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Chemical Characteristics and Feed Value of Moringa (*Moringa oleifera*) Plant#

ABSTRACT

Objective: The experiment was conducted to determine chemical compositions of different parts of *Moringa oleifera* [leaves, stalks and whole (leaves + stalks).

Materials and Methods: : For this purpose, *Moringa oleifera* was harvested 3 times with 1 month of intervals starting from the first flowering period at 5 months old. Dry matter, organic matter, ash, crude protein, ether extract, crude fiber, nitrogen free extract, starch, sugar, neutral detergent fiber, acid detergent fiber, acid detergent lignin, hemicellulose, cellulose, relative feed value, in vitro metabolic energy for ruminant and poultry of different parts of *Moringa oleifera*, also antioxidant activity, phenolic substance and total flavonoid of leaves were analysed.

Results: There were significant differences among harvests in all parameters in the leaves except for organic matter and ash, stalks and whole (leaves + stalks) (P<0.05).

Conclusion: It is concluded that *Moringa oleifera* can be recommended as an alternative source of forages considering nutrients content and feed value.

Keywords: *Moringa oleifera*, chemical composition, feed value

Moringa (*Moringa oleifera*) Bitkinin Kimyasal Özellikleri ve Yem Degeri#

ÖZ

Amaç: Bu araştırmada; *Moringa oleifera* bitkisinin farklı kısımlarının yapraklar, saplar ve tüm bitkinin (yapraklar + saplar) kimyasal bileşimlerini belirlemek amacıyla yapılmıştır.

Materyal ve Methot: Bu amaçla *Moringa oleifera* 5 aylık yaştaki ilk çiçeklenme döneminden başlayarak 1'er ay aralıklarla 3 kez hasat edilmiştir. *Moringa oleifera* 'nın farklı kısımlarında kuru madde, organik madde, kül, ham protein, ham yağ, ham selüloz, nitrojensiz öz maddeler, nişasta, şeker, nötr deterjan lif, asit deterjan lif, asit deterjan lignin, hemiselüloz, selüloz, nispi yem değeri, ruminant ve kümes hayvanları için in vitro metabolik enerji, ayrıca yaprakta antioksidan aktivite, fenolik madde ve toplam flavonoid analizleri yapılmıştır.

Bulgular: Organik madde ve ham kül hariç yapraklarda, saplarda ve bütünde (yaprak + sap) tüm parametrelerde hasatlar arasında önemli farklılıklar bulunmuştur (P<0.05).

Sonuç: *Moringa oleifera*' nın besin maddeleri içeriği ve yem değeri dikkate alındığında alternatif bir kaba yem kaynağı olarak önerilebileceği kanısına varılmıştır.

Anahtar Kelimeler: *Moringa oleifera*, kimyasal kompozisyon, yem değeri

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INTRODUCTION

The dependency on some conventional ingredients that are either imported or that are expensive where they locally exist causes difficulties to sustainably produce livestock in developing countries (Ayssiwede et al., 2011). Therefore, using relatively low cost and locally grown non-conventional feed resources is vital for sustainable commercial animal production (Onu and Aniebo, 2011; Sebola et al., 2019). The inclusion of such non-conventional feed resources in the diets could help reduce feed cost and also minimize the direct competition between the human and livestock industry for the available conventional feedstuffs (Onu and Aniebo, 2011).

Moringa oleifera , it is known as a fast-growing legume plant that is mainly distributed in tropical and subtropical zones (Makkar and Becker, 1997; Ayerza, 2011; Aderinola et al., 2018; Khan et al., 2022; Wiltshire et al., 2022) with a wide array of uses in both animal and human-related fields such as nutrition, purification of river water, medicine, pharmacy, pharmacology, and cosmetic attributes (Ghazali and Mohammed, 2011; Giuberti et al., 2021; Khan et al., 2022; Liu et al., 2018; Lin et al., 2019; Oyeyinka and Oyeyinka, 2018; Wiltshire et al., 2022; Varkey, 2020). It is also reported to have twenty times higher CO2 assimilation rate reducing thus considerably the carbon foot print, consume less water and improve soil fertility (Cattan et al., 2022).

On a dry matter basis, the crude protein content of an *Moringa oleifera* leaf ranges from 23.0 to 30.3%, total content of crude fiber is as low as 5.9%, ash content of up to 12.0% (Wu et al. 2013), approximately 7.09% lipids (Teixeira et al. 2014). *Moringa oleifera* leaf is rich in mineral elements, such as calcium, iron, potassium, phosphorous, and zinc, which are key elements for animal growth and development (Teixeira et al. 2014). In addition, *Moringa oleifera* contains five essential amino acids including lysine and threonine, both of which are lacking in animal staple diet (Saint Sauveur and Broin, 2010). Notably, more than half (57%) of fatty acids in an *Moringa oleifera* leaf are unsaturated fatty acids, among which α-linolenic acid (44.57%) has the highest content (Moyo et al. 2011).

