Original article

Cladode Age and Location Effect on Nutritional Value of *Opuntia ficus indica*

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Abstract. *Opuntia ficus indica* leaves (i.e. cladotus) are vital as a source of fodder for ruminant animals in arid and semi-arid climates of the world. In this study, the purpose was to determine the nutritional values and mineral contents of *Opuntia ficus indica* cladotus of 3 different ages obtained from the natural flora in two different locations in the Mediterranean region of Turkey (Tarsus - Mersin, and Kozan - Adana). The crude protein content (%), acid detergent fiber (%), neutral detergent fiber (%), digestible dry matter ratio (%), dry matter intake value (%), relative fodder value, Ca (%), Mg (%), K (%), P (%), Ca/P (%), and K/(Ca+Mg) (%) were examined in the present study. As a result of the study, it was found that the Tarsus location had higher crude protein, Mg, and Ca/P values, and the Kozan location had higher Ca, K, and P values. Cladotus age had an impact on all these investigated characteristics except for P and Ca/P ratios. It was also found that young cladotus had higher crude protein (13.18%), digestible dry matter (69.16%), dry matter intake (5.47%), relative fodder value (293.43), Ca (2.62%), K (2.44%), and K/(Ca+Mg) (0.75%) values, these characteristics decrease as the age of cladotus proceeds; however, ADF, NDF, and Mg contents are higher in older cladotus. As a result, one- and two-year-old opuntia cladotus can be made use of as an alternative fodder for ruminant nutrition in dry periods of the year when the amount and quality of grass production decreases.

Key words: *Opuntia ficus indica*, cactus, nutritional value, mineral content

Introduction

Opuntia ficus indica is a plant species of the Cactaceae family, which can grow in arid and semi-arid climates with high drought resistance (high temperature, drought, and UV radiation) (1). The inability of many plants to grow naturally in arid areas made this plant become an alternative agricultural resource (2). Especially in areas that have low and insufficient rainfall, finding alternative fodder and food sources may vary depending on the climate and natural resources of the area (3). When the climate and living conditions of the African continent are considered, it is seen that this plant is a very important food source for animals and humans (4). Opuntia species come to the forefront with their development characteristics in arid and semi-arid areas by developing and producing products with the Crassulacean Acid Metabolism (CAM). CAM photosynthesis seen in cacti provides the ability to adapt to water stress, heat, and sunlight (5, 6).

Although *Opuntia ficus indica* is mostly grown in Mexico, it spread naturally in many countries in Africa, Australia, the Mediterranean basin, some parts of Asia, and the African continent over time (7, 8). It also spreads in Adana, Mersin, Osmaniye, Hatay, Antalya, and the South Aegean Region of Turkey. *Opuntia ficus indica* fruits, which can grow naturally in these regions, are collected by people and are sold in local markets (9). In our country, opuntia species is known under the names of *hint inciri* (nopal), *dikenli incir* (thorny fig), and frenk inciri (opuntia) (1). It was reported that its fruits can be used in jam, juice, and

candy products, and young Cladotus are a good source of fiber for human nutrition (10, 11).

Abundant, high-quality, and cheap fodder source is an important issue affecting productivity in animal husbandry (12, 13). Roughage is an indispensable forage source, and the quality roughage gap is still an up-to-date issue (12, 13, 14). Turkey has approximately 60.4 million animals, including 16 million cattle, and 44.3 million sheep - goats (15). It was reported that these animals are not fed with adequate quality fodder, and there is a deficit in this respect of approximately 30 million tons per year (16).

