.025	0.025	0.025	0.025	0.035	0.035	0.036	0.036a
	Mean	0.026a	0.026a	0.025b	*0.025*	0.035	0.035	0.035	*0.035*
	LSD	Year: ns, Season: 0.001*, Year x Season: ns				Year: 0.001*, Season: ns, Year x Season: ns			
Mn (mg g^{-1})	2022	0.013	0.013	0.013	0.13	0.016	0.017	0.016	0.017
	2023	0.014	0.012	0.013	0.013	0.016	0.017	0.016	0.016
	Mean	0.013	0.013	0.013	*0.013*	0.016b	0.017a	0.016b	*0.016*
	LSD	Year: ns, season: ns, Year x Season: ns				Year: ns, Season: 0.001*, Year x Season: ns			
Mo (mg g^{-1})	2022	0.177	0.176	0.178	0.177	0.214	0.213	0.213	0.213a
	2023	0.177	0.177	0.179	0.178	0.212	0.212	0.212	0.212b
	Mean	0.177b	0.176b	0.179a	*0.177*	0.213	0.213	0.213	*0.213*
	LSD	Year: ns, Season: 0.001**, Year x season: ns				Year: 0.001**, Season: ns, Year x Season: ns			

ns: *, **: Non-significant, significant, at 0.05 and 0.01 level, respectively; [¥] Year means and year x season interactions with different letter fort the same column
are significantly different; [†]Season means with different letter for the same row are significantly different

with DM intake than with its digestibility (Tenikecier and Ates, 2018).

Mineral contents: The highest P contents of field elm (2.75 mg g^{-1}) and blackthorn (2.52 mg g^{-1}) leaves were obtained in autumn. The highest K content of elm leaves was obtained in autumn (19.91 mg g^{-1}) and blackthorn leaves were in spring (10.83 mg g^{-1}) and summer (10.86 mg g^{-1}). The highest concentration of Ca was found in field elm leaves during the autumn season (14.30 mg g^{-1}) and the summer season (14.27 mg g^{-1}). In blackthorn leaves, the highest concentration was recorded for Ca (34.77 mg g^{-1}) during the spring season; for Mg content (4.90 mg g^{-1}) in the summer (Table 3). The highest Fe content (0.624 mg g^{-1}). of field elm leaves was recorded in autumn. The highest concentrations of Cu were observed in field elm and blackthorn leaves in the spring, with values of 1.345 mg g^{-1} and 1.855 mg g^{-1}, respectively. No significant seasonal variation in Zn content was observed in blackthorn leaves, whereas field elm leaves exhibited the highest Zn concentrations during spring and summer (0.026 mg g^{-1}). The highest Mn content of blackthorn leaves was determined in summer (0.017 mg g^{-1}). The highest Mo content of field elm leaves was recorded in autumn (0.179 mg g^{-1}) (Table 3).

Maintaining mineral balance is crucial for animal health. A deficiency in one mineral cannot be compensated by the presence of others, and these elements need to be present in specific proportions (Tenikecier, 2021). The skeleton contains approximately 68-73% of the total Mg in an animal's body. The P levels in the rumen are also significant, as higher P concentrations can enhance Mg absorption. In P-deficient pastures, rumen P levels may be low, potentially worsening Mg absorption. Additionally, blood calcium levels influence the onset of grass tetany. When blood Ca drops, Mg levels in the cerebrospinal fluid decrease more rapidly if blood Mg is already low due to insufficient absorption (Ates, 2017). The elements K, Ca, P, Mg, sulfur (S), sodium (Na), and chlorine (Cl) are present in the animal body at concentrations equal to or greater than 400 mg per kg of body weight (BW), thus they are referred to as macro-minerals (Wu, 2018). These seven macro-minerals, along with 16 other trace minerals, including Cu, Zn, Mn, Fe, Mo, cobalt (Co), iodine (I), selenium (Se), chromium (Cr), fluorine (F), tin (Sn), vanadium (V), silicon (Si), nickel (Ni), boron (B), and bromine (Br), are considered nutritionally essential for both ruminants and non-ruminants. According to Suttle (2010), the marginal ranges for Cu concentration (mg kg^{-1} DM) in the diet are 12-36 for sheep (*Ovis aries* L.), 100-300 for cattle (*Bos taurus* L.), and 30-100 for goats. Several reports indicate that the iron requirement is 30-40 mg Fe kg^{-1} DM, with the higher end of the range applicable to calves weighing less than 150 kg, as well as to pregnant and lactating cows and ewes. The macro and micro mineral contents of elm leaves were 19.30 ± 2.76, 2.84 ± 0.30, 4.93 ± 0.09, 0.63 ± 0.03 and 18.20 ± 0.42 g kg^{-1} DM for Ca, P, Mg, Na and K respectively and content of