Although there are nutritional factors in *Moringa oleifera* leaves, such as tannins, phenols, nitrates, oxalates, saponins and phytates which affect protein and mineral metabolism (Makkar and Becker, 1997; Moreki and Gabanakgosi, 2014), the sugars such as raffinose and stachyose which produce bloating in monogastrics (Makkar and Becker, 1997), these levels do not cause negative effects in animals that consume (Makkar and Becker, 1997). However, the folk medicinal uses of *Moringa oleifera* leaves are attributed to the presence of functional bioactive compounds, such as phenolic acids, flavonoids, alkaloids, phytosterols, natural sugars, vitamins, minerals, and organic acids (Saini et al., 2016; Lin et al., 2018).

Furthermore, *Moringa oleifera* leaves contain bioactive compounds, such as saponins and condensed tannins, which have antimicrobial properties that can be exploited in ruminant production to reduce methane emissions and improve fermentation efficiency. Elghandour et al. (2017) observed that methane production in goat and cattle rumen decreased when *Moringa oleifera* was used instead of soybean meal. In addition, diets containing *Moringa oleifera* decreased the number of ruminal ammonia and total protozoa, while increasing the total number of bacteria.

Moreover, its seed contain a high level of oil, said to be similar to olive oil, used for edible and non-edible purposes (Ghazali and Mohammed, 2011; Özcan et al., 2019; Du et al., 2022; Wiltshire et al., 2022). It also contains a high level of protein which could make it a valuable alternative source of protein in animal feeding. Although the limited knowledge of its effects on the metabolism, *Moringa oleifera* seeds are used as a livestock feed across tropical regions due to its availability and palatability (Magalhães et al., 2021).

The current study aims to evaluate the chemical composition and relative feed value of different parts of *Moringa oleifera* grown in the field conditions of İzmir (Türkiye), harvested at 3 different periods, seed and seed oil.

Therefore, the aim of this study were to determine dry matter (DM), crude ash (CA), ether extract (EE), crude protein (CP), sugar, starch, crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), total phenolic content (TPC), total flavonoids (TF), antioxidant activity (AA), relative feed value (RFV), metabolizable energy for poultry (MEP) and ruminant (MER) of different parts of *Moringa oleifera* grown in the field conditions of İzmir (Türkiye), harvested at 3 different periods.

MATERIAL and METHOD

Growing and sampling procedures

The first growth of *Moringa oleifera* grown on the farm located in Ege University Agricultural Research and Application Center located at Bornova, İzmir, Türkiye (38°27.07 N, 27°13.28 E and 26 m). In the region where the experiment was established, are typical Mediterranean climate characteristics. The soil on trial area is classified as silty-clay loam. The mean rainfall of the area is approximately 600 mm and the mean annual temperature is 17.8 °C. A drip irrigation system was installed in the experimental field during the growing period. Weed control was performed manually when necessary. No pesticide or insecticide was applied. After five months on the field (first flowering period), harvests were made three times with one-month interval between each harvest (September, October and November respectively). Each harvest was divided into 3 groups [leaf, stalk, and whole (leaf + stalk)] by hand.

Analytical methods and determination of in vitro feed value

Shade-dried samples were ground in a laboratory mill to pass through a 1 mm screen for chemical analyses. DM was determined by drying the samples at 105 °C for 16 h in the oven. Kjeldahl method was used to determine the nitrogen (N) content, and then CP content was calculated according to the formula N x 6.25. CA content was determined by burning the feed sample at 550 °C for 16 hours in a muffle furnace. EE analysis was determined by Soxhlet extraction using anhydrous diethyl ether (AOAC, 1990). Sugar and starch analyzes were performed according the method of AOAC (1990). CF was determined using 12.5% H2SO4 and 12.5% NaOH solutions according to Naumann and Bassler (1993). Nitrogen-free extracts (NFE) were calculated as 100 - % (moisture + ash + CP + EE + CF). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents were analyzed according to the methods reported by Goering and Van Soest (1970). Also, hemicellulose and cellulose contents were calculated as follows: Hemicellulose % = NDF % – ADF % and Cellulose % = ADF % – ADL %.