The leaves of *Opuntia ficus indica* (cladotus) have vital importance as a fodder source for ruminants in arid and semi-arid climates. In a study that was conducted in Turkey (17), it was reported that the crude protein, Ca, and P contents of young Cladotus were higher than those of older ones. Pinos-Rodriguez et al. (18) reported that the dry matter, ash, protein, NDF, and ADF contents of cactus Cladotus were 73.3%, 9.1%, 16.3%, 22.3%, and 9.7%, respectively. It was reported in a study that was conducted in Kenya that the nutritional composition of the cultivars changed according to age and season (19); in another study that was conducted in Ethiopia with different varieties (20), it was reported that the ash content was 20.15%–22.79%, the organic matter content was 77.21%–79.85%, and the crude protein content was 5.38%–6.02%. In the study that was conducted with Portuguese *Opuntia ficus indica* cladotus ecotype, the dry matter was found to be 12.85%-14.58%, crude protein was 68.01–82.52 g kg^{-1} dry matter, NDF 164.67–198.99 g kg^{-1} dry matter, and ADF 95.49–114.35 g kg^{-1} dry matter (20).

It was found that studies were conducted worldwide regarding the nutritional value and medicinal use of *Opuntia ficus indica* Cladotus and fruits (21, 22), polyphenol content, and antioxidant capacity (23, 24, 25, 26, 27), chemical and nutritional contents (19, 28, 29, 30, 31, 32, 33); however, there are limited studies conducted on this plant in Turkey (34). It was found that there is only one study conducted on its use in animal nutrition, silage, and nutritional value (17). This study was conducted to determine the fodder value and mineral content of *Opuntia ficus indica* plant Cladotus that had different ages obtained from different locations, and also to investigate their usability in animal nutrition as an alternative fodder source.

Materials and Methods

Experimental Site and Conditions

The study was conducted on the *Opuntia ficus indica* plant in the natural flora in two different locations (Tarsus - Mersin, and Kozan - Adana) in 2020 (Figure 1). Some climatic data of these locations are given in Table 1 for many years (35).

The city of Tarsus is located in the Mediterranean Region, between 36°55'02.23" Northern Latitude and 34°53'34.88" Eastern Longitude at an altitude of 23 m above sea level. The average monthly temperature of the county is 19.2°C for many years (1940-2020), the highest average temperature is 23.4°C, the lowest average temperature is 14.8°C, and the total annual precipitation is 615.5 mm. Kozan County is located in the Mediterranean Region between 37°27'07.37" Northern Latitude and 35°49'12.17" Eastern Longitude, at an altitude of 120 m above the sea level. The average monthly temperature of the county for many years (1940–2020) is 19.2°C, the highest average temperature is 25.4°C, the lowest average temperature is 13.9°C, and the annual total precipitation is 668.1 mm.

Figure 1. Location information of experimental areas. A: Tarsus, B: Kozan

Table 1. Some climatic data of locations for many years

Many years (1940 – 2020)								
	Average temperature (°C)		Average maximum temperature (°C)		Average minimum temperature (°C)		Monthly total rainfall (mm)	
Months	Tarsus	Kozan	Tarsus	Kozan	Tarsus	Kozan	Tarsus	Kozan
January	10.2	9.5	14.6	14.8	6.3	5.2	119.9	111.1
February	11.1	10.5	15.5	16.2	6.9	6.0	86.7	89.6
March	13.8	13.4	18.1	19.5	9.2	8.3	56.2	65.0
April	17.5	17.5	21.6	23.7	12.9	11.9	34.1	51.1
May	21.3	21.8	25.0	28.3	16.9	15.8	23.4	48.7
June	25.0	25.6	28.2	31.7	20.9	19.8	10.1	22.2
July	27.8	28.2	30.8	33.9	24.0	23.0	11.6	10.2
August	28.3	28.7	31.6	34.7	24.3	23.3	6.8	9.6
September	25.8	26.1	30.1	33.1	21.0	20.1	11.7	19.6
October	21.5	21.7	26.7	29.1	16.3	15.7	38.9	43.6
November	16.2	15.9	21.6	22.6	11.6	10.7	77.1	71.2
Dicember	11.9	11.2	16.5	16.8	7.9	6.9	139.0	126.2
Total/average	19.2	19.2	23.4	25.4	14.8	13.9	615.5	668.1

Experimental Material and Design

The study material consisted of *Opuntia ficus indica* plant Cladotus in the natural flora in Tarsus - Mersin and Kozan - Adana. Cladotus were taken from these locations on October 3–4, 2020 from 10 different roots as 3 replications for 3 different maturity years.