Table 4. Provitamin contents of field elm and blackthorn leaves

Specification	Year	Field elm				Blackthorn			
		Spring	Summer	Autumn	Mean[¥]	Spring	Summer	Autumn	Mean[¥]
α-tocopherol (mg kg^{-1})	2022	120.55	115.58	118.60	118.24	118.71	111.64	114.37	114.91
	2023	120.57	115.36	118.55	118.16	118.82	111.53	114.30	114.89
	Mean[†]	120.56a	115.47c	118.58b	*118.20*	118.76a	111.58b	114.35c	*114.90*
	LSD	Year: ns Season: 0.402** Year x Season: ns				Year: ns Season: 0.389** Year x Season: ns			
β-carotene (mg kg^{-1})	2022	330.59c	330.67b	330.68b	330.65b	310.92	311.20	310.70	310.83
	2023	330.71a	330.71a	330.67b	330.69a	310.59	310.78	310.57	310.65
	Mean	330.65c	330.69a	330.67b	*330.67*	310.76ab	310.99a	310.47c	*310.74*
	LSD	Year: 0.012** Season: 0.014** Year x Season: 0.002**				Year: ns Season: 0.314* Year x Season: ns			
Ergocalciferol (μg kg^{-1})	2022	6.08d	7.39a	7.07b	6.85b	7.53	8.69	8.39	8.20
	2023	6.42c	7.38a	7.11b	6.97a	7.51	8.73	8.42	8.22
	Mean	6.25c	7.39a	7.09b	*6.91*	7.52c	8.71a	8.40b	*8.21*
	LSD	Year: 0.119** Season: 0.146** Year x Season: 0.206**				Year: ns Season: 0.065** Year x Season: ns			

ns, *, **: Non-significant, significant at 0.05 and 0.01 level, respectively; [¥] Year means and year x season interactions with different letter fort the same column are
significantly different; [†]Season means with different letter for the same row are significantly different

Cu, Zn, Fe and Mn were 5.57 ± 0.18, 33.00 ± 1.00, 410.00 ± 5.86 and 37.00 ± 2.65 mg kg^{-1}, respectively determined by Beigh *et al*. (2020). Smith *et al*. (2020) reported that the macro mineral content of field elm leaves consisted of 16.8% Ca, 2.4% P, 2.31% N, 2.8% Mg, 1.7% S, and 20.9% K. The same study also reported micro mineral contents of 258 mg kg^{-1} Fe, 38 mg kg^{-1} Mn, 9.3 mg kg^{-1} Cu, and 40 mg kg^{-1} Zn in the same leaves. Blackthorn was determined to be one of the richest species that contains high levels of Ca, K and Fe (Mahieu *et al*., 2021). The present results were similar to those reported by these workers.

Vitamin contents: The highest concentration of α-tocopherol was determined in field elm and blackthorn leaves during the spring season, with values of 120.56 mg kg^{-1} and 118.76 mg kg^{-1}, respectively. The change of season from spring to autumn negatively affected α-tocopherol content in both species. The highest β-carotene content of field elm and blackthorn leaves was recorded in the summer. The highest ergocalciferol content of field elm and blackthorn leaves was found to be 7.39 μg kg^{-1} and 8.71 μg kg^{-1}, respectively, in the summer (Table 4). The fresh foliage of plants generates α-tocopherol and β-carotene, both of which serve as antioxidants. Their main role is to safeguard plant and animal cells from oxidation and the detrimental byproducts associated with the oxidation process (Muhonen, 2018). In a study conducted by Danielsson *et al*. (2008), it was observed that the vitamin content of herbage harvested in the autumn was higher than that of herbage harvested at other times of the year. This finding suggests that climate may exert an influence on the vitamin content of harvested herbage. The findings presented here differ from those previously reported.

Many factors that influence the ergocalciferol content of forage crops include: growth stage, leaf/stem ratio; climatic and edaphic factors, such as geographic location and topographic properties, seasonal and yearly variation, illuminance-associated diurnal variation, soil traits; biotic damage; conservation methods of herbage/hay (dehydration, ensiling, drying and etc.) and storage conditions of forage (Ateş and Tenikecier, 2024). Jäpelt *et al*. (2011) reported that the maximum ergocalciferol content reached 2% of the ergosterol content, suggesting that it is not UVB radiation, but rather the concentration of ergosterol that serves as the limiting factor for ergocalciferol production in plants.

Conclusion

The study indicates that field elm and blackthorn leaves meet the nutritional requirements for consumption by livestock, particularly small ruminants. These characteristics suggest that they can serve as an alternative source of supplementation in feeding programs. Small ruminants, particularly goats, will make the best use of these species and when goats graze these leaves, although their nutritional value is generally sufficient, appropriate additional feeding will be required to close the protein deficit in the winter period. Furthermore, as these species retain their green foliage throughout the summer months, when herbaceous species typically dry up, they consistently offer green forage for grazing small ruminants. It can, therefore, be concluded that the integration of these species into grazing systems will result in an extension of grazing time in pasture, thus enabling a more profitable animal husbandry by reducing roughage costs.

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