Estimates for MEP were based on CP, EE, starch and sugar levels determined from the samples using a prediction equation (TSI, 1991); MEP, Mcal/kg = (3.69 x CP + 8.18 x EE + 3.99 x Starch + 3.11 x Sugar). Estimates for MER were based on CP, CF and EE levels determined from the samples using a prediction equation (TSI, 1991); MER Mcal/kg = ((3260 + (0.455 x CP + 3.517 x EE - 4.037 x CF)) and CP, EE, CF quantities in OM (g/kg). Metabolic energy values of the samples are given on a dry matter basis.

To prepare the extract for analysis, 0.5 g of samples were mixed with 20 mL of 75% ethanol solution in a shaking bath at 60°C for 30 minutes, and then centrifuged at 3000 rpm for 10 minutes. After centrifugation, samples were filtered and prepared for analysis of total phenolic content (TPC), total flavonoid content (TFC) and antioxidant activities (AA). TPC was determined using Folin–Ciocalteu reagent (FC) described by Singleton and Rossi (1965), with slightly modified. TFC was determined using the protocol described by Zhishen et al. (1999). AA was determined using the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging method described by Garcia et al. (2012). The % scavenging activity of the DPPH radical was calculated using the following equation: Radical scavenging effect (%) = [(Control absorbance - Absorbance values of samples)/ Control absorbance × 100].

Relative Feed Value (RFV) was calculated from the estimates of dry matter digestibility (DMD, %) and dry matter intake (DMI, %) (Rohweder et al., 1978). Dry matter digestibility (DMD, %) was calculated from the ADF value; DMD, % = 88.9 – (0.779 × ADF, %). Dry matter intake (% DMI) depending on the animal's body weight (BW) was calculated from the NDF value; DMI, % of BW = 120 / (% NDF) RFV = (DMD x DMI) / 1.29. Chemical analyses were performed with 5 replications for each group.

Statistical analysis

All data obtained from the experiment were analyzed based on a one-way analysis of variance (ANOVA) using SPSS (2003) software. The significance of all tests was assessed at a P value of 0.05. Duncan's multiple range test was used to determine the significance level of the differences.

RESULTS

The chemical composition and the results of the TPC, TF and AA of *Moringa oleifera* leaves, in vitro metabolic energy and relative feed value of *Moringa oleifera* leaves harvested at different stages of maturity are shown in the Table 1. There were no significant differences among three harvests (first, second and third harvest) in terms of DM (92.14, 92.15 and 91.96 %), OM (89.38, 89.49 and 89.70 %) and CA contents (10.62, 10.51 and 10.30 %), starch (2.16, undetermined and 1.18 %), TF (4.69, 4.70 and 4.78 mg QE/g), TPC (2.70, 2.69 and 2.72 mg GAE/g) and AA (49.53, 49.55 and 49.57 %) of leaves respectively (P>0.05).

Table 1. Chemical composition, in vitro metabolic energy, relative feed value, total flavonoid, total phenolic compounds and antioxidant activitiy of *Moringa oleifera* leaves harvested at different stages of maturity

Tablo 1. *Farklı olgunluk zamanlarında hasat edilen Moringa oleifera yapraklarının kimyasal bileşimi, in vitro metabolik enerji, nispi yem değeri, toplam flavonoid, toplam fenolik bileşikler ve antioksidan aktivitesi*

Parameters	First Harvest	Second Harvest	Third Harvest	Probability
Dry matter, %	92.14±0.33	92.15±0.51	91.96±0.13	0.6407
Organic matter, %	89.38±0.40	89.49±0.45	89.70±0.21	0.3998
Ash, %	10.62±0.09	10.51±0.36	10.30±0.12	0.1120
Crude protein, %	22.96±0.40^c	29.14±0.23^b	39.30±0.18^a	0.0000
Ether extract, %	5.63±0.07^a	4.86±0.18^b	5.79±0.18^a	0.0000
Crude fiber, %	8.83±0.17^a	6.56±0.36^b	5.68±0.16^c	0.0000
Nitrogen free extract, %	51.96±0.77^a	48.94±0.76^b	38.93±0.38^c	0.0000
Starch, %	2.16±1.48	undetermined	1.18±0.00	0.3163
Total sugar, %	16.61±0.48^b	19.55±0.67^a	12.34±0.25^c	0.0000
Neutral detergent fiber, %	16.46±0.65^a	15.69±0.34^b	12.25±0.54^c	0.0000
Acid detergent fiber, %	10.00±0.42^b	10.44±0.42^b	11.80±0.48^a	0.0001
Acid detergent lignin, %	2.56±0.23^b	2.56±0.22^b	5.03±0.26^a	0.0000
Cellulose, %	7.45±0.25^a	7.88±0.36^a	6.76±0.41^b	0.0009
Hemicellulose, %	6.45±0.90^a	5.25±0.72^b	0.45±0.31^c	0.0000
ME_R, Mcal/kg	2.86±0.02^c	2.96 ±0.02^b	3.08±0.02^a	0.0000
ME_P, Mcal/kg	1.88±0.06^c	2.09±0.02^b	2.35 ±0.04^a	0.0000
Dry matter digestibility, %	81.11±0.33^a	80.77±0.33^a	79.71±0.37^b	0.0001
Dry matter intake, %	7.30±0.29^b	7.65±0.16^b	9.81±0.45^a	0.0000
Relative feed value	458.90±17.65^b	478.99±8.93^b	606.23±30.38^a	0.0000
Total flavonoid, mg QE/g	4.69±0.20	4.70±0.12	4.78±0.21	0.3163
Total phenolic content, mg GAE/g	2.70±0.12	2.69±0.15	2.72±0.14	0.3261
Antioxidant activitiy, %	49.53±0.77	49.55±0.78	49.57±0.76	0.2100