Data Collection

Cladotus that were taken from two different locations as 3 replications for 3 different maturity years were cleaned in Kahramanmaraş Sütçü Imam University, Faculty of Agriculture Laboratory, cut into 2–3 cm^2 pieces, and were left at room temperature for two days, and were then dried in an oven at 105°C (±5°C) for 24 hours. The dried material was passed through a grinding device that had 1 mm mesh and made ready for chemical analyses. Three replications were performed for each analysis (21).

The Kjeldahl Method was used in determining the nitrogen contents of the samples. The crude protein rate was calculated with the formula of N × 6.25 (36). The Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) analyzes were made by using the ANKOM200 Fiber Analyzer (ANKOM Technology Crop., Fairport, NY, USA) according to the method described by Van Soest et al. (37). The Digestible Dry Matter (DDM), Dry Matter Ingestion (DMI), and Relative Fodder Value (RFV) were calculated with the following standard formulas (38).

$$\text{Digestible Dry Matter (DDM)} = 88.9 - (0.779 \times \text{ADF\%})$$

$$\text{Dry Matter Ingestion (DMI)} = 120 / \text{NDF\%}$$

$$\text{Relative Fodder Value (RFV)} = \text{DDM (\%)} \times \text{DMI (\%)} / 1.29$$

The Ca, Mg, P, and K contents of *Opuntia ficus indica* Cladotus were determined by using the WINISI Package Program in FOSS 6500 NIR Systems Device.

Statistical Analyses

The variance analyzes of the data obtained in the study were made according to a completely randomized with a factorial arrangement of 2 × 3 by using the SAS Statistical Package Program (39), and the

significance of the difference between the mean values was determined with the LSD Test.

Results

Nutritional Value

The results of the analyses of the variance of the nutritional values of *Opuntia ficus indica* cladotus of three different ages obtained from two different locations are given in Table 2, which also shows that the effects of locations on CPC, Cladotus age on all the parameters in question, and location-Cladotus age interaction on NDF, DDM, and RFV were statistically significant. No significant differences were detected between Tarsus and Kozan locations in ADF, NDF, DDM, DMI, and RFV, except for CPC. The CPC value of the Tarsus location (10.73%) was higher than the Kozan location's CPC value (9.75%). When the effects of Cladotus age on nutritional values were examined (Table 2), the highest CPC (13.18%), DDM (69.16%), DMI (5.47%), and RFV (293.43) values were obtained from one-year cladotus; however, the highest ADF (36.46%) and NDF (38.53%) values were obtained from three-year-old Cladotus. Also, it was determined that L × CA interaction is important for NDF, DDM, and RFV.

Mineral Composition

The variance analysis results of the mineral composition of *Opuntia ficus indica* Cladotus are given in Table 3.

The effect of locations on all parameters in question except for K / (Ca + Mg), the effect of Cladotus age on Ca, Mg, K, and K / (Ca + Mg), and L × CA interaction on Ca, K, and K / (Ca + Mg) were at statistically significant levels. No significant differences were detected between Tarsus and Kozan locations in terms of K / (Ca + Mg). The Ca (2.71%), K (2.35%), and P (0.44%) contents of Kozan location Cladotus were higher than those of Tarsus location. When the effects of Cladotus age on mineral composition were examined (Table 3), the highest Ca, K, and K / (Ca+Mg) values were found in one and two-year-old Cladotus; however, the highest Mg content (0.78%) was found in 3-year old Cladotus. Also, the L × CA interaction was important for Ca, K, and K / (Ca+Mg).

Table 2. Effects of cladode age on nutritional value of the *Opuntia ficus-indica* cladodes at two different locations in East Mediterranean region of Turkey.