P: Probability, ±: Standart error, MER: Metabolic energy value for ruminants, MEP: Metabolic energy values for poultry, QE: Quercetin equivalent, GAE: Gallic acid equivalent, a,b,c: Means with different supercripts within a row are significantly different (P<0.05).

In the study highest value with respect to CP content in leaves was found in the third harvest (39.30 %) and followed by the second harvest (29.14 %) and the first harvest (22.96 %). These values are statistically significant (P<0.05). EE values were found to be higher and different significantly in third (5.79 %) and first harvests (5.63 %) compared to second harvest (4.86 %) (P<0.05). According to the findings about CF, NFE, NDF and hemicellulose contents respectively, the highest value (8.83%) was found in the first harvest and followed by second (6.56%) and third harvest (5.68%); the highest value (51.96%) was found in the first harvest and followed by second (48.94%) and third harvest (38.93%); the highest value (16.46%) was found in the first harvest and followed by second (15.69%) and third harvest (12.25%); the highest value (6.45%) was found in the first harvest and followed by second (5.25%) and third harvest (0.45%) (P<0.05). ADF and ADL contents were significantly higher in the third harvest leaves (11.80% and 5.03%) than the first harvest (10.00% and 2.56%) and second harvest (10.44% and 2.56% DM) (P<0.05). According to the findings about total sugar content respectively, the highest value (19.55%) was found in the second harvest and followed by first (16.61%) and third harvest (12.34%) (P<0.05). In the study, cellulose contents and DMD of third harvest leaves (6.76% and 79.71%) were significantly lower than first harvest (7.45% and 81.11% DM) and second harvest (7.88% and 80.77% DM) (P<0.05). In vitro metabolic energy and RFV of *Moringa oleifera* leaves harvested at different stages of maturity were found statistically significant (P<0.05). Considering MER and MEP respectively increased with the harvesting rank. Highest values (3.08 Mcal/kg and 2.35 Mcal/kg) were observed in the third harvest and the lowest values (2.86 Mcal/kg and 1.88 Mcal/kg) were observed in the first one (P<0.05). DMI and RFV were found in the third harvest (9.81% and 606.23 respectively) and followed by the second harvest ((7.65% and 478.99 respectively) and the first harvest (7.30% and 458.90 respectively) (P<0.05). In all the harvests *Moringa oleifera* leaves are the supreme quality category. TF, TPC and AA of *Moringa oleifera* leaves were not significantly different (P>0.05). During this study, *Moringa oleifera* leaves were found to contain 4.69-4.78 mg QE/g TF, 2.69-2.72 mg GAE/g TPC and 49.53-49.57 AA%.

The chemical composition, in vitro ME and RFV of *Moringa oleifera* stalk harvested at different stages of maturity are shown in the Table 2. The highest DM concentration in stalk was determined in the first harvest (93.57%), the highest OM in the first and third harvest (90.50 and 90.07%), the highest ash in the second harvest (10.30%), the highest CP in the third harvest (13.28%), the highest EE in the second harvest (2.11%), the highest CF in third harvest (35.98%) (P<0.05). NFE content was significantly higher in first (43.49%) and second harvest (43.48%) (P<0.05). Total sugar contents were higher in first harvest (12.43%) (P<0.05). NDF content was significantly higher in first (53.10%) and third harvest (52.69%) (P<0.05). ADF contents were significantly higher in the third harvest leaves (43.97%) than the first and second harvest (42.43% and 39.62%) (P<0.05). ADL content was lower in second harvest than the others (7.06%) (P<0.05). In the study, cellulose content was highest in third harvest (35.81%) hemicellulose content was highest in first harvest (10.68%) (P<0.05). Highest MER and MEP values were observed in second harvest (1.73 Mcal/kg and 1.00 Mcal/kg respectively) (P<0.05). In all the harvests *Moringa oleifera* stalk are the low/utility quality category.