	CPC (%)	ADF (%)	NDF (%)	DDM (%)	DMI (%)	RFV
Locations (L)						
Tarsus	10.73 a	29.67	28.07	65.79	4.49	231.38
Kozan	9.75 b	29.65	27.96	65.78	4.66	241.06
$LSD_{0.05}$	0.80	ns	ns	ns	ns	ns
Cladode ages (CA)						
One	13.18 a	25.34 c	21.98 c	69.16 a	5.47 a	293.43 a
Two	10.31 b	27.21 b	23.53 b	67.70 b	5.12 b	268.85 b
Three	7.24 c	36.46 a	38.53 a	60.50 c	3.12 c	146.39 c
$LSD_{0.05}$	0.98	1.47	1.26	0.23	1.14	14.07
Analysis of variance for parameters combined over locations						
L	*	ns	ns	ns	ns	ns
CA	**	**	**	**	**	**
L × CA	ns	ns	**	*	ns	*

*, **significant at the 0.05 and 0.01 level, respectively; for each trait, values within columns followed by the same letter are not significantly at P=0.05; ns, non-significant.

Table 3. Effects of cladode age on mineral composition of the *Opuntia ficus-indica* cladodes at two different locations in East Mediterranean region of Turkey.

	Ca (%)	Mg (%)	K (%)	P (%)	Ca/P (%)	K/(Ca + Mg) (%)
Locations (L)						
Tarsus	2.39 b	0.73 a	2.12 b	0.34 b	7.16 a	0.68
Kozan	2.71 a	0.65 b	2.35 a	0.44 a	6.16 b	0.70
$LSD_{0.05}$	0.07	0.05	0.06	0.05	0.80	ns
Cladode ages (CA)						
One year	2.62 a	0.62 b	2.44 a	0.41	6.46	0.75 a
Two years	2.60 a	0.67 b	2.45 a	0.40	6.79	0.75 a
Three years	2.43 b	0.78 a	1.82 b	0.39	6.74	0.57 b
$LSD_{0.05}$	0.09	0.06	0.07	ns	ns	0.04
Analysis of variance						
L	**	**	**	**	*	ns
CA	**	**	**	ns	ns	**
L × CA	*	ns	**	ns	ns	**

*, **significant at the 0.05 and 0.01 level, respectively; for each trait, values within columns followed by the same letter are not significantly at P=0.05; ns, non-significant.

Discussion

Nutritional Value

The effects of locations on other characteristics that were examined, except for the CPC value, were not at significant levels; however, the effects of Cladotus age on all characteristics were at significant levels. According to the locations, the CPC of *Opuntia ficus indica* varied between 9.75% and 10.73%, and the highest value was obtained in Tarsus. The CPC varied between 7.24% and 13.18% according to the cladotus age. It was also found that the CPC value decreased as the cladotus age proceeded. The highest CPC value was detected in young Cladotus, and the lowest crude protein content was found in ripe Cladotus. De Kock (40) reported that there was crude protein at a rate of 4%, Tegegne et al. (31) reported as 5%, Abidi et al. (5) as 3.8%, and Rekik et al. (41) as 4.4% in Opuntia plant Cladotus. Retamal et al. (28) reported that the crude protein rate ranged between 10.6% and 15.0% in young Cladotus to 4.4% and 11.3% in older Cladotus. Erol et al. (42) reported the crude protein rate as 3.05% in Cladotus of *Opuntia ficus indica*. Our findings were higher than the crude protein values reported by De Kock (40) and Erol et al. (42) and were found to be consistent with the values reported by Retamal et al. (28). According to Rodrigues et al. (21), the crude protein rate decreases as the Cladotus age proceeds, and the crude protein content is higher in young Cladotus. In the present study, ADF rates were found to be between 29.65–29.67% according to locations, and between 25.34% and 36.46% according to Cladotus ages; NDF rates varied between 27.96% and 28.07% according to locations, and 21.98%–38.53% according to Cladotus ages. It was also found that the ADF and NDF rates increased as the Cladotus age proceeded. The L × CA interaction was important for NDF (Figure 2).

In the study locations, NDF rate increased at significant levels with increasing Cladotus age. Taylor (43) reported that the quality standards must be ADF <31% and NDF <40% for legumes, grass, and legume-wheat mixed straw. It was determined in the study that the ADF and NDF values of *Opuntia ficus indica* cladotus were in line with the quality standards. Tegegne et al. (31) %23.9, Abidi et al. (5) %25.1, Rekik et al. (41) %30.6 and Costa et al. (44) reported NDF values of 31.2%. In some studies conducted with *Opuntia ficus indica*, it was reported that ADF values

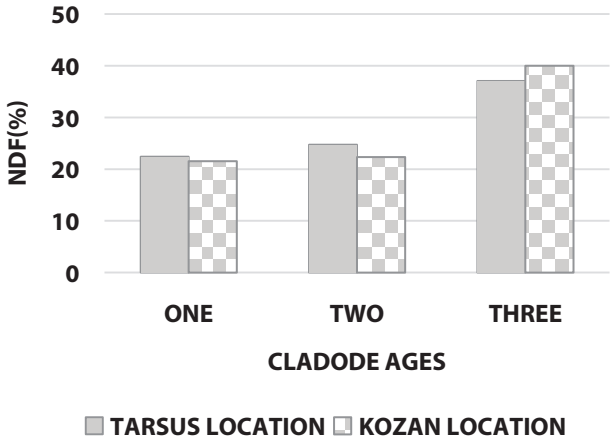

Figure 2. Location x cladode age effect on NDF of *Opuntia ficus-indica* cladotus

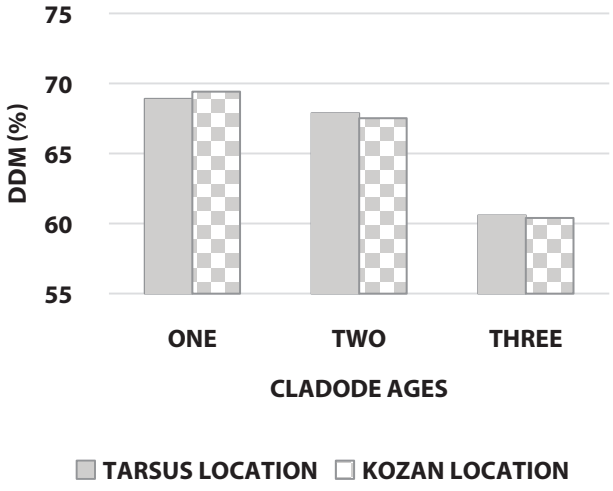

Figure 3. Location x cladode age effect on DDM of *Opuntia ficus-indica* cladotus

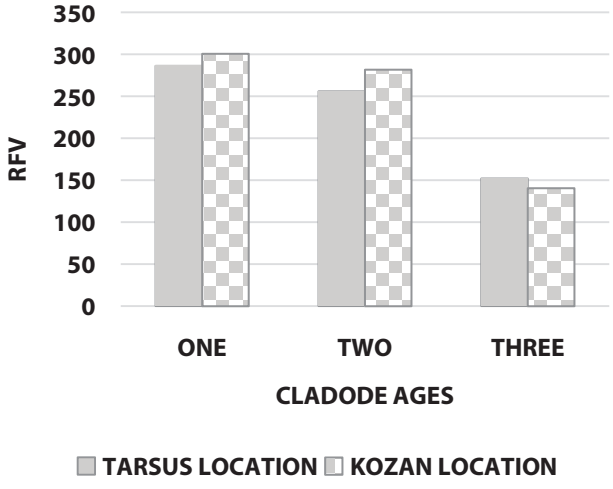

Figure 4. Location x cladode age effect on RFV of *Opuntia ficus-indica* cladotus

varied between 13.7% and 28.7% (44, 45, 46, 47). The ADF and NDF values, which vary according to cladotus age, are similar to the findings of many researchers. In a study that was conducted in Turkey, it was reported that it was 12.55% in ADF and 60.94% in NDF (42). This difference in results is considered to be because of the Cladotus age.