Table 2. Chemical composition, in vitro metabolic energy and relative feed value of *Moringa oleifera* stalks harvested at different stages of maturity

Tablo 2. *Farklı olgunluk zamanlarında hasat edilen Moringa oleifera saplarının kimyasal bileşimi, in vitro metabolik enerji ve nispi yem değeri*

Parameters	First Harvest	Second Harvest	Third Harvest	P
Dry matter, %	93.57±0.26^{a}	91.44±0.50^{c}	92.06±0.05^{b}	0.0000
Organic matter, %	90.50±0.25^{a}	89.70±0.58^{b}	90.07±0.12^{ab}	0.0155
Ash, %	9.50±0.07^{c}	10.30±0.05^{a}	9.93±0.10^{b}	0.0000
Crude protein, %	9.76±0.16^{c}	11.40±0.13^{b}	13.28±0.15^{a}	0.0000
Ether extract, %	1.79±0.03^{c}	2.11±0.08^{a}	2.00±0.04^{b}	0.0000
Crude fiber, %	35.47±0.49^{b}	32.71±0.58^{c}	35.98±1.19^{a}	0.0001
Nitrogen free extract, %	43.49±0.37^{a}	43.48±0.57^{a}	38.82±1.06^{b}	0.0000
Starch, %	not detected	1.78±0.00	not detected	-
Total sugar, %	7.45±0.16^{c}	12.43±0.38^{a}	8.85±0.28^{b}	0.0000
Neutral detergent fiber, %	53.10±0.30^{a}	47.71±0.56^{b}	52.69±0.52^{a}	0.0000
Acid detergent fiber, %	42.43±0.48^{b}	39.62±0.73^{c}	43.97±0.22^{a}	0.0000
Acid detergent lignin, %	7.83±0.31^{a}	7.06±0.26^{b}	8.16±0.30^{a}	0.0002
Cellulose, %	34.60±0.34^{b}	32.56±0.78^{c}	35.81±0.22^{a}	0.0000
Hemicellulose, %	10.68±0.57^{a}	8.10±0.71^{b}	8.72±0.55^{b}	0.0001
ME_R, Mcal/kg	1.63±0.02^{b}	1.73±0.02^{a}	1.62±0.05^{b}	0.0000
ME_P, Mcal/kg	0.74±0.01^{c}	1.00±0.04^{a}	0.93±0.01^{b}	0.0000
Dry matter digestibility, %	55.85±0.37^{b}	58.04±0.57^{a}	54.65±0.17^{c}	0.0000
Dry matter intake, %	2.26±0.01^{b}	2.52±0.03^{a}	2.28±0.02^{b}	0.0000
Relative feed value	97.81±0.83^{b}	113.14±2.07^{a}	96.46±1.03^{b}	0.0000

P: Probability, ±: Standart error, MER: Metabolic energy value for ruminants, MEP: Metabolic energy values for poultry, QE: Quercetin equivalent, GAE: Gallic acid equivalent, a,b,c: Means with different supercripts within a row are significantly different (P<0.05).

The chemical composition, in vitro ME and RFV of whole (leaf+stalk) *Moringa oleifera* harvested at different stages of maturity is shown in the Table 3. No significant differences were observed in DM and OM contents of whole (P>0.05). the highest ash in the second harvest (10.33%) (P>0.05). The CP contents increased with the harvesting rank were and significantly higher in the third harvest (32.39%) and lower in the first one (17.28%) (P<0.05). EE content was significantly higher in the third harvest than the others (4.82%) (P<0.05). CF content was significantly higher in the first harvest than the others (23.46%) (P<0.05). NFE content was significantly higher in first harvest (47.19%) (P<0.05). Total sugar contents were higher in second harvest (19.32%) (P<0.05). the First harvest had significantly higher NDF, ADF, ADL, cellulose and hemicellulose contents than the others (34.74%, 27.36%, 4.87%, 22.49% and 7.38% respectively) (P<0.05). Considering MER and MEP values increased with the harvesting rank and the highest values were observed in third harvest (2.68 Mcal/kg and 1.96 Mcal/kg) (P<0.05). The lowest DDM (67.59%) was observed in first harvest (P<0.05). On the other hand, the highest DMI and RFV values were determined in the second harvest while the lowest ones are observed in the first harvest (P<0.05). According to the quality standards, *Moringa oleifera* as a whole is in the prime quality class in all the harvests with the highest value (312.34) obtained in the second harvest.

Table 3. Chemical composition, in vitro metabolic energy and relative feed value of *Moringa oleifera* leaf + stalk harvested at different stages of maturity

***Tablo 3.** Farklı olgunluk zamanlarında hasat edilen Moringa oleifera bitkisinin kimyasal bileşimi, in vitro metabolik enerji ve nispi yem değeri*

Parameters	First Harvest	Second Harvest	Third Harvest	Probability
Dry matter, %	92.12±0.40	91.51±0.54	92.00±0.06	0.0656
Organic matter, %	90.24±0.40	89.67±0.85	89.96±0.08	0.2918
Ash, %	9.76±0.09^{b}	10.33±0.50^{a}	10.04±0.06a^{b}	0.0314
Crude protein, %	17.28±0.30^{c}	24.09±0.16^{b}	32.39±0.20^{a}	0.0000
Ether extract, %	3.40±0.08^{c}	3.68±0.07^{b}	4.82±0.15^{a}	0.0000
Crude fiber, %	23.46±0.22^{a}	14.70±0.30^{b}	14.16±0.46^{c}	0.0000
Nitrogen free extract, %	46.11±0.18^{b}	47.19±1.04^{a}	38.58±0.73^{c}	0.0000
Starch, %	undetermined	1.78±0.00^{a}	1.77±0.00^{b}	0.0000
Total sugar, %	16.29±0.50^{b}	19.32±0.58^{a}	11.22±0.53^{c}	0.0000
Neutral detergent fiber, %	34.74±0.63^{a}	22.23±0.31^{b}	23.88±0.73^{b}	0.0000
Acid detergent fiber, %	27.36±0.44^{a}	18.29±0.33^{c}	18.31±0.60^{b}	0.0000
Acid detergent lignin, %	4.87±0.25^{a}	3.54±0.28^{c}	4.06±0.19^{b}	0.0000
Cellulose, %	22.49±0.34^{a}	14.74±0.22^{b}	14.25±0.77^{b}	0.0000
Hemicellulose, %	7.38±0.63^{a}	3.95±0.38^{c}	5.57±1.12^{b}	0.0000
ME_R, Mcal/kg	2.19±0.01^{c}	2.57±0.04^{b}	2.68±0.02^{a}	0.0000
ME_P, Mcal/kg	1.42±0.01^{c}	1.81±0.05^{b}	1.96±0.04^{a}	0.0000
Dry matter digestibility, %	67.59±0.34^{b}	74.65±0.26^{a}	74.64±0.47^{a}	0.0000
Dry matter intake, %	3.46±0.06^{c}	5.40±0.08^{a}	5.03±0.15^{b}	0.0000
Relative feed value	180.99±3.66^{c}	312.34±4.76^{a}	290.89±8.41^{b}	0.0000

P: Probability, ±: Standart error, MER: Metabolic energy value for ruminants, MEP: Metabolic energy values for poultry, QE: Quercetin equivalent, GAE: Gallic acid equivalent, a,b,c: Means with different supercripts within a row are significantly different (P<0.05).

DISCUSSION and CONCLUSION

The stage of maturity is one of the most parameters that influence the nutritive value of forage (Ramos et al., 2015; Sebola et al., 2019). The lowest values of the CP content of all parts of *Moringa oleifera* plant were obtained in the first harvest (Mabapa et al., 2017). However, for the CF content of harvests, the highest values were obtained in the first one, while among the parts the highest values were observed in the stalk of the plant. These are the expected results according to the age of the plant (stage of maturity). In fact, in the first harvest, the plant was 5-month-old, while the second and third harvests were performed at one-month interval. Sebola et al. (2019) obtained similar results in their study with the mature and immature *Moringa oleifera* plant leaves.