The effect of location on the Digestible Dry Matter (DDM) values of *Opuntia ficus indica* cladotus was not at significant levels; however, the age of Cladotus and L × CA interaction had significant impacts in this respect. DDM values varied between 60.50% and 69.16% according to cladotus ages. In both locations, the highest DDM value was detected in young Cladotus, and the lowest was found in ripe Cladotus (Figure. 3), which indicates that as the Cladotus age proceeds, the digestibility rate for animals will decrease. DMI values ranged between 3.12 and 5.47 according to the age of cladotus. As the cladotus age proceeded, the DMI value decreased at significant levels, which was because of the decreased DDM values. Cladotus age and L × CA interaction had a significant effect on the RFV value. In both locations, the RFV value decreased as the Cladotus age proceeded, and the lowest RFV value was detected in the 3-year-old Cladotus (Figure 4)

Mineral Composition

Kozan location had higher values in terms of Ca, K, and P, and Tarsus location had higher values for Mg and Ca/P. The age of the Cladotus had an effect on Ca, Mg, K, and K / (Ca + Mg) rates. The highest Ca, K, and K / (Ca + Mg) rates were obtained from one and two-year-old Cladotus, and the content of these minerals decreased at significant levels as the Cladotus age increased. Also, the L × CA interaction of the Ca, K, and K / (Ca + Mg) rate was found to be significant (Figure 5, 6, and 7).

As the Cladotus age increased, the Ca, K, and K / (Ca + Mg) rates decreased in the study locations. This decrease was more in the Tarsus location. This was because of the fact that the Tarsus location had a lower annual total precipitation than the other location

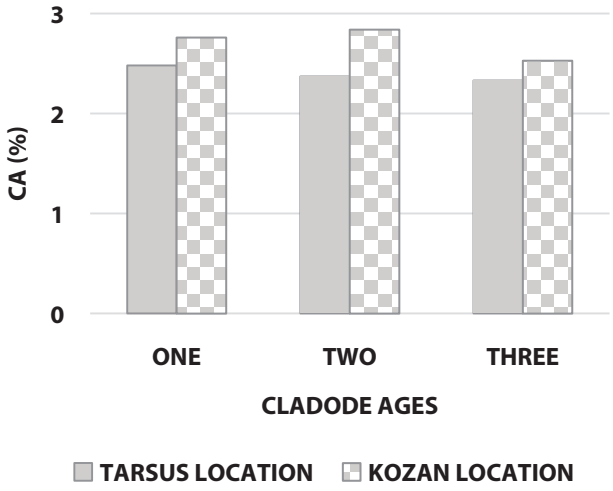

Figure 5. Location x cladode age effect on Ca content of *Opuntia ficus-indica* cladotus

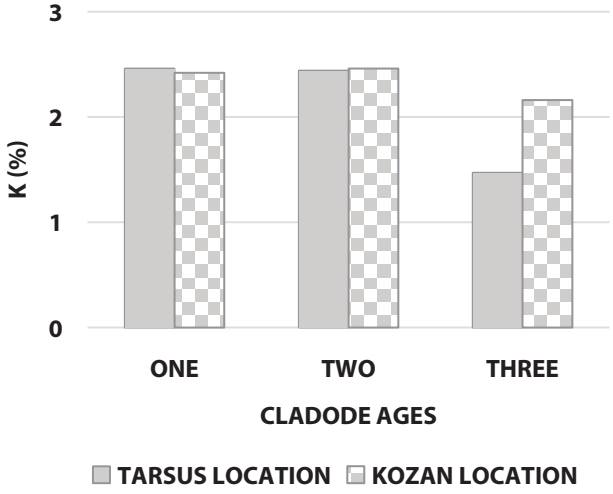

Figure 6. Location x cladode age effect on K content of *Opuntia ficus-indica* cladotus