In the literature, most researchers report similar results of CP values (20-35%) as obtained in first and second harvests in the present research (Abbas, 2013; Foidl et al., 2001; Kwena Mokoboki et al., 2019; Laouali Manzo et al., 2016; Liu et al., 2018; Mabapa et al., 2017; Sebola et al., 2019; Ziani et al., 2019). Even if the CP content determined in the third harvest in our study (39.30%) is higher than the levels reported in some publications, there are articles that present similar results of CP content level (Chodur et al., 2019; Ndong et al., 2007). Indeed, Ndong et al. (2007) and Chodur et al. (2019) found 39.69 % and 39.51 %, respectively for CP content of *Moringa oleifera* leaves. This is because researches usually use older plants that have less CP and more CF because of the maturity stage (Ramos et al., 2015; Sebola et al., 2019). Also, Moringa oleifera varieties have been reported to have significant differences in CP content (15-39%) in some researches (Chodur et al., 2019; Hassanein, 2018). As was expected, the highest values of CP content were obtained in the third harvest, while the values of CF content were the lowest. However, Quintanilla-Medina et al., (2018) found the highest CP content in first harvest and reported that the CP content decreased with the rank of harvest. These differences may result from different harvesting time intervals and in different seasons. Among the parts, the highest values of CP content were obtained in the leaves and the lowest values were found in the stalk. Similar results have been reported by several researchers (Abbas, 2013; Foidl et al., 2001; Saint Sauveur and Broin, 2010). On the other hand, when evaluated in terms of CP content (an important nutrient that determine feed value), Moringa oleifera tree stands out among other legume roughages commonly used as forage crops. In their study on commonly used legume roughages as a feed plant in Turkey, Canbolat and Karaman (2009) show that the CP content varied between 14.89 % and 19.11 % with the highest value found in clover. In similar studies, the highest CP was found in clover with 19.75 % and 22.1 % by Canbolat et al. (2006) and Yavuz (2005) respectively. In this study, the CP content of the *Moringa oleifera* plant as a whole varied between 17.28 % and 32.39 %. The legume forages examined by these researchers are found to be inferior to *Moringa oleifera* plant in terms of CP, CA, and EE contents. Studies have been conducted to evaluate the effects of *Moringa oleifera* on various animal species e.g, dairy cows (Mendieta-Araica et al. 2011; Reyes-Sánchez et al. 2006), sheep (Aregheore, 2002; Gebregiorgis et al. 2012), goat (Qwele et al. 2013), layer (Abbas, 2013; Valdivié et al. 2016), broiler (Nkukwana et al. 2014;

Wapi et al. 2013), rabbit (Sun et al. 2018) and fish (Afuang et al. 2003; Puycha et al. 2017). All these studies reported that *Moringa oleifera* can be used as an good alternative protein source for livestock.

Among the parts of the plant, the highest CA, EE and NFE contents were found in the leaves, whereas the lowest EE content was observed in the stalk. The lowest NFE contents including all parts were obtained in the third harvest. These findings are compatible with previous studies (Liang et al., 2019; Mendieta-Araica et al., 2013; Quintanilla-Medina et al., 2018; Sebola et al., 2019; Ziani et al., 2019).

Very low levels of starch were detected in all harvests and all parts. Among harvests, the highest sugar content was obtained in the second one and among the parts, the highest value was in the leaves. The sugar content found in the leaves (12.34-19.55 %) was higher than the value presented by Ziani et al. (2019) who indicated a value of 3.82 %. However, the researchers did not report at which age the plant leaves were harvested.

When cell wall contents are examined in the leaves, NDF (16.46 % to 12.25 %), hemicellulose (6.45 % to 0.45 %) and cellulose (7.45 % to 6.76 %) decreased with the rank of harvest, while ADF (10.00 % to 11.80 %) and ADL (2.56 % to 5.03 %) increased. Quintanilla-Medina et al. (2018) found the same trend for ADF and hemicellulose and the opposite trend for NDF. However, these values are compatible with the values found in this study. These researchers reported NDF as 13.55-18.00 %, ADF as 8.25-11.64 %, and hemicellulose as 4.01-6.98 %. On the other hand, the current findings contradict with that of some researchers who found higher values because they used more mature leaves (Mendieta-Araica et al., 2013; Sebola et al., 2019). In this study, the contents of the cell wall in the stalk slightly varied among harvests. However, as was expected, it was found higher than the values in the leave and are similar to the values reported in previous studies (Abbas, 2013; Mendieta-Araica et al., 2013; Sebola et al., 2019).

In this study, on average *Moringa oleifera* leaves contained MER ranged between 11.96-12.88 Mcal/kg; MEP ranged between 7.87-9.81 Mcal/kg; *Moringa oleifera* stalks contained MER ranged between 6.76-7.24 Mcal/kg; MEP ranged between 3.10-4.17 Mcal/kg; *Moringa oleifera* plant as a whole (leaf + stalk) contained MER ranged between 9.17-11.21 Mcal/kg; MEP ranged between 5.96-8.20 Mcal/kg. ME contents of legume hays examined by Canbolat and Karaman (2009) using the Gas Production Technique has been reported to be between 2222.75 and 2652.96 kcal / kg DM. In another study, Kwena Mokoboki et al. (2019) reported the ME value of *Moringa oleifera* leaves as 0.53 Mcal/kg [ME, Mcal / kg = 0.821 × DE (Mcal / kg, digestible energy)] Insufficient studies have been reported on this subject.

In the previous studies, the DDM is reported to be in a range of 44.4 %-59.7 % for legume hays and between 59.5-66.8 % for dry grasses (Canbolat et al., 2006; Canbolat and Karaman, 2009; Kwena Mokoboki et al., 2019; Yavuz, 2005). Whilst DDM values of Moringa oleifera hay ranged between 67.59 % and 74.64 %. On the other hand, the DMI of the mentioned hays ranged from 2.26 to 2.28, while that of the *Moringa oleifera* tree ranged from 3.46 to 5.03. It can be concluded that the lower ADF value in the *Moringa oleifera* a plant than the others increased the DDM, and the lower NDF value than the others increased the DMI.

While monogastric animals cannot digest structural carbohydrates in roughages, ruminants can digest structural carbohydrates by the cellulolytic microorganisms. Structural carbohydrates NDF (cellulose, hemicellulose, and lignin) and ADF (cellulose, hemicellulose) found in roughages are important for maintaining rumen health and increasing feed efficiency. RFV, developed using the feed ADF and NDF contents, is important in this aspect. In the study conducted by Canbolat and Karaman (2009), the RFV value of legume hays (common clover, button clover, hairy clover, yellow stone clover, white stone clover, castor clover, sainfoin and gazal horn) varies between 120.30 and 159.90. In this study, the RFV of the *Moringa oleifera* plant was determined to between 180.99 and 312.34. The high RFV of *Moringa oleifera* is due to the low NDF and ADF content and the variation of the feed variety. In another study, Kwena Mokoboki et al. (2019) reported the superiority of *Moringa oleifera* plant from other common forage crops (M. azedarach, A. hebeclada, M. oleifera, L. leucocephala, and S. lancea) in terms of ME, DMI, DDM, and RFV.

Moringa oleifera contains high amounts of polyphenols, flavonoids and phenolic acids. Due to its rich nutritional content, it has been used as a therapeutic in traditional medicine from past to present (Ma et al., 2020). However, it has been reported that this rich content may differ according to geographical location and environmental conditions (Panwar and Mathur, 2020). During this study, *Moringa oleifera* leaves were found to contain 4.69-4.78 mg QE/g TF, 2.69-2.72 mg GAE/g TPC and 49.53-49.57 AA%. The TPC of *Moringa oleifera* leaves grown in Mexico was between 241.3 and 468.4 µg GAE/mL; it has been reported that the TF content is between 107.9 and 316.3 µL RE/mL (Coz-Bolanos et al., 2018). In previous studies, total phenol contents were reported as 2.7% by Gupta et al. (1989); as 4.32% by Foidl et al. (2001) and as 2.2% by Moyo et al. (2011). Sankhalkar and Vernekar (2016) determined that TFC was 4.44 mg/mL, TPC was 2.28 mg/mL of *Moringa. oleifera* Lam.leaf. Öztürk et al. (2022) reported that total phenolics were between 68.23 and 92.30 g GAE/kg dw; TFC content ranged from 37.75 to 70.29 g QE/kg dw and AA ranged from 12.20 to 23.78 DPPH (mmol TE/kg dw) of *Moringa oleifera* grown in different districts (Bulancak, Camoluk, Espiye, Şebinkarahisar and Tirebolu) of Giresun province of Türkiye.

One of the major determinants of feed quality is the stage of maturity at harvesting (Sebola et al., 2019) and climate-soil conditions. Up-to-date, most of the research done on *Moringa oleifera* focuses on those grown in India, Madagascar is in Africa or other African countries (Lin et al., 2019). According to precedent researches, soil properties and climatic conditions significantly affect the yield and chemical composition of the Moringa oleifera plant (Laouali Manzo et al., 2016; Wasonowati et al., 2019; Zheng et al., 2016).

The stage of maturity of foliage at harvesting is a major determinant of feed quality in terms of biomass yield and nutritive value. This study showed that *Moringa oleifera* plant can maintain its feed value after the first harvest performed at the flowering period. In the upcoming studies, *Moringa oleifera* should be examined in terms of nutrient content and biomass yield by making more harvests (up to 9) at different intervals of time. Such research could help to optimize the timing of harvesting so that the most suitable interval of time in which the optimum feed value and the optimum forage yield is attempted could be thoroughly defined. This study on the Moringa oleifera tree emphasis grown in İzmir-Turkey is done for the first time and the data presented in this paper might support further research and the exploration of potential local applications. Therefore, there is a need to evaluate this plant in different soil and climatic conditions. It is clear from these results that *Moringa oleifera* has substantial nutritional value for ruminant and poultry. Further, it is need such as minerals, amino acids, vitamins, nutraceutical and bioprotective substances and also digestibility should be obtained in future study.

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