(Table 1). It was reported that the Ca and P contents of Cladotus of opuntia were 1.4% and 0.2%, respectively (40). Nobel (48) reported that younger Cladotus had higher K contents. The P value that was found in the study was higher than those that were reported by De Kock (40). Although the effects of locations on Ca/P rate were significant, the effects of Cladotus age were not at significant levels. Açıkgöz (49) reported that the Ca/P rate should be 2:1, and the risk of milk fever/hypocalcemia increased in excessive amounts. In the study, Mg and K/(Mg+Ca) contents were affected by the Cladotus age at significant levels. As the maturation period proceeded, the Mg rate increased, and

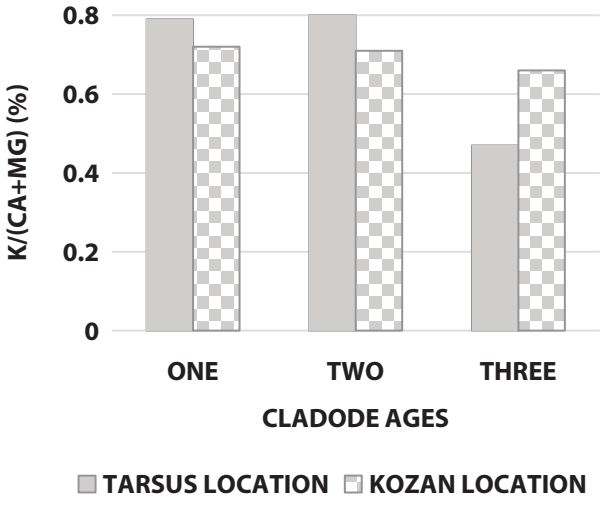

Figure 7. Location x cladode age effect on K/(Ca+Mg) content of *Opuntia ficus-indica* cladotus

the K/(Mg+Ca) rate decreased. As a matter of fact, the highest Mg (0.78%) and the lowest K/(Mg+Ca) rate (0.57%) were found in 3-year-old ripe cladotus. Kidambi et al. (50) reported that the K/(Ca+Mg) rate must be less than 2.2%. At least 0.3% Ca, 0.1% Mg, 0.8% K, and 0.2% P must be present to cover the nutritional needs of animals (51). It was found that *Opuntia ficus indica* Cladotus in the natural flora of Tarsus and Kozan in the Eastern Mediterranean Region of Turkey had good K/(Ca+Mg) rates and high Ca/P rates. It was also found that *Opuntia ficus indica* Cladotus were superior in terms of Ca, Mg, K, and P contents, and might be sufficient for ruminant animal nutrition.

Conclusion

The present study was conducted to determine the nutritional value and mineral content of *Opuntia ficus indica* cladotus of three different ages obtained from the natural flora in two different locations (Tarsus - Mersin, and Kozan - Adana) in the Mediterranean Region in Turkey. It was found as a result of the study that the Tarsus location had higher crude protein, Mg, and Ca/P values, and the Kozan location had higher Ca, K, and P values. It was also found that crude protein, Digestible Dry Matter, Dry Matter Ingestion, and Relative Fodder Value, Ca, K, P, and K/(Mg+Ca) values decreased when ADF, NDF, and Mg values

increased as the Cladotus age proceeded. The important thing in animal nutrition is to cover the protein requirement. The results show that *Opuntia ficus indica* can be an alternative fodder source in the face of increasing drought conditions. One and two-year young opuntia Cladotus can be considered to be an alternative fodder in ruminant nutrition. The issues on the reproduction of this plant in arid areas with different evaluation methods must be investigated.

Conflict of interests: No potential conflict of interest relevant to this article was reported by the author.

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